Visualizing patterns of energy use in households – the activity approach

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Abstract

The aim of this paper is to present an activity approach on energy use in households. The activity approach emanates from time-geography (Hägerstrand 1985, 1974) and forms the basis of VISUAL-TimePAcTS (Vrotsou, Ellegård & Cooper 2007, Ellegård & Cooper 2004), a software developed to visualize householders' complex everyday life activity patterns, here applied with special reference to the equally complex patterns of energy use. The visualizations show activity patterns on individual, household as well as aggregate levels. We show how national time use surveys – by utilising VISUAL-TimePAcTS – can be used on aggregate levels to discern energy consuming activity patterns in individuals' activity contexts. In doing so, the activity approach may contribute to a deeper understanding of the relation between the citizens' everyday activities and energy consumption. Based on a qualitative household study (Karlsson & Widén 2008) in which time-diaries, logbooks, interviews and VISUAL-TimePAcTS were used and a typology of basic use patterns (individual and collective) of electric appliances were developed, the applicability of the activity approach for the promotion of more energy efficient habits among householders is explained. The activity approach brings energy consuming *activities* to the fore, but how the energy demand on aggregate, household, and individual levels can be accounted for by means of estimations of the amount of energy consumed by various technologies (Widén et al 2008) is also described. Limitations and need for further development of the method are discussed.

Introduction

Energy use in households is often considered from the results of studies measuring electricity use on appliances at households' disposal in the home. For example, in Sweden a large measuring study is performed by the Swedish Energy Agency in about 400 households (Bennich 2008). Such investigations give detailed information about the distribution of end-use-specific electricity consumption in terms of how much electricity is consumed by what appliances at what times of the day. Depending on what background variables that have been collected, the distribution of electricity consumption in different "types" of households can be compared. This kind of knowledge of "how energy is used" is often limited to average figures on electricity consumption (total and per appliance) for different "types" of households. However, results from earlier research reveal that even households with similar background variables show great variation in electricity consumption (Karlsson & Widén 2008, Gram-Hanssen 2004, Gaunt 1985). Electricity use needs to be explained by various factors but two overall aspects are discernable: technology and behaviour (Carlsson- Kanyama & Lindén, 2002). Accordingly, differences in consumption in households with similar background variables can be referred to differences concerning the number of appliances in the dwellings, the energy efficiency of the appliances and how the appliances are used (ibid.). Applying this on the wider concept of "energy use", "appliances" can be changed for "technologies" and include the use of non-electrically-driven heating, hot water and vehicles, which can be more or less energy efficient and/or eco-friendly. The number of energy consuming technologies and their energy-efficiency refer to the technology aspect. That is to say, to gain knowledge about them the energy consuming technologies need to be studied, not the people using them.

This corresponds to an *appliance/technology approach* on energy use and some knowledge about this can be gained through, for instance, electricity measurement studies. In order to gain knowledge about how the energy consuming technologies are used, we suggest an *activity approach*. People behave and use energy differently and if we want to identify persons in need of different kind of information related to important energy issues, such as the attainment of less energy consuming behaviours, we need to gain new knowledge about who uses the energy consuming technologies, how and why they do as they do. Some answers to this are given in the study of people's everyday lives and activity patterns. Such an activity approach claims for other ways of collecting data in order to get a hold on energy use in households, including diary data. If the household is the target, then the diaries are used in combination with visits in the homes and interviews. If the population (or a group in it) is targeted then the diaries from large time use surveys can be utilised. The aim of the paper is to present the activity approach on energy use which enables visualizations of patterns of energy use on the various levels.

The approach is a way of visualizing the *complexity* of individuals' energy consuming activities in everyday life. An important point of departure for us is, thus, that visualizations facilitate descriptions of and discussions about such complex matters. What actually can be said about the complex issue of "how energy consuming technologies are used" on the individual household and aggregate levels respectively differ and we will return to this. Methods for calculating the amount of energy that different energy consuming activity patterns require will also be mentioned. In order to facilitate the reading, the visualizations that we show and analyse will focus on the use of electric appliances and mostly, ICTs. However, we will describe how these analyses can be extended and what they can say regarding *how* and *how much* energy is used on the different levels. We believe that these visualizations together with estimations of the energy demand of individual households as well as larger populations can contribute to a deeper understanding of energy use in the household sector and, in doing so, may serve as basis for discussion with both household members and policy makers about energy use. Concerning energy use on the aggregate level the idea is that by using already recurrent national time use surveys based on diaries the activity approach may serve as a complement to energy measurement studies in households. Moreover, the recurrent national time use surveys can be utilised for more purposes than today. Another way of collecting data on households' energy use is to use questionnaires and, thus, informants' self-reported perceptions of their use of energy consuming technologies. These may differ from their actual behaviours, which the use of time-diaries do not capture completely either, but probably to a larger extent than questionnaires, as people tend to forget about their more or less taken-for-granted daily habits (Ellegård, 1999).

The research presented is developed in an interdisciplinary research group, with technical and social scientists (Widén, Wäckelgård & Ellegård 2008, Widén 2008, Lundh, Wäckelgård & Ellegård 2008, Ellegård 2008, Karlsson & Widén 2008, Green & Ellegård 2007, Vrotsou, Ellegård & Cooper 2007, Ellegård & Cooper 2004). The point of departure is the time-geographical approach (Hägerstrand 1985, 1974) and its specific notation system. One corner stone of time-geography is to withhold the individuals' characteristics even at aggregate levels, not least to maintain the sequences of activities performed by each and every individual. The time-geographical approach forms the basis of the software VISUAL-TimePAcTS (Vrotsou, Ellegård & Cooper 2007, Ellegård & Cooper 2004), which enables visualizations of householders' everyday life activity patterns and will be applied here with special reference to energy use.

In the following we begin by describing how data from national time use surveys that has been worked up in VISUAL-TimePAcTS can be used to discern energy consuming activity patterns in individuals' activity contexts on aggregate levels. These visualizations will then be linked to methods of calculating the amount of energy that these electricity consuming activity patterns require (Widén et al. 2008). Next, based on a qualitative study of 14 households using the activity approach and VISUAL-TimePAcTS (Karlsson & Widén 2008, Green & Ellegård 2007) we present a typology of basic patterns of electric appliance use (individual and collective) on the individual household level. The typology not only takes into account the direct utilisation of appliances, but also appliances not directly in use by any household member but still consuming electricity as well as the coordination of household members' appliance use in time and space. Visualizations focusing on individuals and their activities on one hand and individuals and their appliances on the other are then applied on household level by means of an example showing the interplay between household members' and some of their ICTs during one day. The applicability of the activity approach for other kinds of energy use will also be discussed. Before closing the paper with final conclusions we describe some limitations and need for further development of the method.

The activity approach on aggregate level

The use of the activity approach on an aggregate level is based on the following points of departure; *activities*, *individuals* in a population, and the 24 hour *time* period. The goal for everybody is assumed to be to live a life that each individual finds good in a short and long time perspective. Activities are planned and some of them are performed each and every day to reach the goal. It is obvious that individuals do not find the same things making up a good life. People give priority to different activities and they perform activities differently. People use energy in their daily life for many purposes: heating/cooling, cooking, baking, washing, laundry, ironing, cleaning, lighting, communication, transportation, entertainment and services via information and communication technologies and so on. The activity approach on population level shows collective activity patterns during weekdays and reveals variations in activities performed among the individuals in the population. We base the presentation on data from individual household members, 10 years and older, in households of different size in different types of regions in Sweden. The data was collected by Statistics Sweden in a pilot study in 1996, and it consists of about 460 individuals in 180 households. Each individual has written time diaries for one weekday and one weekend day, and the members in each household have written diaries during the same days. The 24 hours of weekdays are in focus. The data set also include weekend days but we leave them aside here.

Thereby all activities performed during weekdays are captured, not only the activities performed at home, but also transportation activities and activities at other places. This can be utilised for expanding the model to include other energy use than that emanating from home based activities. Thus, time (type of day and time of the day, sequences of activities and their duration) and the individuals in a population and their activities are the cornerstones of our time-geographically inspired approach.

Next the model used for visualizing everyday activities, VISUAL-TimePAcTS (Vrotsou, Ellegård & Cooper 2007, Ellegård & Cooper 2004), is presented. First the principle for the visualization is shown and then some examples of activities that are closely related to energy use will be visualized.

PRINCIPLE FOR VISUALIZATION: INDIVIDUAL AND POPULATION

It is common to use averages in order to represent time used for activities in a population (see for example Eurostat 2004). An average individual's time use for various activities then may represent the individual level. Within the average variations between individuals in the population hide. We are interested in highlighting the variations between individuals in the context of the population as a whole. The time-geographic visualization allows each individual's characteristics (in terms of the sequence of his/her activities performed in the course of the day and the duration of each activity) to be displayed in the context of all other individuals in the population. Thereby variations between the individuals in the population as they are generated from the notes in all of the individual diarist's time-diaries are shown. The activities in the diaries have been coded according to an activity oriented time-geographical approach (Ellegård, 1999). The coding scheme is hierarchic and consists of about 600 numerical codes with five levels of detail and grouped into seven main activity categories (care for oneself, care for others, household care, reflection/recreation, transportation, procure and prepare food, and gainful employment or education). The codes have been entered into and worked up in the software VISUAL-TimePAcTS (Vrotsou, Ellegård & Cooper 2007, Ellegård & Cooper 2004). The abbreviation TimePAcTS stands for Time, Place, Activities, Technologies and Social relations. That is to say, the coding process includes noting *what* activity is taking place, *when*, *where* (in the home or elsewhere) and together with *whom*, which can mean individuals, animals and technological artefacts.

Most individuals start the day sleeping, while they perform other activities during daytime and finally end the day sleeping, thus constituting the basic structure of human daily life. Below, this dominating structure is visualized in order to show the basic visualization principle of the VISUAL-TimePAcTS.

This basic visualization principle is used in the following illustrations. We have presented the individuals in the population according to the same order in the illustrations to give additional information. The order is: men are displayed to the left in the visualizations, women to the right and within each gender section the youngest individuals are placed to the right and the oldest to the left. In VISUAL-TimePAcTS the seven main activity categories have been assigned one colour each; care for oneself – green, care for others – turquoise, household care – pink, reflection/recreation – purple, transportation – yellow, procure and prepare food – dark blue, and finally, gainful employment or education – red (Vrotsou, Ellegård & Cooper 2007, Ellegård 1999).

ACTIVITIES CLAIMING ENERGY: SOME EXAMPLES

We have chosen two types of activities to exemplify the visualization of energy consuming activities: *prepare meals* and *watch TV*. Each visualization is complemented with a frequency curve to show in a more well known way the peaks of activity generated energy use.

Preparing meals

One frequently performed household activity is to prepare meals. Some devices used for preparing meals demand energy, especially electricity, for example oven, micro wave oven, stove, water boiler and many small electric devices. Both men and women prepare meals, and we know that women are more occupied by preparing meals than men. This is shown to the left in the visualization in figure 2. However, it is obvious that men prepare meals too, and that middle aged men are more active in this activity than are the older men. Men and women prepare breakfast to almost the same extent, some more women than men prepare lunch, whereas the domination of women active in dinner and evening meal preparation is obvious. Especially dinner preparation takes longer time among women than among men. Children seldom prepare meals, either boys or girls. The frequency curve shows the peak for meal preparation at about 17.30 and two lower peaks at breakfast and lunch time.

Watching TV

Use of electricity for ICT-appliances (such as TV, computer, phones and related appliances) is shown by the Swedish Energy Agency to be rapidly increasing in Sweden (Bennich 2008). In our data from 1996 there are not much computer use, but watching TV is spread over the whole population. It is much more evenly spread than preparing meals between men and women and between younger and older people. Children are frequently watching TV on weekdays, see the right part of figure 2. Men and women too, but they are occupied with other activities in the afternoon, while children amuse themselves with TV. Boys watch TV in mornings more than girls and adults.

Any activity related to energy consumption and categorized in accordance with the categorization scheme of the VISUAL-TimePAcTS can be visualized like the examples presented here. Based on the knowledge of these and other energy consuming activity patterns it is possible to estimate the aggregate energy demand as it is spread over the day.

ESTIMATING THE AGGREGATE ENERGY DEMAND

Based on figures on energy demand by technologies in use when activities aiming at fulfilling household members basic needs are performed by one or more household member we can visualize the electricity use of the population. Activities relate to energy consumption in different ways depending on how technologies are used, as Widén et al (2008) suggest:

1. Energy is consumed during the performance of the activity, for example vacuum cleaning or going by car, and thus, among other things the amount of energy consumed de-

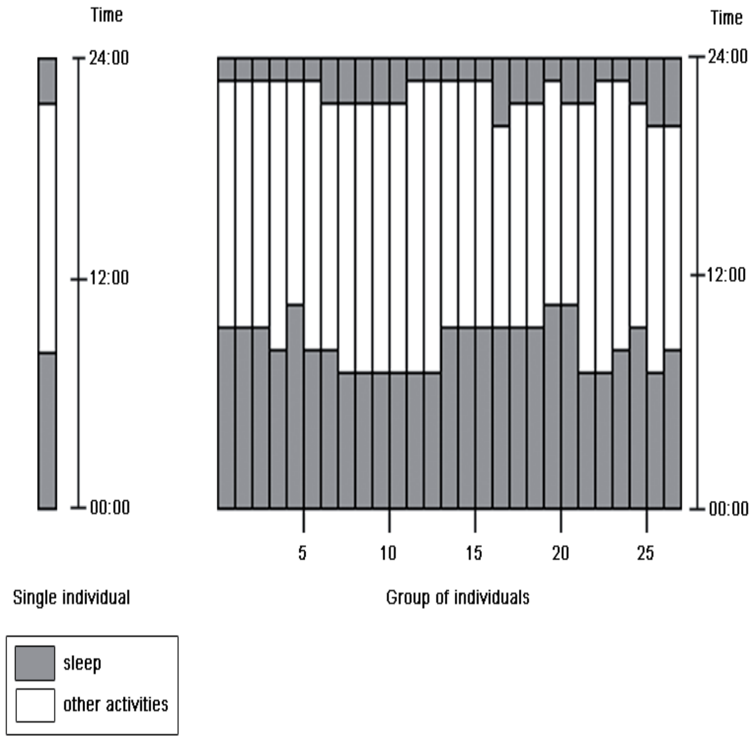


Figure 1a: The basic visualization principle of the VISUAL-TimePAcTS showing the dominating basic structure of human life; sleep, other activities, sleep. The visualization principle is to regard time as a continuum (to be read from the bottom at 00.00 to the top 24.00), eventually filled with activities of different kinds (here only sleep and "other activities" are displayed). To the left a single individual (individual activity pattern), to the right a group of 27 individuals (collective activity pattern).

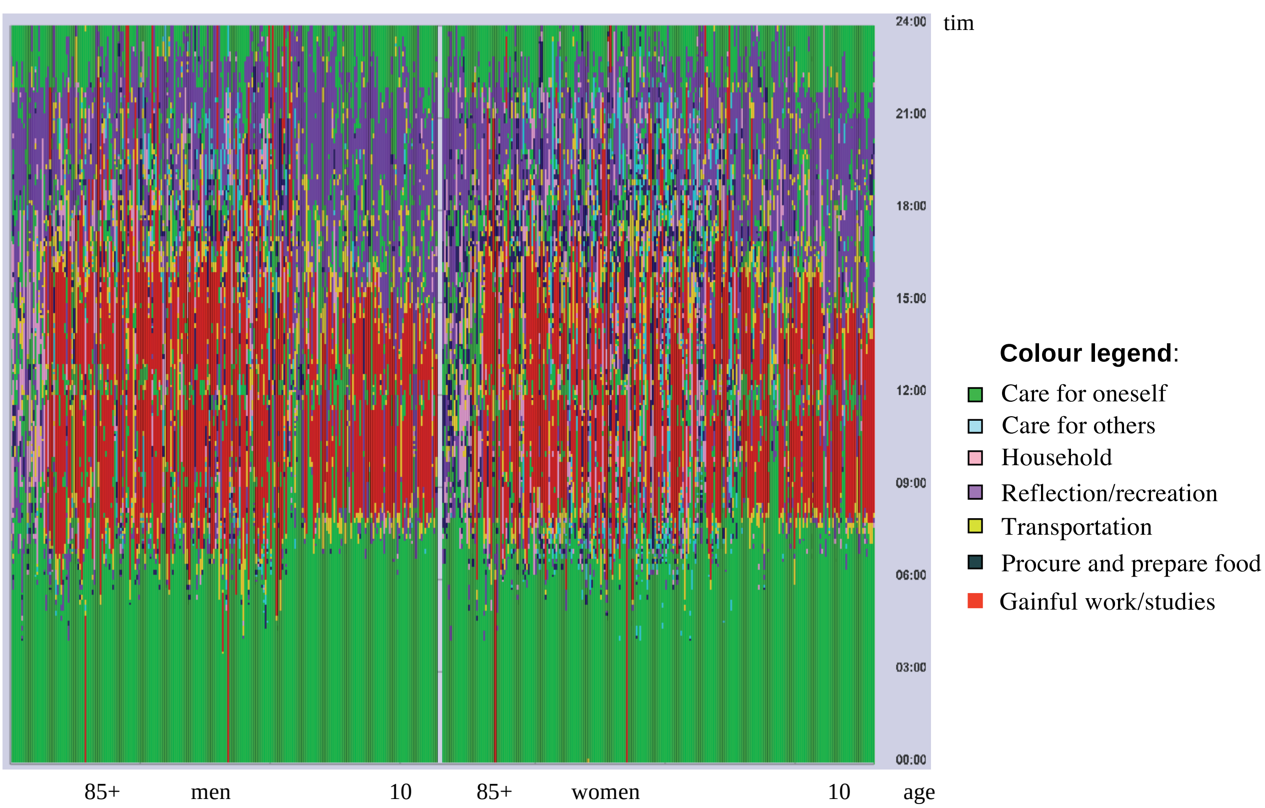


Figure 1b: Visualization of the activity pattern in the population of the data set, weekdays (1996). The individuals (N=463) are ordered according to sex and age: Men to the left, women to the right. Within each group the youngest (10 years old) are to the right and the oldest to the left.

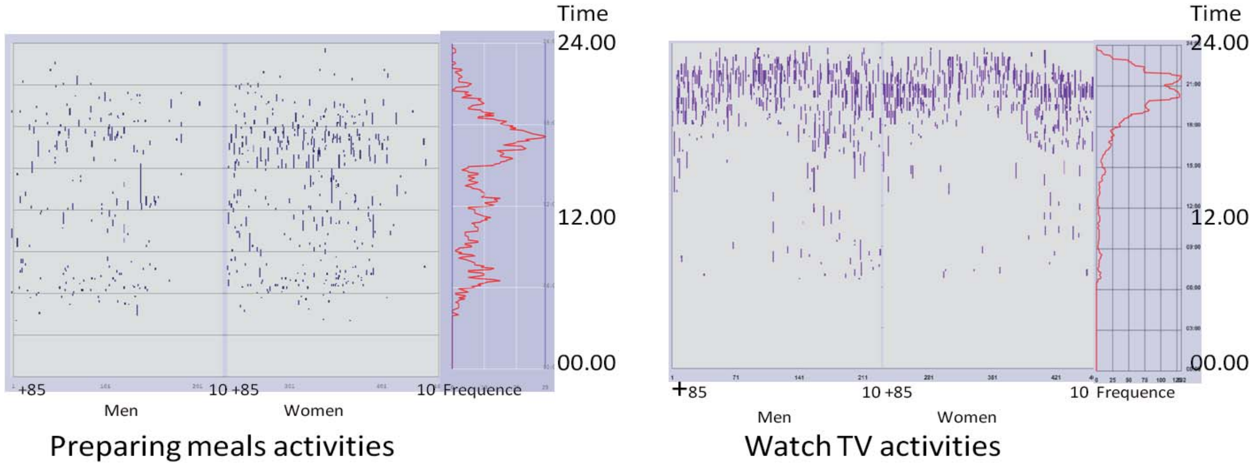


Figure 2. Left part of the figure: The distribution of the activity "preparing meals" during one weekday. The population to the left and the frequency of the activity to the right. Men to the left and women to the right in the population. Children to the right and old people to the left in each population group. Right part of the figure: The distribution of the activity "watch TV" during one weekday

pends on the reported length of the activities "vacuum" and "take the car to work".

2. Energy is consumed during a limited period of time after an activity is performed, for example after filling and starting the washing machine, and thus, among other things the amount of energy consumed depends on the time that the machine works after being started.
3. Energy is consumed more or less constantly after the installation of a device, e.g. cold storage of food in the freezer or fridge and non-manoeuvrable heating, and thus, this energy consumption will not be noted in time-diaries and not represented in the activity patterns but can be estimated and added to the estimation of the total energy demand.

In Widén et al (2008) a model of energy consumption for using various appliances is presented. This model was validated with data from the measurement study of electricity use and at the aggregate level the curves fit well. At the population level, using the activity approach, the aggregate energy demand can be accounted for from the activity data and the energy consumption data. We are now integrating the model into the VISUAL-TimePAcTS software (VISUAL-TimePAcTS/energy use) and it will be presented in 2009.

UNDERSTANDING "HOW ENERGY CONSUMING TECHNOLOGIES ARE USED" ON THE AGGREGATE LEVEL

Visualizations of energy demanding activities performed by the individuals in a population can serve as a ground for increased understanding of the complexity of the energy issue, but to what extent? What can we actually say about "how energy consuming technologies are used" on the aggregate level? From the point of departure of the figures above we discern *who*, here in terms of age and sex, perform *what* energy demanding activities, *when* and with what *duration* and *frequency* during the day, and, as the national time use surveys include both *weekdays* and *weekend days*, possible differences in the activity patterns between these days. Regarding "who" it is possible to link activity patterns to other background variables, e.g. city/rural/small town inhabitants and those living in apartments and detached houses. The kind of energy use that is discernable is thus the *direct* use of technologies in terms of hot water, vehicles and appliances, excluding the kind of appliance use that we call *background use* (Karlsson & Widén, 2008), which is similar to the type (3) of energy consuming activities of Widén et al (2008) described above. The background use is possible to estimate to a certain extent. The "direct use" corresponds to energy consumption that is "switched on". However, apart from background use, some switching on activities as well as other energy relevant behaviours seldom get noted in time-diaries and/or are not represented in the coding scheme, and, thus, do not become visualized, for example, the turning on and off of lights, thermostat adjustments, if lids are put on saucepans, food are chosen with ecological motives, washing machines and dishwashers are filled up, the water is turned off while one soaps oneself down, computers and TVs are not left in stand-by, etc. On the other hand, some of these activities may actually be possible to note in the diary, code and visualize. All depends on the design of the diaries, the information given to the diarists and to what extent they endure a detailed keeping of the diaries. The activity approach is possible to develop and adjust to the aim of the research in question. We will return to this.

By presenting the activity patterns as in figures 1 and 2 we discern dominating differences in activity patterns in different groups of individuals. However, what is unique is the visualization of the context in which the energy consuming activities are performed in terms of the intertwining of other everyday activities and habits and, thus, the organisation of everyday lives. It helps to gain new knowledge about who uses the energy consuming technologies and explains how it turns out as it does. Getting a hold on the energy use as revealed by activity patterns it is possible to identify activities that appear in combinations and claim a lot of energy. This might be input to policy formulation. The intertwining and coordination of activities in households are the focus when using the activity approach on the individual household level.

The activity approach on the individual household level

Applying the activity approach on the individual household level is a way of capturing energy use from deeper knowledge about the duration and interplay of household members' activities involving the use of energy consuming technologies. To some extent this is accomplished by means of a typology of basic patterns of electric appliance use (Karlsson & Widén 2008, Green & Ellegård 2007) and two techniques for visualizing these use patterns of which one is VISUAL-TimePAcTS used at individual and household levels. We show the basic principles for these kinds of analyses using an example from one household that took part in a qualitative study of 14 households (ibid.), which in turn supplemented the Swedish measuring study performed by the Swedish Energy Agency (Bennich 2008). We begin by briefly describing the method of the household study and presenting the typology of basic use patterns as well as examples of simple illustrations of these patterns using common time-geographical representations of paths of appliances and individuals. After that the patterns of ICT use performed by two household members in the household in question are visualized in two different ways.

THE DEVELOPMENT OF A TYPOLOGY OF BASIC PATTERNS OF ELECTRIC APPLIANCE USE

The household study (Karlsson & Widén 2008, Green & Ellegård 2007) that resulted in a typology of basic patterns of electric appliance use involved 14 households of different types concerning, for instance, type of dwelling, and number and ages of household members. One of the research questions addressed the household members' patterns of electric appliance use for satisfying their needs of food, information and communication and for being clean and live in a clean home (Carlsson-Kanyama & Lindén, 2002). Three categories were used; "food and cold storage", "entertainment and information", and "washing and cleaning" (ibid.). It inquired household members' descriptions of who uses which appliances, when and where the use is taking place, for what purposes, and, in households with more than one member, how this electricity use is distributed among the members. Initially all 14 households were interviewed once in their dwellings and at these occasions each household were represented by one to three persons. Accordingly, all members in all of the households have not been interviewed. The interviews were structured around open-ended questions and taped and transcribed verbatim. In addition, during two weekdays and two weekend days members over 12 years in five of the 14 households wrote time-diaries and kept logbooks over their use of stoves, microwave ovens, TVs, computers, washing machines, and drying appliances that were installed in the dwelling. In one of the columns in the time-diaries the members were requested to specify their use of any kind of technology/appliance. The notes in the time-diaries were coded, entered into and worked up in VISUAL-TimePAcTS (Vrotsou, Ellegård & Cooper 2007, Ellegård & Cooper 2004). The resulting visualizations of activities as well as results from the measurement study were presented when the five households in question were revisited. Follow up interviews were also made and taped during these visits.

As mentioned previously, the time-geographical approach (Ellegård & Wihlborg 2001, Ellegård 1999, 1977, Hägerstrand 1985, 1974) consider "time", "place" and "activities" analytic key concepts. On the individual household level we also pay attention to the fact that energy consuming activities may occur, not only during a certain time period, inside and outside the home, but also in different rooms in the dwelling. Based on Ellegård (1977) we also bring use of appliances demanding as well as *not* demanding the presence of a person to the fore. The "use" can go on during either "person-time", which demands the presence of a person (e.g. watching TV), or "process-time", which does not demand the presence of a person (e.g. when the dishwasher is running). This corresponds to the type (1) and (2) respectively of energy consuming activities according to Widén et al (2008) (p.5). Moreover, all kinds of electricity consumption, including different forms of stand-by, are looked upon as "appliance use". The concept "switch off" will be defined as "breaking the current supply completely". Any device that is left switched on, or put into stand-by, is considered to be "used" during "process-time". Mostly we regard this kind of use "non-necessary". However, computer servers that store data, and mobile phones that are being charged are examples of use during process-time which we consider "necessary". Yet other appliances, e.g. freezers and clock radios, have to be switched on almost all of the time in order to function and uphold a certain service and are used during a necessary and continuous process-time. We call this *background use,* corresponding to the (3) type of energy consuming activities of Widén et al. Another important aspect on energy use in relation to activities that we consider is whether the appliance is used by one or more individuals (individual and collective use). In table 1 the typology of basic patterns of electric appliance use is presented.

These basic use patterns are visualized in order to illustrate and thereby facilitate understanding of the complexity of what seemingly are simple patterns. The visualization leans on a time-geographical representation showing patterns (in time and space) of appliances and individuals. Time-geographical representations show the paths of appliances and individuals. First we show the main components of these kinds of representations.

Based on these components, for example, the serial individual and serial collective patterns can turn out according to the following.

Based on the activities performed in one of the households that took part in the study we now show visualizations of how some of these basic patterns of electric appliance use were manifested during one day and night. The visualizations put either individuals and their activities or individuals and their appliances to the fore.

APPLYING THE BASIC PATTERNS OF ELECTRIC APPLIANCE USE IN EVERYDAY LIFE

In this section we show how visualizations of household members' activities during one day and night can be used in order to discern and visualize patterns of appliance use. We will focus on the use of ICTs during one weekday in family Larsson's household. Data on the activities have been derived from the household members' individual time-diaries. Information from interviews and logbooks that were placed nearby the TVs and

Table 1. Basic patterns of electric appliance use.

	Individual use	Collective use
The simple patterns	one appliance is used by one person	one appliance is used by two or more persons at the same time
Serial	the same appliance is used by one person at different occasions during one day	the same appliance is used by different persons at different occasions during one day
Parallel	two or more appliances are used at the same time by one person in the same or different rooms	two or more appliances are used at the same time by two or more persons in the same or different rooms
Background use	appliances that have to be switched on all of the time in order to function and uphold a certain service, e.g. refrigerators and freezers, clock radios	
Use during person-time Use during process-time	Use *with* the presence of a person Use *without* the presence of a person	

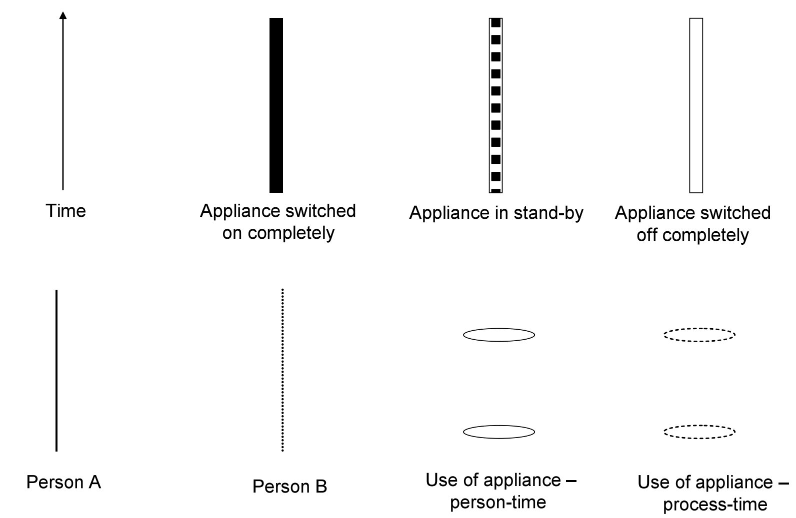
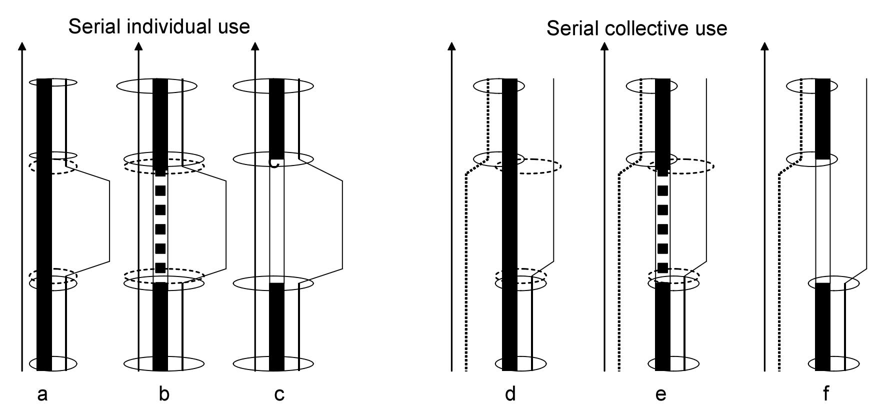


Figure 3. Main components of time-geographical representations of the basic patterns of electric appliance use.



Person A uses one appliance during person-time. After a while he/she leaves it either
(a) switched on completely, or
(b) in stand-by, both cases during process-time, or
(c) switched off completely (non-use).
He/she then returns to the appliance and starts using it again during person-time.

Person A uses one appliance during person-time. After a while he/she leaves it either
(d) switched on completely, or
(e) in stand-by, both cases during process-time, or
(f) switched off completely (non-use).
Person B then starts to use the same appliance during person-time. The change of user A to B may occur without any pause in between.

Figure 4. Time-geographical visualizations of serial individual and serial collective use.

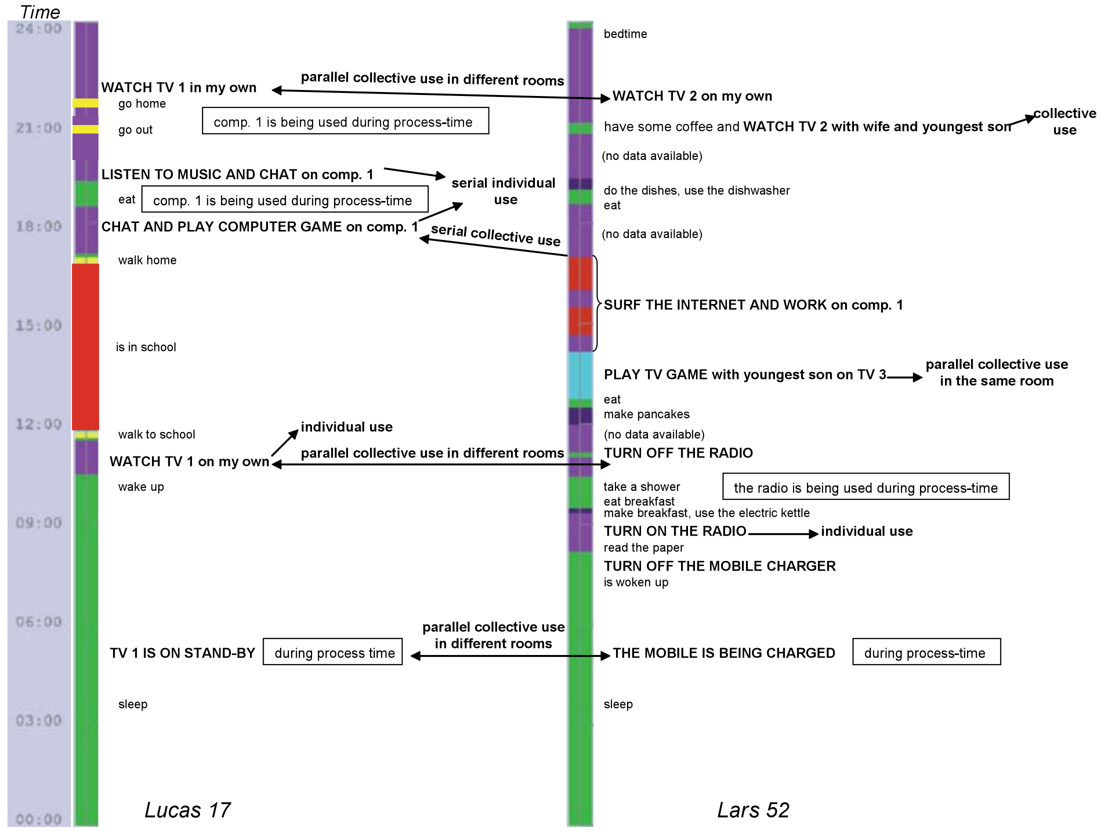


Figure 5. Visualization of activity data and patterns of electric appliance use. The activity graphs represent two household members' activities during one day and night and are based on notes from their individual time-diaries which have been coded and then worked up in the software VISUAL-TimePAcTS. The significations of the different colours in the graphs are presented on page 4 and 5.

computers also contribute to the understanding of the activities. We have left out the activities that were performed by two of the members; the mother and the youngest son and focus on the oldest son and the father, that is to say, on Lucas 17 years old and Lars 52.

Putting individuals and their activities to the fore

In order to highlight the activities performed by Lucas and Lars we use VISUAL-TimePAcTS and illustrate their day. The activities are based on notes from their individual time-diaries which have been coded. The codes have then been entered into and worked up in the software VISUAL-TimePAcTS. The significations of the different colours in the graphs are presented on page 4. In figure 5 all activities that were performed during a weekday by Lucas and Lars are shown and the ones involving ICTs have been typed in capitals. They watch TV, play computer games, listen to music, chat, listen to radio, use the cell phone charger, surf on the internet by using the appliances (the household has 3 TV-sets and 2 computers). TV 1 and computer 1 are placed in Lucas' own room, whereas TV 2 is placed in the living room and TV 3 in the youngest son's room.

In figure 5 it is revealed that this weekday Lucas is not using any other kind of ICT device than TV 1 and computer 1. He uses the computer serially, that is to say, we discern a *serial individual* use when focusing only on him. If we include Lars' use of the computer, it is a *serial collective* use. In Lars' activity graph we discern use of other kinds of appliances and some parallel use. For example, after lunch he plays video game with his youngest son. They then use TV 3 and one video game which correspond to the *parallel collective* use performed by two persons in the same room. Later in the evening Lars watches TV 2 together with his wife and youngest son. This is another example of a *collective* use. At about 22.00 Lars continues to watch TV 2 on his own. However, this activity is performed at the same time as Lucas is watching TV 1 in his room and consequently, it is a question of *parallel collective* use in different rooms. During the night and early morning we also see that Lars is charging his mobile phone, which we consider to be a kind of necessary process-time related use. However, when Lars is taking a shower and leaves the radio on during process-time it is a kind of non-necessary use. After he has taken his shower the radio is still on and Lucas starts watching TV 1 in his room, which is to regard as a parallel collective use. Every time Lucas and Lars use one device on their own it is also a question of *individual* use.

We have assumed that TV 1 is put into stand-by during the night and morning and that Lucas leaves computer 1 switched on when he goes out in the evening. However, either Lucas' notes in his diary or in the logbooks reveal whether this really is the case. We base these assumptions on the interviews. At the revisit Lucas admits that he does not always turn his TV off completely in the evening. If he watches TV in the bed before he goes to sleep he may only use the channel selector in order to switch it off. Moreover, in the interviews it is revealed that the sons often turn their computers on when they come home from school and then turn them off completely at about bedtime. Accordingly, information from time-diaries may not be sufficient and need often to be supplemented by interviews. We

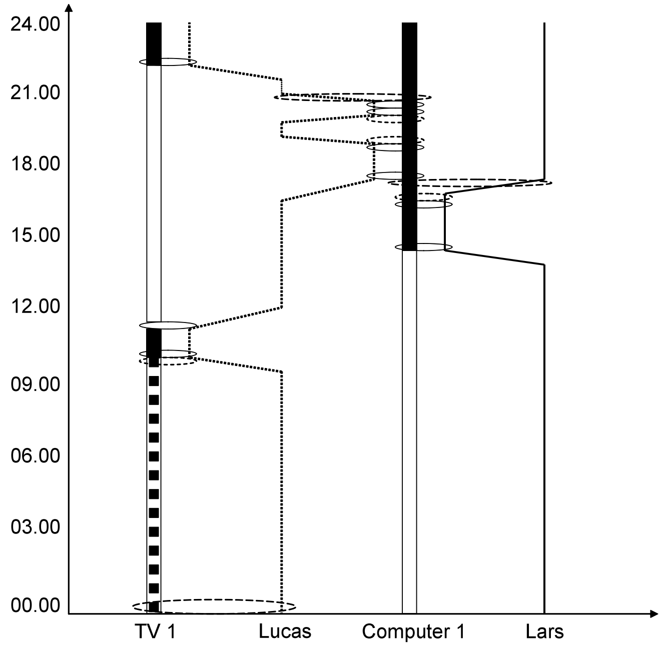


Figure 6. Visualization of patterns of electric appliance use. Legend: see figure 3.

return to this issue later. The fact that Lucas may not switch his computer off until later could mean that both the TV and the computer are consuming electricity late in the evening and we could then speak of *parallel individual* use.

Based on the use of computer 1 and TV 1 this weekday we will now present another kind of visualization technique. This puts the devices and their electricity consumption, instead of the activities, to the fore.

Putting individuals and their appliances to the fore

We now make use of the common time-geographical representations of the basic use patterns, such as serial individual and serial collective use, presented in connection with the typology in table 1. We exemplify how these kinds of representations can be used to visualize Lucas' and Lars' use of TV 1 and computer 1 during the weekday referred to above.

This kind of illustration thus focuses on the appliances and the duration and size of their electricity consumption. However, the individuals are also represented, which means that their use of the devices as well as the implications of their way of using them in an energy perspective become visualized and, hopefully, made more explicit and understandable. Activity data from time-diaries, logbooks and interviews still form the basis of the analysis. The serial use of computer 1, collectively as well as individually, is found between 14.00 and 22.00. Both the use of computer 1 and TV 1 include process-time related use, which is visualized by means of the broken circles. The process-time related use of TV 1 goes on during the night and early morning and in a stand-by mode, whereas computer 1 is switched on completely when used during process-time. Data on how much electricity these devices consume per hour when switched on completely or put into stand-by, enables calculations on the actual consumption of these devices during this day. Other aspects of the context in which these devices are used are not revealed, including for what purposes they are used and what activities that precede and succeed to Lucas' and Lars' direct use of them.

Hence, the aim of using the activity approach on the individual household level and of combining the visualizations focusing on activities and appliances respectively is not solely on calculating the amount of electricity used, but also on getting a better understanding of the reasons behind households' different figures and, thus, how electric appliances as well as other energy demanding technologies are used; for what purposes, by whom, when, where, how long, and in what way. Such information helps identifying different persons in need of different kind of information related to important energy issues, such as the possibility of bringing about behavioural changes. But, once again, what can actually be said about "how energy consuming technologies are used" on the individual household level?

UNDERSTANDING AND CHANGING "HOW ENERGY CONSUMING TECHNOLOGIES ARE USED" ON THE INDIVIDUAL HOUSEHOLD LEVEL

In the analyses we focused on the use of ICTs, which is an area of use in which the electricity consumption is steadily increasing (Bennich 2008). However, the activity approach includes all activities and, thus, enables visualizations of the use of almost all electric appliances and other kinds of energy demanding activities. We have already mentioned that the background use is not getting visualized on the aggregate level but that the energy it demands can be estimated. Examples of other energy relevant behaviours that seldom get visualized have been given, but depending on the design of the diaries, the information given to the diarists and their endurance of keeping detailed diaries, we have explained that these activities might be possible to visualize as well. However, using the activity approach on the individual household level and for the purpose of promoting behavioural changes and less energy consuming activity patterns, the approach is not leaning only on time-dairies and what is possible to code and visualize. The visualizations serve as a basis for discussion about the household members' organisation of their everyday activities and habits. The analyst may supplement the information given from the diaries with notes in logbooks and bring up other aspects of the householders' energy use in follow-up discussions. Very often the writing of diaries with a special focus in mind becomes the starting point for a reflective process. Most often the time-diaries include one column for "own reflections", which can mean or be altered into "how I do". For example, when noting the activity washing clothes, the diarist can have been told also to note whether the machine is filled up or not, what temperature is used, etc. Such information will not be coded and visualized, but brought to the fore, possible to discuss, and, thus, in a way "visualized".

Hence, the ultimate use of the activity approach for the promotion of less energy consuming activities in households is to offer householders the possibility of writing time-diaries a couple of days, to analyse these using VISUAL-TimePAcTS, to discuss possible activity changes from the point of departure of the visualizations of their present use patterns as well as calculations of their energy consumption, and finally, to follow this up by means of a new round of diary keeping, analysis and discussion of visualizations and calculations. Supplementing the keeping of diaries with the filling in of questionnaires at the beginning and end of the intervention, which focus on the household members' attitudes towards energy saving and their own perceptions of their appliance use, contribute important knowledge on possible discrepancies between attitudes and behaviour and between reported and actual behaviour (cf. Cames and Brohmann 2003).

Limitations and need for development of the method

The activity approach thus rely on time-diaries as primary data source and the software VISUAL-TimePAcTS as primary analysis and visualization tool. The use of both of them is coupled with some limitations and/or need for further development. The main limitation of the data collection method relates to the dilemma described by Cames and Brohmann (2003); "…the need for detailed information, on the one hand, and the presumably declining readiness to participate, on the other hand" (p.1089). To the latter we can add the sometimes declining ability to complete the keeping of a diary that has already begun if the diary period is more than two or three days. Similarly, concerning the analysis method and VISUAL-TimePAcTS the main limitation has to do with the treatment of a lot of detailed and sometimes confusing information. We discuss these aspects and how they appear on the aggregate and individual household level respectively.

ON THE AGGREGATE LEVEL

The recruitment of informants to the Swedish national time-use surveys has passed off quite well. Slightly more than 6000 individuals are included in the national group of selection (SCB 2003). In the 1990/91 time-use survey 75 percent participated and the corresponding share 2000/01 was 61 percent. On the whole, this development follows a general pattern with increased falling off in surveys of selection (ibid.).

VISUAL-TimePAcTS is developed on the basis of a specific categorization scheme generated empirically from diary data. This does not correspond to the category scheme used by Statistics Sweden (or the one used in the harmonized EU time-use surveys). In order to use the data from Statistics Sweden we need to recode all diaries and it is a hard work. We suggest that a translation key is developed that facilitate the translation into the specific code scheme used for VISUAL-TimePAcTS.

In large time-use surveys another problem is related to coding, namely that it is not always possible to understand what is meant by a note in a diary. This problem is not solvable by going back to the diarist and making follow-up interviews, which adds problems of validity.

ON THE INDIVIDUAL HOUSEHOLD LEVEL

We assume that the use of the activity approach as an intervention tool on the individual household level is suitable for householders already interested in energy issues and how to make changes and, thus, who are willing to make the effort the writing of time-diaries demand. These householders are probably to be found via local institutions, such as agenda 21 groups and energy advisors, and are assumed to serve as role models who can spread their experiences and influence others. As such, the activity approach may serve as a "social marketing process" (Cames & Brohmann 2003, p.1080). In more clearly-defined research/intervention projects on the household level the diarists tend to be more accurate than the diarists participating in large-scale time-use surveys. The former have chosen to participate in a study with an aim that is of interest for them selves (Karlsson & Widén 2008, Skill 2008, Nordell 2002). However, the accuracy usually varies between different diarists, including different members of the same household, as their interest in the study and/or their tolerance with the writing may differ (Karlsson & Widén 2008, Skill 2008, Löfström 2008).

The issue of accurately kept diaries is of relevance for the coding of the notes. Presumably, the problem of incompletely filled-in diaries never can be avoided completely but is manageable. Possible problems in interpreting the notes can be resolved by contacting the householders or checking an already made coding during the follow-up discussions. Moreover, in order to be able to discern the patterns of electric appliance use exemplified here as well as other energy consuming activity patterns the design of the diaries and how the householders are to be informed of the writing of the diaries need to be thoroughly planned. For example, not only activities but also accompanying individuals and technologies used need to be documented. If they have several appliances of the same kind, e.g. TVs, they may need to number or name them in order for the analyst to discern the parallel collective use taking place in different rooms. Writing down activities such as "switch on", "switch off completely" and "put into stand-by" would facilitate the analysis and demand the development of new codes. The issues of the design of diaries and information given to the diarists are relevant for the aggregate level as well. This needs to be coordinated with Statistics Sweden and decides, apart from the diarists' accuracy and endurance, the scope of energy consuming behaviours that will be visualized.

For the moment the activities that are typed in figure 5 have been typed manually and not automatically by VISUAL-TimePAcTS. This is a time-consuming activity but an issue for the on-going development work of the software.

Conclusions

The aim of this paper has been to present an activity approach on energy use in households which enables visualizations of patterns of energy use on aggregate as well as individual household levels. More specifically, the time-geographically based activity approach is a way of visualizing individuals' very complex and energy demanding everyday lives by means of time-diaries and the software VISUAL-TimePAcTS. A very important point of departure is, thus, that visualizations facilitate descriptions of and discussions about such complex matters. Concerning energy use on the aggregate level the idea is that by using already recurrent national time use surveys based on diaries the activity approach may serve as a complement to energy measurement studies in households and the recurrent national time use surveys can be utilised for more purposes than today. Moreover, comparing the use of time-diaries with the use of questionnaires the former would probably to a greater extent capture individuals' actual behaviour. By focusing on the use of electric appliances, we have shown examples of visualizations representing electricity consuming activity patterns in a population of households as well as the interplay between household members and their ICT devices, based on a typology of patterns of electric appliance use, on the individual household level. Combining visualizations with estimations of the energy demand of larger populations as well as individual households may facilitate communication with both policy makers and household members about households' energy use. The methods can serve as tools for deepening households' understanding of their energy use in terms of their activities. The method also can serve as an instrument to develop activity-relevant policies to reduce energy consumption.

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