User behavior and patterns of electricity use for energy saving

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Abstract:

In this study patterns of domestic electricity consumption for 51 houses in Austria were studied. In these samples although type of house, its location, floor area, household size, electrical appliances, occupant's job, age and occupancy patterns are different, have significant influence on annual electricity consumption. A clear correlation was found between average annual consumption and daily base load. Energy consumption varies with the house type. Detached and terraced dwellings have more noticeable consumption during winter days. During the day the difference between peak and minimum consumption per floor area varies between 9.9 and 3.8 Wh/m² according to house type. During one year difference between peak and minimum consumption per floor area varies between 7.1 and 1.1 KWh/m² according to dwelling type. Terraced house have highest difference and apartment stands at last position. As the annual energy consumption per person decreases, the number of occupants increases.

Keywords: household energy consumption, house type, occupancy

1. Introduction

Due to the increasing in energy consumption and rise of dependency on energy imports, the efficient use of energy is becoming increasingly important. Austria is obliged to reduce its greenhouse gas emissions by 13% relative to the 1990 level by 2010 (Kyoto objective) and decrease it's energy consumption by 20% by 2020 according to the EU directive on energy end-use efficiency 2006/32/EC (energy efficiency directive) also 20 % more renewable should apply to supplier resources[1].

As about 30% of total energy consumption in Austria is related to households, focus of this study is on household sector and their energy consumption pattern.

Annual electricity consumption is increasing in Austria by 2%~3% [4] per year. Not only incremental penetration rate of the electrical devices in recent years [2], increasing the standby power consumption in new generation of electronic devices, decreasing the number of the person per household are drivers for this reason but it also can be affected from the different user behavior in the household. In this paper the result of investigating the effect of different parameter on user behavior is presented.

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Household Energy consumption is highly dependant to their location, type of dwelling, specification of heating system, socio-demographic of occupants, age of children, number of electrical appliances and their energy labels and user behavior.

Various studies have been done in the field of impact of user behavior on the total amount of energy consumption in the households. G.Wood [3] achieved to 10~20% reduction in energy consumption of households by changing the user behavior. Here we just assess the influence of various parameters on load pattern and the study will continue with the aim of reducing the energy consumption by changing the user behavior.

In this study, for getting the detail information about house type, number of occupants, type and number of electrical appliances, questionnaire has been prepared and distributed among 80 customers and filled questionnaire were returned with the response of 80%.

Also measurements were taken from 64 household over a 15 min time interval. Over a 77 household which have filled questionnaire or consumption measurement, 51 households have both information together. For this study it is supposed to consider these 51 dwelling as analyzing sample.

2. Characteristics of selected household

The 51 household which has been studied included 71 % rural area and 29% urban area. 76% detached, 18% semi-detached, 2% apartment and 4% terraced dwelling were involved in this study. 2% of the households had one occupant, 8% had two, 35% had three, 45% had four, 25% had five and 14% had six or more than six occupants. Among these occupants 39% had full time job, 13% had part time job and 3% were retired.

In surveyed household, 39% provide their warm water with electrical boiler, 4% with Geyser and 57% use fossil fuels. Regarding space heating 31% use electrical heater, 8% use heat pump and 59% use other fossil fuels.

In these household, 14% have controlled living space ventilation.

The distribution of different lighting system which has been installed in these household are like: 54% Incandescent lamp, 11% fluorescent tube, 26% halogen lamp and just 7% are energy saving lamp.

In kitchen, the survey showed that all of the household have wash machine, 92% have dish washer, 96% use electric stove, 76% have microwave and 157% , 125% have fridge and freezer respectively which means there are more than one cooling devices in some household.

Number of other entertainment devices which has been used in these households is listed in the table.1.

Although most of the households have at least one TV, PC, HiFi and Receiver but TV with 76%, PC with 75% and HiFi and Receiver with 55% are devices which have high ranking of being more than one in some households.

2. Smart metering

For assessing the affect of different parameter on amount of electricity consumption, direct measurements were made on the base of 15 Min. time interval. The measurement started from 1st of June 2007 and lasted one year. The measurements were not started contemporary and complete measurement is exist from 7th of November 2007. Due to

mentioned reason analysis are based on maximum number of information which are exist in this period of time.

The detail analysis has been coupled with building data and electrical appliances from questionnaire which was distributed between mentioned customers.

For ease of analysis, the data were formatted into a detailed excel data base that includes all parameter regarding the time and type of energy consumption.

Table.1: number of entertainment appliances in the household (%)

Appliance	Owner (%)	Owner of more than two devices (%)
PC	98	75
Printer	96	31
HiFi	90	55
Video recorder	84	22
DVD player	80	25
SAT/DVB-T Reciever	75	55
wireless telephone	69	27
Halogen table lamp	67	39
Scaner	65	2
Electrical toothbrush	61	31
TV	45	76
play station	29	4
Answering machine	24	0
hard disk recorder	22	0
Fax	14	0

3. Household energy use based on floor area

Average energy consumption per month varied between 450 and 950 KWh per household. Winter energy consumption is roughly two times more than summer energy consumption. Energy consumption in summer days, decrease between 24% and 58% in comparison to winter days according to house type.

Result of filled questionnaire shows that households mainly are divided to four types in Austria, Detached or one family household, Semi-Detached or two family household, Apartment and terraced or row households.

Analyzed data shows that in general monthly energy consumption in detached and terraced households are more than the other type of dwellings.

Not only the type of dwellings affects the annual energy consumption but also the size of dwelling in the term of floor area is an important parameter in this case.

The floor areas of houses represented in this study are as following table below.

Table.2: distribution of dwellings based on their floor area

Floor area(m²)	90~120	120~160	160~200	20~240	240~280	>280
(%)	6	41	27	8	14	4

Fig.1 depicts the average annual energy consumption as a function of floor area.

Regarding to correlation factor, it is clear that electricity consumption is highly dependant to the floor area and its relation can be represented as below equation:

E=1724.8 F+2419.6

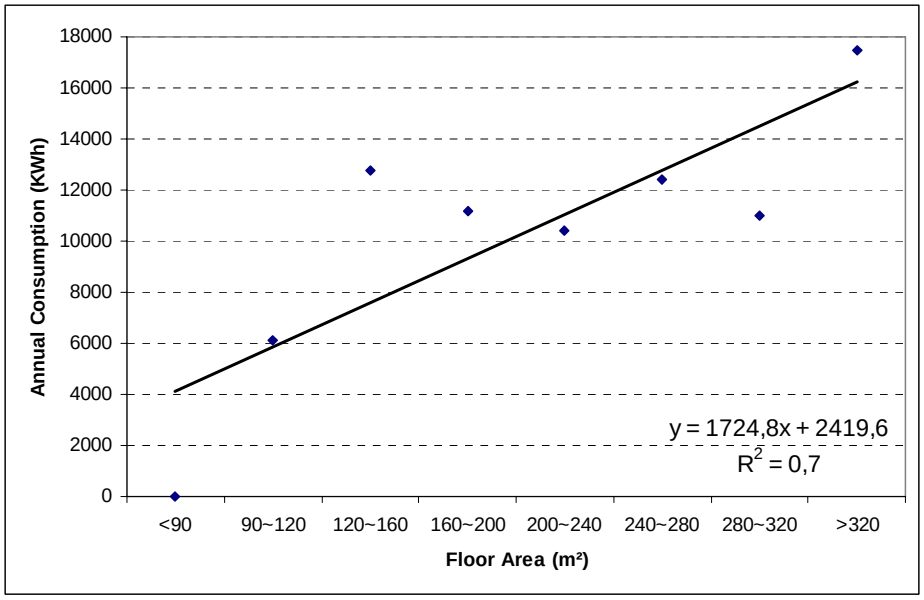

Fig.1: correlation between annual energy consumption and floor area

3.1. Monthly household energy use

Average energy consumption per month for each dwelling type has been depicted in fig.2 also Fig.3 shows normalized electricity consumption to floor area of these different house types.

Monthly consumption for detached houses varies between 3.6 and 7.9 KWh/m² and the average is about 5.4 KWh/m². For semi-detached households monthly consumption varies between 1.8 and 3.5 KWh/m² and the average is about 2.6 KWh/m². In the apartments monthly consumption is between 3.4 and 4.5 KWh/m² and terraced houses have monthly average consumption between 4.9 and 11.4 KWh/m².

As a matter of the fact, terraced and detached household have high consumption and apartment and semi-detached stand on the next steps.

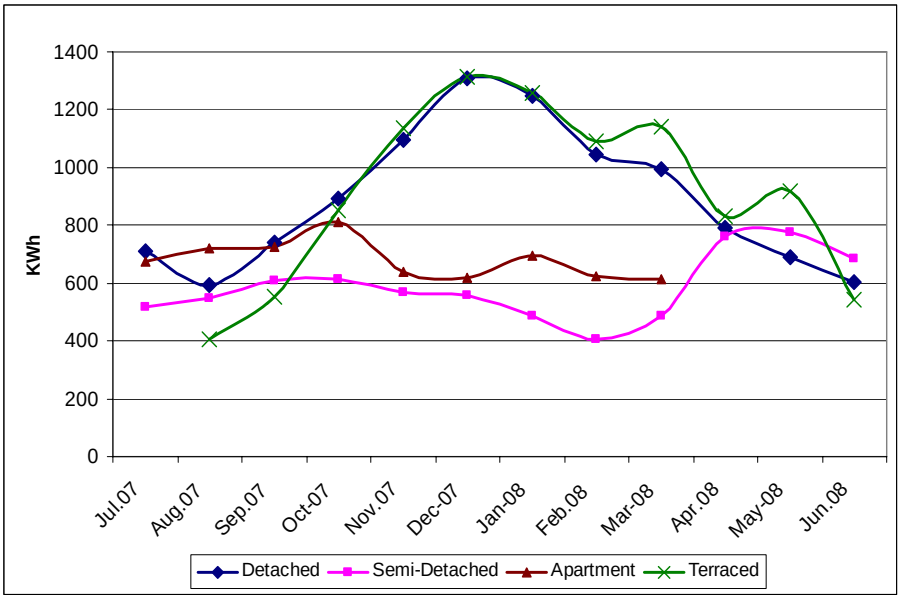

Fig.2: monthly energy consumption based on house type

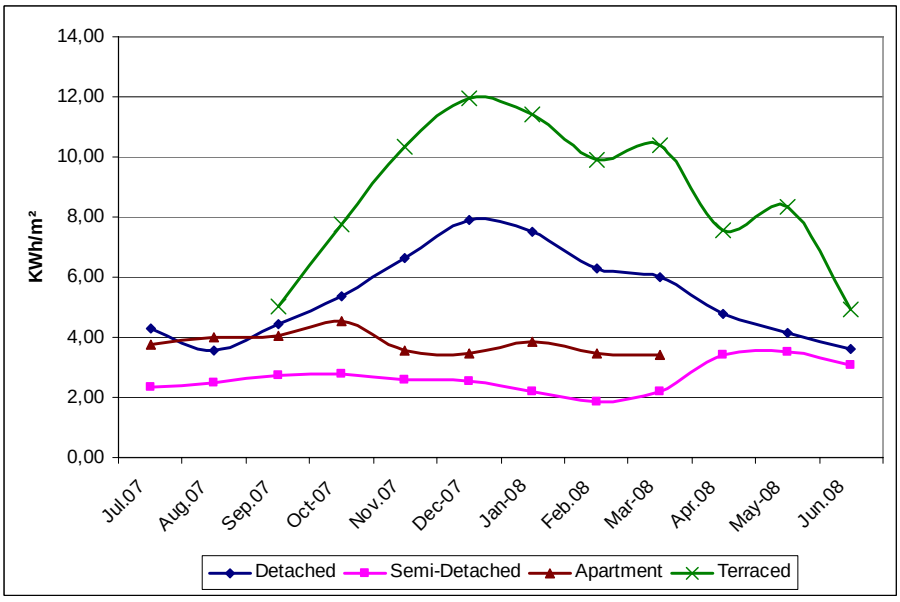

Fig.3: energy consumption per year per floor area according to house type

It is expected that energy consumption of terraced houses should be less than detached houses. As just 4% of involved houses are terraced dwelling the information is affected by these families and it can not be a representative of terraced houses.

It is notable that energy consumption in semi-detached and apartment is roughly flat and there isn't any big change between summer and winter demand but in detached and terraced houses demand in winter is three times more than summer time.

3.2. Impact of household appliances on electricity use

Fig.4 shows the number of electrical appliances which are used in these household. In average household have 17 to 23 electrical appliances. It is obvious that increasing the number of the appliances in the household affects the energy consumption as it is shown in Fig.5.

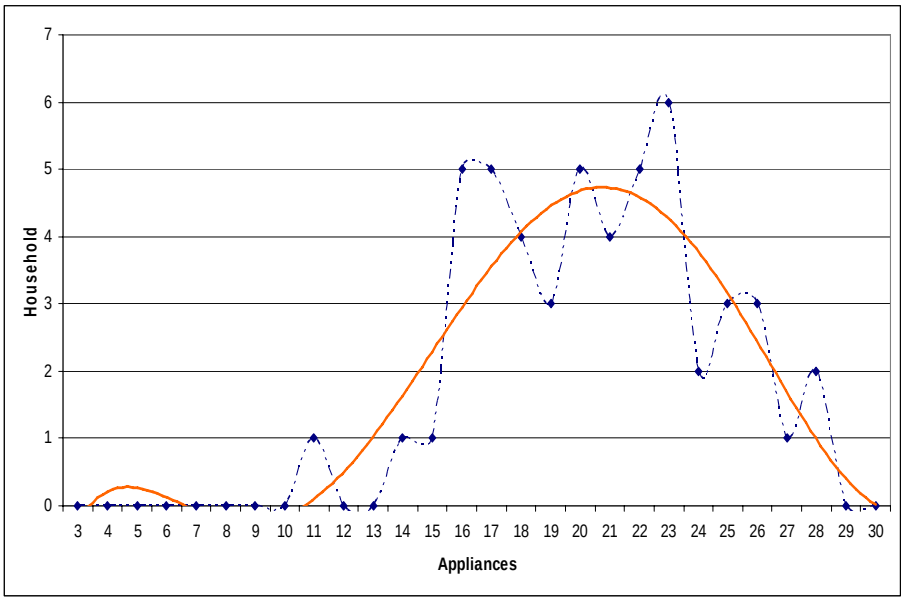

Fig.4: distribution of number of electrical appliances in different households

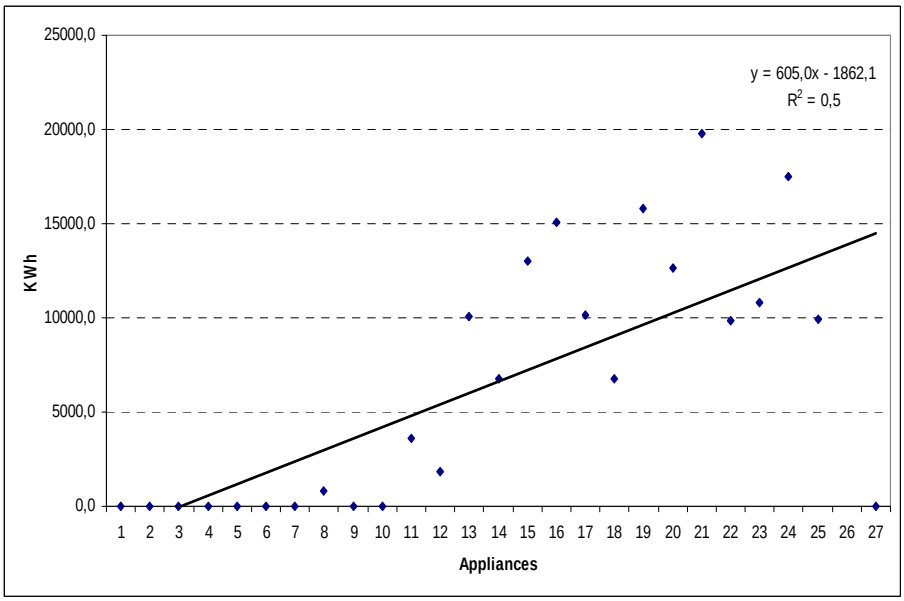

Fig.5: correlation between annual energy consumption and number of appliances

3.3. Influence of dwelling characteristics on energy consumption

Assessing the average daily annual consumption of different house type shows that generally the load profiles have similar pattern. The peaks and minimums happen in the same time period. We separated the weekdays and weekends and extracted the load pattern of these two groups. Fig.6 and Fig.7 shows that the load pattern and energy amount are different in week days and weekends.

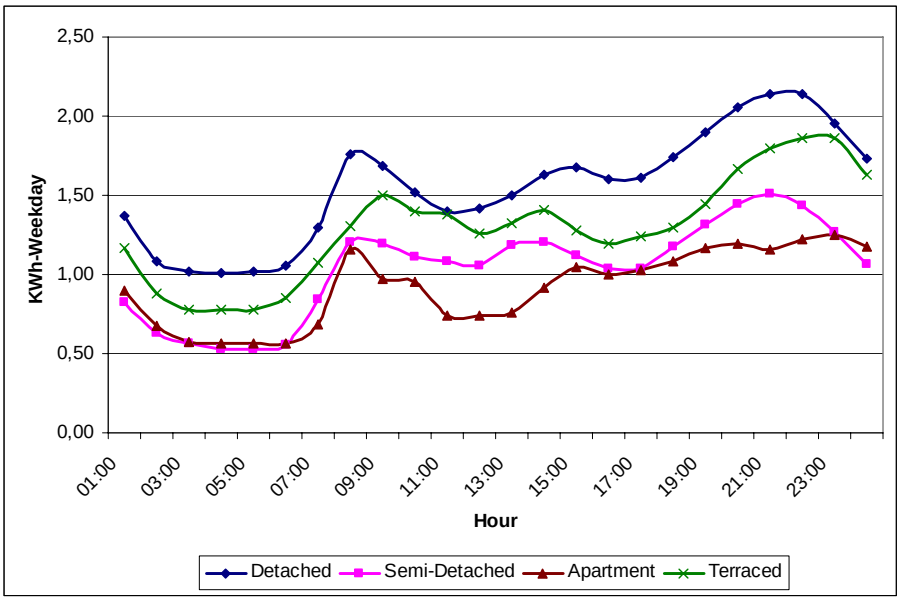

Fig.6: average daily energy consumption during weekday

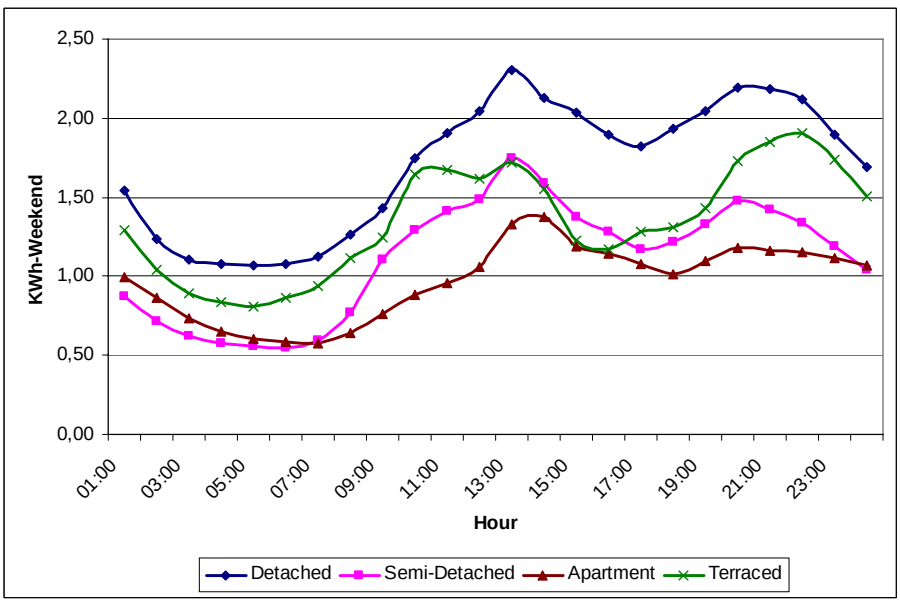

Fig.7: average daily energy consumption during weekends

During the weekday the minimum load occurs between 2:00 and 6:00 in the morning when most of occupants are sleeping and morning peak is started from 7:00 to 10:00 for preparing breakfast and taking shower and the night peak starts from 19:00 to 00:00 when the occupants are at home, making dinner and using the entertainment appliances.

At weekend there is mid-day peak load between 10:00 and 15:00 and nigh peak occurs between 19:00 and 22:00.

The variation about 1.03 KWh or 0.01 KWh/m² has been seen between the minimum and maximum load in daily pattern. This variation is more considerable in detached houses and it is smaller in apartments.

As it is shown in fig.8 and Fig.9, despite of same load pattern there is big difference between energy consumption of different type of house per floor area.

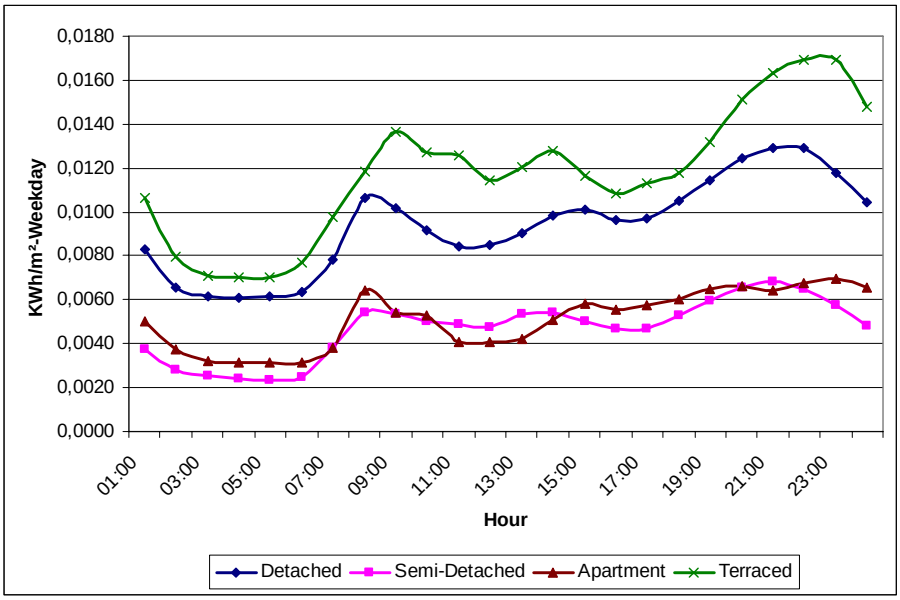

Fig.8: average daily energy consumption per floor area during weekdays

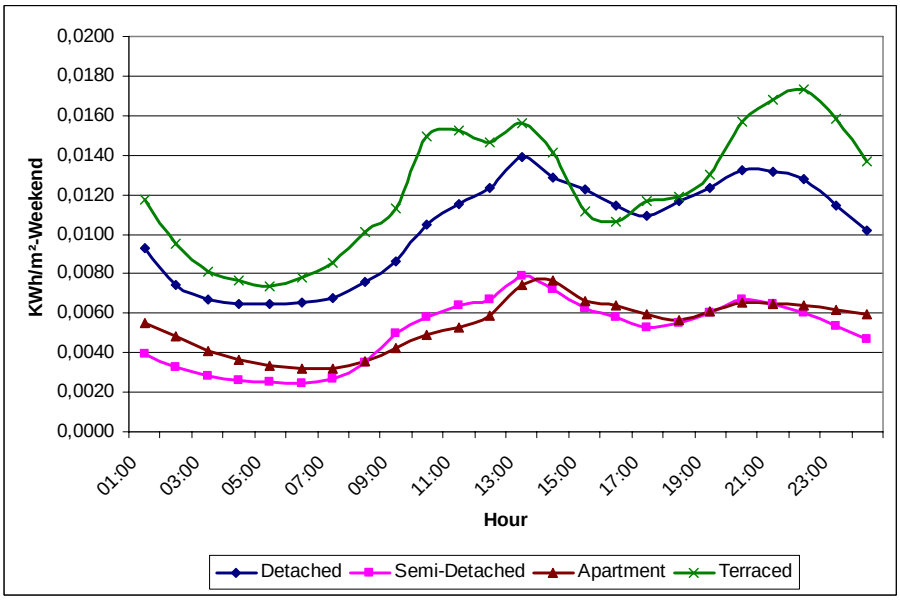

Fig.9: average daily energy consumption per floor area during weekends

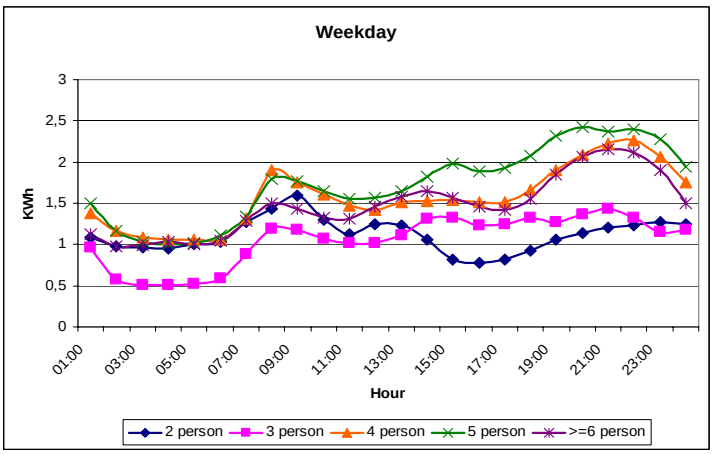

Fig.10: daily consumption based on occupant's number During Weekdays

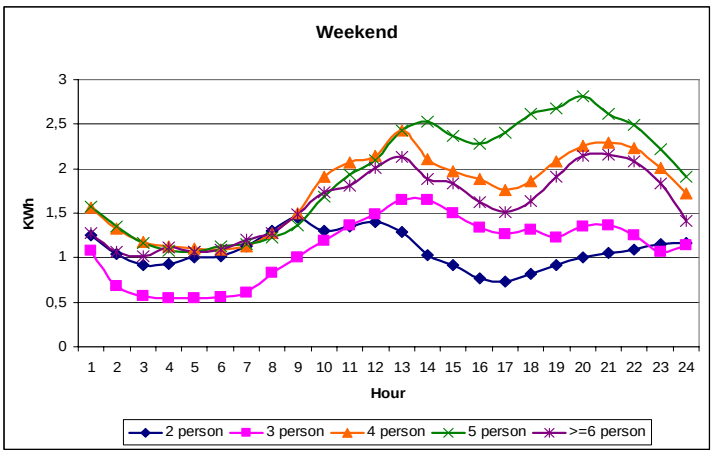

Fig.11: daily consumption based on occupant's number during weekends

Fig.12 shows that although the daily energy consumption is increasing by increasing the number of occupants but annual energy consumption per person will increase according to increasing the household members.

Fig.12: annual energy consumption per person based on occupant's number

A load drop in the energy consumption of household with 2 occupants in comparison with 3 occupants is because of having not representative data in this category.

Not only the number of the people affects the daily load profile but also the age of the children which are living in the household influences the load profile and energy consumption.

Fig.13 and Fig.14 show that despite of same load pattern the amount of base and peak loads vary with age of children.

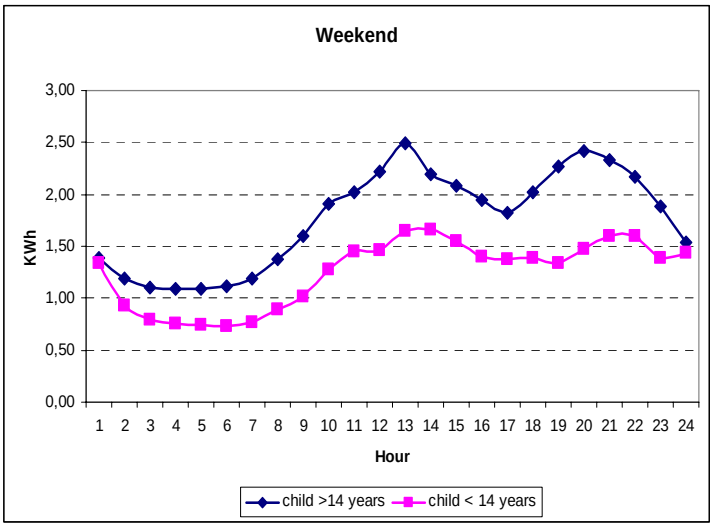

Fig.13: difference of weekdays load pattern by the age of Childs

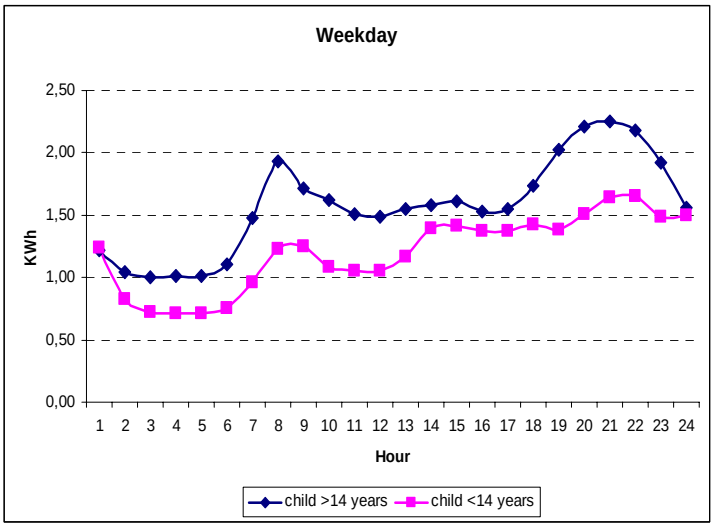

Fig.14: difference of weekends load pattern by the age of Childs

The effect of location has been shown in the Fig.15 and 16. The only difference is the amount of peaks during the week and weekend.

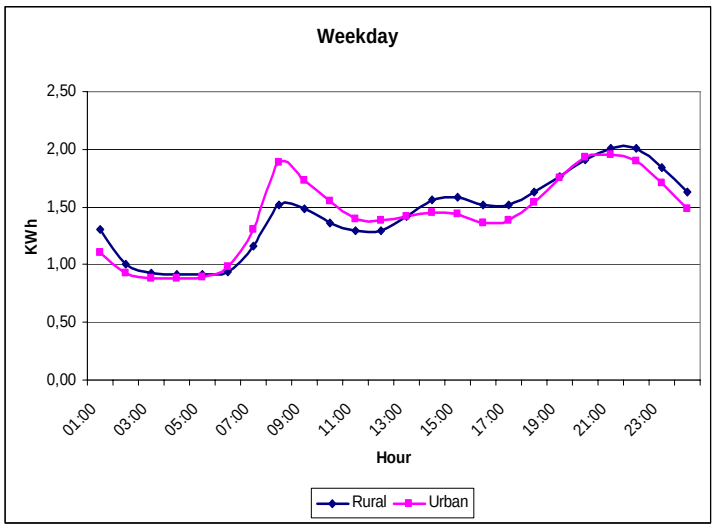

Fig.15: weekday's energy consumption based on location

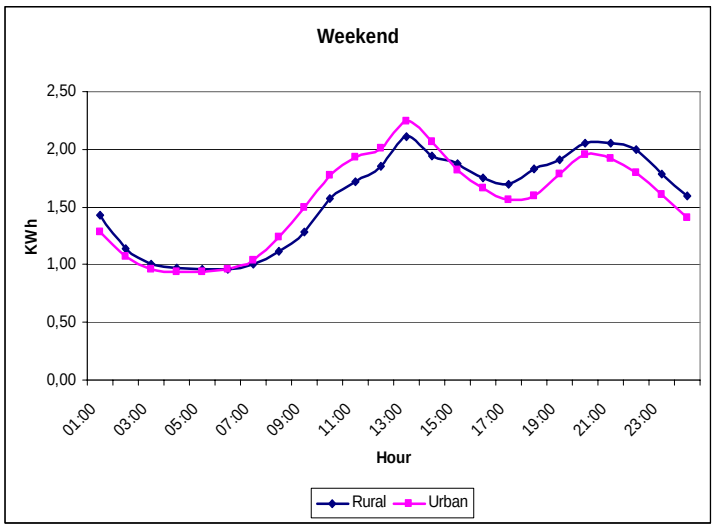

Fig.16: weekend's energy consumption based on location

4. Base load analysis

Base load in the household is composed of two components, consumption of appliances such as fridge and freezer which are tick away in the background of daily consumption and standby energy consumption. Fig.17 shows that the base loads have a good correlation with the annual energy consumption of household.

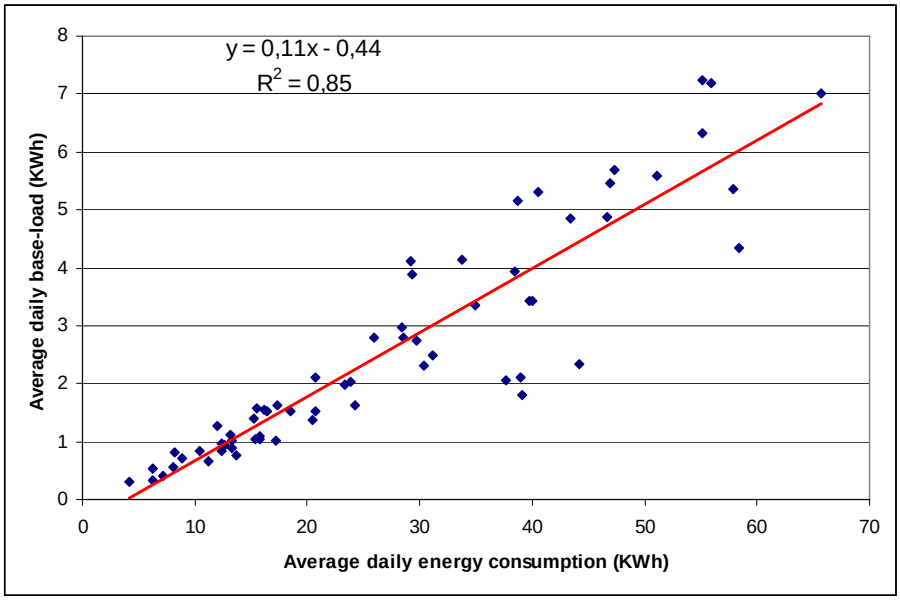

Fig.17: correlation between base load annual energy consumption

Here there is a need to have a standard load profile for comparing the result of study. As finding the detail consumption data on the scale of household in Germany is easier than Austria, the normalized load profile has been made of multiplying the distribution of household size in this study with their standard load consumption over a year in Germany [5] and normalized standard load profile over 1000KWh per year in Germany.

Fig.18 shows the normalized load profile of this study compared with normalized standard load profile [6]. It has been shown that the amount of base load in our study is higher than standard value. The peak loads in standard format are about 50% more than average load while in our study it is between 20% to 40% more.

Fig.19 shows that despite of having similar load pattern in two case energy consumption of electricity user in the case of this study is about 2~2.5 times more than standard pattern and The spread of time over base load in standard format is wider than the case of this study.

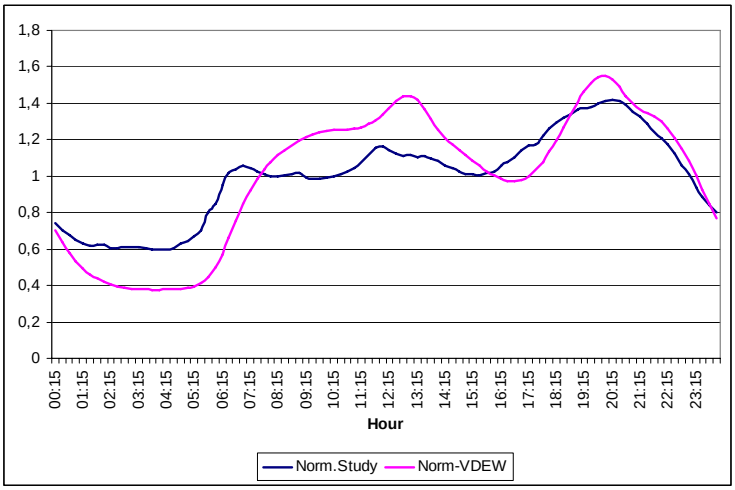

Fig.18: Normalized average consumption pattern compared with VDEW profile

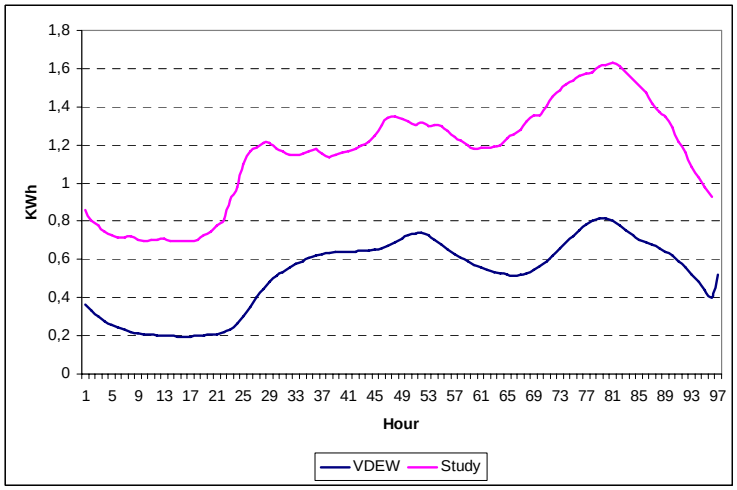

Fig.19: Average consumption pattern compared with VDEW profile

5. Conclusion

In this paper we have shown that the electricity consumption in the household is highly dependent on the floor area of dwelling, area of living and age of children. Energy consumption considering individual appliances declares the time and duration of electricity use in the household. For example the high peak in Fig.15 and Fig.16 shows the high share of consumption of entertainment devices such as TV, PC, audio devices and such appliances.

Also high amount of consumption in the early morning shows the considerable amount of standby power consumption of mentioned devices.

Refrigerator and freezer are independent from the number of family members, age of children and floor area of dwelling. Whereas other wet appliances such as wash machine, dryer and lighting are dependent to age of people in the household.

This study also confirms the feasibility of smart metering in the household and provides a solid basis for designing an end use energy efficiency program or efficiency policy.

6. Acknowledgment

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7. References

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