Energy Analysis of the FutureLife-House

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1. Introduction and problem setting

This paper is based on a research project (Huser and Aebischer, 2002) financed by the Swiss Federal Office of Energy.

1.1 Starting point

With the fast increasing use of the Internet for private purpose, the "intelligent home", having been a wishful thinking for many years, may become a reality in the near future. The fusion of the different media is the catalyst and at the same time the first visible sign of this evolution. The development of user-friendly people-machine interfaces and of new services and the possibility to "have a look" back home and to intervene in the house at every moment from everywhere will foster the interconnection of white-goods and the intelligent control of other building equipment and services.

Aebischer and Huser (2000) showed that the impact on energy demand of this interconnecting everything in- and outside the house is manifold and can be considerable. Inside the house, the induced increase of energy demand is probably far more important than the energy saved by better control. Scenario calculations for electricity demand in the household-sector in the coming 20 years lead to an annual increase of up to 1.3% per year (+ 30% in 20 years) due to interconnecting purposes alone. Even if this internet-induced increase were only half as fast, the interconnection of equipment and services would still be the most important driver of electricity demand in the household sector. The most promising measure to reduce this increase consists in minimising the electricity consumption of components and equipment in the standby- and off-mode.

These results were discussed at the eceee summer study conference (Aebischer and Varone, 2002) and at the IEA-workshop *The Future Impact of Information and Communication Technologies on the Energy System* in February 2002 (Aebischer, 2002). At that occasion Thomas (2002) presented an alternative scenario differing essentially by more optimistic assumptions regarding standby losses and fewer equipment attributed to multi-media activities. The increase of electricity demand in Germany could then be as low as 0.15%/year (+3% in 20 years). In a recent overview-paper about standby losses (Bertoldi et al., 2002) the potential in-

crease of standby losses due to home automation is highlighted: "Standby power consumption may increase as households become “totally automated.” A Swiss study (Aebischer & Huser 2000) indicates that standby power use in the Swiss residential sector may be as high as 400 kWh per household per year in 2020. The main contributor will be electronic components in white goods. Estimates of standby power usage by interconnected white goods (including networking and controllers) in the year 2000 are already as high as 350 kWh per totally automated household per year."

The potential importance of additional standby losses and electricity increase due to home automation is thus recognised by the scientific community. But the empirical basis is almost non-existing and to our knowledge no comprehensive study has been undertaken so far.

1.2 Objective

Many of the inputs used in the simulation of the networked household in Aebischer and Huser (2000) and Aebischer and Varone (2001) were based on estimations of power loads and the number of equipment networked and additional equipment needed for networking purposes or purchased in order to make use of the networking facilities. The measurement and analysis of energy use in a real networked home is expected to allow a more realistic simulation. But, no substantial improvement regarding today's and future diffusion of networking in household can be gained from analysis of this single house. And therefore the question, whether networking in household brings a substantial nation-wide increase in electricity demand, cannot be answered more accurately than before.

2. Approach/Method

In the FutureLife-House (www.futureLife.ch) no monitoring of electricity consumption was done before we started the analysis.

In the few months of the analysis the following measurements and evaluations of electricity consumption and use in the fully networked house were done:

- analysis of electricity bills over 16 months,
- measurement (15 minutes intervals) of total electricity consumption over several weeks,
- detailed measurement of power loads and electricity consumption of some individual equipments and components,
- estimation of usage pattern of equipment by interviews of inhabitants,
- analysis of automatically registered data of the use of steamer, dishwasher, washing machine and tumbler,
- establishment of a data bank with characteristics of some 100 equipment,

- correction of measured consumptions in order to allow a comparison with electricity consumption in a typical house in Switzerland.

3. Outcomes/Results

3.1 Total electricity consumption

The electricity bills showed a yearly consumption of 22.6 MWh/year, with a significant higher consumption in winter of 2.2 MWh/month compared to 1.6 MWh/month in summer. Heating is not the reason of this difference: gas and solar energy are used for heating and preparation of warm water. The difference is probably due to more lighting in winter term, possibly more cooking of warm dishes and mainly longer absence of inhabitants and reduced business activities in summer time.

The measured (Mai/June) total electricity consumption of 58.2 kWh/week corresponds well with the yearly consumption determined from the electricity bills. The variation of the power load on five weekdays (Figure 1) shows a very high base load of 2 kW mainly due to ICT-equipment and UPS. This base load is responsible for 86% of electricity consumption. The question how much of this consumption can be considered as standby losses is discussed in section 3.2.

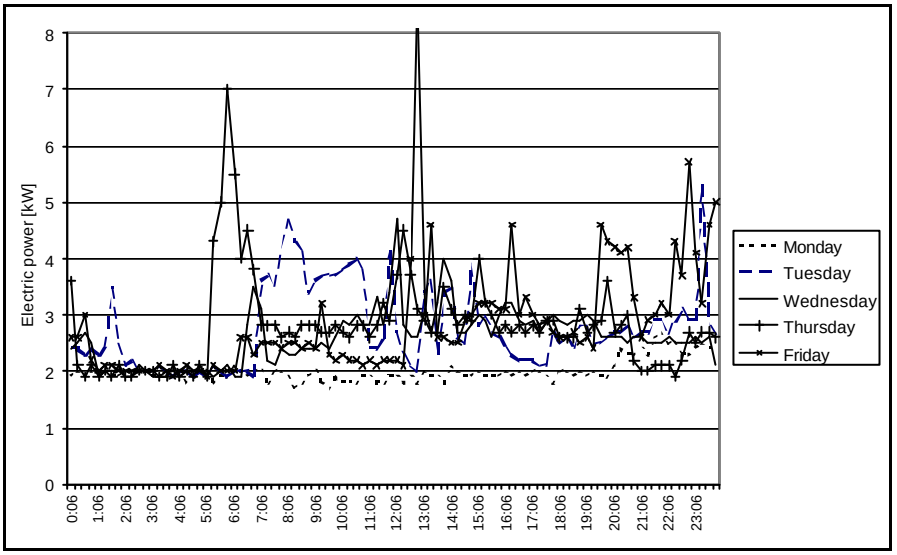

Figure 1: Power load (measured in intervals of 15 minutes) of the FutureLife-House on five weekdays (20. – 25. 5. 2002)

3.2 Electricity consumption of individual equipments and by functional groups of equipments

The power load and electricity consumption of all the equipment was determined for two technically defined (not functional!) modes: "Normalbetrieb"[1] and "Bereitschaftsbetrieb"[2]. Theses technical modes differ substantially from the functional modes "on" and "standby/off"[3]. In this study, electricity consumption of an equipment, which is in the on mode even though it is not used (either because it is not switched off, or it does not have a low power or off mode, or this other mode is not enabled), is counted among "Normalbetrieb". Following the functional definition this electricity consumption would be counted among "Bereitschaftsbetrieb". This methodological difference is unfortunate but inevitable in an automatic measuring process without a detailed monitoring of the instantaneous functional use of the individual equipment. As a first immediate consequence, the base load of the FutureLife-House (Figure 1) is counted among "Normalbetrieb" and is not considered explicitly as standby loss.

Power loads, hours of use and electricity consumption of all the equipment are summarised in a table in (Huser and Aebischer, 2002, Annex 3: http://www.cepe.ethz.ch/download/projects/sb_energieanalyse_futurelife.pdf). They are ordered following eight functional groups:

- white goods,
- lighting,
- entertainment and communication,
- comfort and climate,
- security,
- maintenance and health care,
- home office and
- central infrastructure.

The highest annual electricity consumption is by far due to the group central infrastructure, which contains mainly servers and UPS (Figure 2).

[1] In this study we consider that electricity is used in the "Normalbetrieb", if
- the equipment fulfils (one of) its main function(s)
- there is only one operating mode
- other operating modes are disabled.

[2] In this study we consider that electricity is used in the "Bereitschaftbetrieb", if the equipment is in a mode other than in the one fulfilling its main function(s).

[3] Standby power is the electricity consumed by end-use electrical equipment when it is switched off or not performing its main function (Bertoldi, P. et. al., 2002)

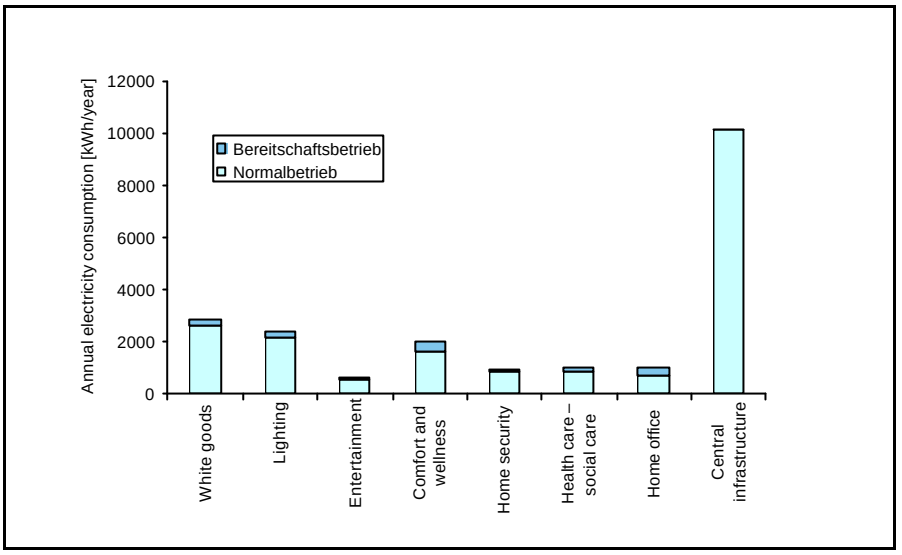

Figure 2: Annual electricity consumption of the FutureLife-House per functional groups of equipment

The twenty largest electricity consuming equipment are shown in Figure 3.

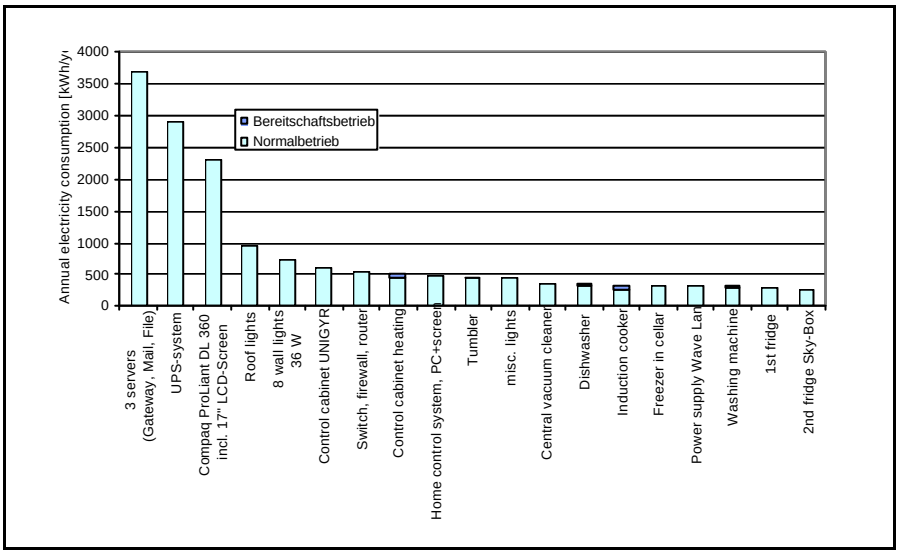

Figure 3: Annual electricity consumption of the 20 largest electricity consuming equipment in the FutureLife-House

3.3 Energy efficiency potentials

We considered four types of efficiency improvements and energy saving measures:

- automatic power management of all electronic equipment
- low power mode of 1 Watt for all electronic equipment
- use of a single central gateway
- renouncement to use a UPS
- replacement of halogen lamps by fluorescent lamps

The detailed assumptions and the resulting electricity consumptions can be found in a table in (Huser and Aebischer, 2002, Annex 4: http://www.cepe.ethz.ch/download/projects/sb_energieanalyse_futurelife.pdf). Annual electricity consumption is reduced by about 2/3 (Figure 4). The largest savings (95%) are possible in the central infrastructure and in the other equipment used for networking (80%). Many other efficiency improvements are possible – e.g. by using the most efficient equipment available on the market – but were not considered in this study which focuses on the question of (additional) electricity consumption by networking in households.

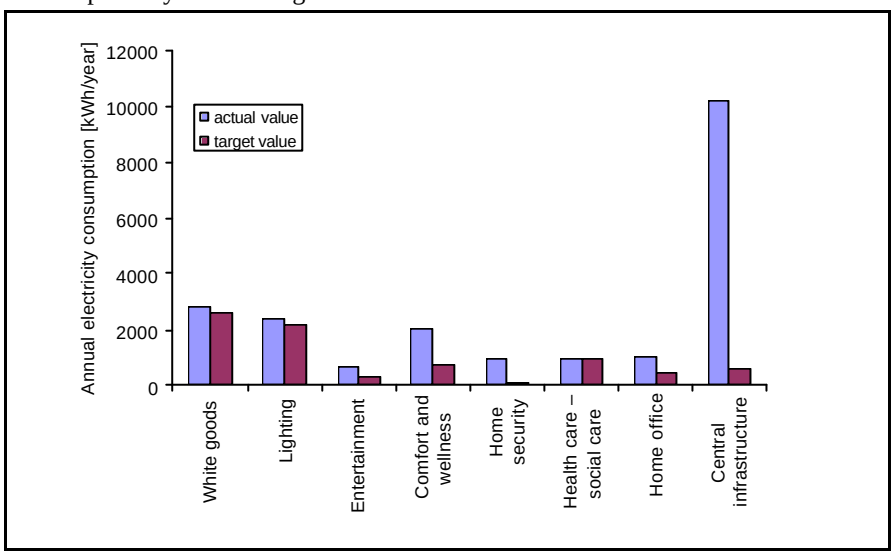

Figure 4: Measured and with the proposed energy saving measures achievable annual electricity consumption of the FutureLife-House per functional groups of equipment

3.4 Comparison of electricity consumption in the FutureLife-House and in a typical house in Switzerland

The measured electricity consumption of the FutureLife-House of 22 MWh/year is more than 3 times higher than in a typical higher standard single-family house in Switzerland of about 6.6-7 MWh/year. There is no significant difference in what concerns electricity consumption of the standard equipment used in households today. But, in the FutureLife-House we find in addition:

- new equipment and new uses of electricity (steamer, plasma TV, mechanical aeration, mechanically moved curtains, shower-toilet, ionisation column, massage-chair, water dispenser, fitness equipment, central vacuum cleaner),
- equipment needed for networking and installed in order to use the facilities of networking (refrigerator sky-box, sound system, beamer, PC and monitor in home office, TV Internet gateway, home infotainment, web cams, door opener, alarm equipment, fingerprint sensors, etc.),
- servers and UPS.

Table 1 shows orders of magnitude of electricity consumption by these different groups of equipment – normalised to the consumption of standard equipment in a typical household in Switzerland – in the FurureLife-House before (today) and after (optimised) applying the energy efficiency measures described in section 3.3.

	FutureLife-House today	Typical house Switzerland	FutureLife-House optimised
Servers and UPS	**100**		**5**
Equipment for and due to networking	**100**		**25**
New applications	25		25
Standard equipment	100	100	100
Total	325	100	155

Table 1: Electricity consumption, measured relative to electricity consumption in a typical house in Switzerland, of the FutureLife-House before and after applying energy efficiency measures (100 = 6 MWh/year)

3.5 Simulation of electricity use in a household due to home automation

In this exercise we consider only the equipment grouped in table 1 into "Equipment for and due to networking". The equipment considered and the input data used are presented in Table 2.

	Bus	Electric power today		Electric power optimised		Time of use today		Time of use optimised	
		Bereit-schafts-betrieb	Normal-betrieb	Bereit-schafts-betrieb	Normal-betrieb	Bereit-schafts-betrieb	Normal-betrieb	Bereit-schafts-betrieb	Normal-betrieb
White Goods									
2nd Fridge Sky-Box	--	-	28.2 W	-	28.2 W	-	8760 h	-	8760 h
5 Modems-PLC	PLC	7.5 W	-	0.0 W	1.0 W	8760 h	-	8322 h	438 h
Powerline Phase Coupler	PLC	-	6.0 W	0.0 W	6.0 W	-	8760 h	8322 h	438 h
Powerline central modem	PLC	-	1.0 W	0.0 W	1.0 W	-	8760 h	8322 h	438 h
Lighting									
157 Data points EIB	EIB	17.8 W	-	1.0 W	-	8760 h	-	8760 h	-
Entertainment									
Soundsystem	--	10.0 W	70.0 W	1.0 W	70.0 W	6570 h	2190 h	6570 h	2190 h
Home Infotainment	Ethernet	2.0 W	50.0 W	1.0 W	50.0 W	6570 h	2190 h	6570 h	2190 h
Beamer	--	5.0 W	220.0 W	1.0 W	220.0 W	8577 h	183 h	8577 h	183 h
Comfort and Wellness									
49 Datapoints EIB	EIB	4.8 W	-	0.5 W	-	8760 h	-	8760 h	-
Power supply Wave Lan	Ethernet	-	36.8 W	0.0 W	36.8 W	-	8760 h	7600 h	1160 h
WAVE LAN single antenna	Wave LAN	-	25.0 W	0.0 W	25.0 W	-	8760 h	7600 h	1160 h
Control cabinet UNIGYR	EIB	-	69.0 W	0.0 W	69.0 W	-	8760 h	8000 h	760 h
Home security									
3 Data points EIB	EIB	0.6 W	-	0.1 W	-	8760 h	-	8760 h	-
WEB-Cameras	Ethernet	-	24.8 W	1.0 W	24.8 W	-	8760 h	8000 h	760 h
KABA Door opener	EIB	-	21.0 W	1.0 W	21.0 W	-	8760 h	8000 h	760 h
Alarm system	Telefon	-	20.7 W	1.0 W	20.7 W	-	8760 h	8000 h	760 h
Finger print sensor	EIB	10.4 W	100.0 W	1.0 W	100.0 W	8687 h	73 h	8687 h	73 h
Power supply door camera	--	-	8.0 W	1.0 W	8.0 W	-	8760 h	8000 h	760 h
Health Care – Social Care									
Home Office									
Workstation 1		2.0 W	50.0 W	1.0 W	50.0 W	4380 h	4380 h	7700 h	1060 h
TFT Display 17"		2.0 W	30.0 W	1.0 W	30.0 W	4380 h	4380 h	7700 h	1060 h
Central infrastructure [1)]									
12 Data points EIB	EIB	2.2 W	-	0.5 W	-	8760 h	-	8760 h	-
Compaq ProLiant DL 360 incl. 17" LCD-Display	Rack 1	-	265.0 W	0.0 W	265.0 W	0 h	8760 h	8000 h	760 h
Compaq Deskpro (Homeserver)	Rack 2	-	60.7 W	0.0 W	60.7 W	0 h	8760 h	8000 h	760 h
TV Internet Gateway	Ethernet	1.0 W	15.0 W	1.0 W	15.0 W	0 h	8760 h	8395 h	365 h
Set Top - Box	TV-Kabel	1.0 W	10.0 W	1.0 W	10.0 W	0 h	8760 h	8395 h	365 h
Home control system, PC+Display	EIB	-	54.0 W	1.0 W	54.0 W	0 h	8760 h	8395 h	365 h
2 Tablet PC (Home control system)	Wave LAN	0.0 W	0.0 W	0.0 W	0.0 W	8760 h	0 h	8760 h	0 h

[1)] in the scenario "today" we use only 25% of the electric power shown in this table

Table 2: Electric power load and annual time of use of the equipment grouped into "Equipment for and due to networking" in the scenarios "today" and "optimised"

FutureLife-House			(Aebischer and Huser, 2000)				
	today	optimised		Var 1		Var 2	Var 2 2020
White Goods	**374 kWh**	**250 kWh**		**301 kWh**		**301 kWh**	**301 kWh**
2nd Fridge Sky-Box	247 kWh	247 kWh	Use of cooker	37 kWh	Use of cooker	37 kWh	37 kWh
5 Modems-PLC	66 kWh	0.4 kWh	6 Modems	264 kWh	6 Modems	264 kWh	264 kWh
Powerline Phase Coupler	53 kWh	2.6 kWh					
Powerline central modem	9 kWh	0.4 kWh					
Lighting	**156 kWh**	**8.8 kWh**		**31 kWh**		**153 kWh**	**153 kWh**
157 Data points EIB	156 kWh	8.8 kWh	Use of light	20 kWh	Use of light	100 kWh	100 kWh
			10 Data points EIB	11 kWh	50 Data points EIB	53 kWh	53 kWh
Entertainment	**425 kWh**	**325 kWh**		**256 kWh**		**508 kWh**	**1174 kWh**
Soundsystem	219 kWh	160 kWh	PC	86 kWh	4 equipment mm	508 kWh	1174 kWh
Home Infotainment	123 kWh	116 kWh	Digital TV	170 kWh			
Beamer	83 kWh	49 kWh					
Central infrastructure[1)]	**3091 kWh**	**278 kWh**		**216 kWh**		**461 kWh**	**470 kWh**
12 Data points EIB	19 kWh	4 kWh	Controler (white goods)	123 kWh	Gateway	219 kWh	220 kWh
Compaq ProLiant DL 360 incl. 17" LCD-Display	2321 kWh	201 kWh	Controller (lighting)	26 kWh	Controller (white goods)	67 kWh	75 kWh
Compaq Deskpro (Homeserver)	532 kWh	46 kWh	Controller (entertainm.)	67 kWh	Controller (lighting)	175 kWh	175 kWh
TV Internet Gateway	131 kWh	14 kWh					
Set Top - Box	88 kWh	12 kWh					
2 Tablet PC (Home control system)	0 kWh	0 kWh					
Total	**4047 kWh**	**862 kWh**		**804 kWh**		**1423 kWh**	**2098 kWh**
Total-Infrastr.	**955 kWh**	**584 kWh**		**588 kWh**		**962 kWh**	**1628 kWh**

Table 3: Increase of electricity demand in a household due to home automation in the three fields of application: white goods, lighting and entertainment (and communication). Electricity consumption in these domains of the FutureLife-House is compared to the simulations of an earlier study (Aebischer und Huser, 2000)

In the earlier study (Aebischer and Huser, 2000) only four out of these eight groups were considered and the specific equipment chosen to describe electricity use in the four groups are rather different in (Aebischer and Huser, 2000) and in this study. We therefore do not compare individual inputs, but electricity consumption (Table 3). Not surprisingly, the details differ a lot. But the measured data in the FutureLife-House support the order of magnitude chosen in the previous study to describe the potential increase in electricity demand due to networking in households (or due to home automation).

4. Conclusions

The measured energy consumption of the equipment found in the FutureLife-House confirm the order or magnitude of the potential increase of electricity demand due to networking in households in Aebischer/Huser (2000).

But the much more important/fundamental question whether the information society is a road towards a more sustainable society was not even formulated in this paper. The 1st World Summit on the Information Society taking place later this year (December 8-12 2003 in Geneva) should be the place to discuss that question. But - at the moment when this article is written - it seems that the organisers do not want to discuss this aspect. A group of scientist (www.wsis.ethz.ch) is working hard – together with many other groups and organisations from the civil society side – to get the question of the relation between sustainability and ICT on the agenda.

Abstract

For the first time, electricity consumption of an “intelligent home” has been measured in detail and attributed to the individual equipment or component and to the different applications. Total electricity consumption in this home is more than three times the amount of electricity used in an ordinary non-intelligent home in Switzerland. The central infrastructure and the other equipment/components used for networking purposes in the FutureLife-House consume each as much electricity as an ordinary home. Huge electricity savings are possible – in the range of 95% in the central infrastructure and about 80% in the other equipment used for networking – mainly by integrating infrastructural functions in a few energy efficient equipment and by applying an efficient power management of the equipment and components. Nevertheless, the additional electricity demand for networking purposes is substantial and may cause a significant increase in nationwide electricity demand in the coming years. The results of this analysis are compared to the inputs used in an earlier simulation of energy use in a household with interconnected appliances and installations.

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