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Energy consumption by electronic equipment in Hungarian schools: analysis and opportunities for energy savings

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Author's declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Steven GRANING

Table of contents

List of tables

List of figures

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The environmental harms linked to energy production are well documented — global climate change, air pollution and acid rain are all effected by the combustion of fossil fuels. Reducing the end user demand for energy is one way to reduce these harms, but many areas of consumption are poorly understood. Although experts know that buildings are a large consumer of electricity, there is considerable need for information on specific areas of consumption. Disaggregated data on consumption in the educational sector is particularly obscure, especially in Central and Eastern Europe.

This thesis seeks to analyze the data collected in Hungary for the European Union's El Tertiary project, which performed electricity metering in seven school buildings. In addition to lighting and large motor metering, a total of 330 individual electronic devices were metered for two-week periods. This thesis involves cataloguing and analyzing this data for clues as to how electricity in consumed in schools by information and communication technology (ICT) and other plug-in devices. The data is divided into in-use, standby, and low-power consumption to look for signs of power management, technology uptake, trends and room for conservation. A percentage of times that devices were left running overnight is also given.

The results of the analysis are then extrapolated to make a rough estimate of how much electricity is consumed by ICT and plug-in equipment in grades 1-12 of the Hungarian educational sector. Lastly, recommendations are provided for school officials looking to reduce their own school's electricity consumption.

Keywords: Energy, energy consumption, electricity, disaggregated analysis, energy savings, school, Hungary, information and communication technology, computer, monitor, printer

1. Introduction

The environmental harms resulting from the production of electric energy from fossil fuels have been well chronicled. Combustion processes pollute the air and contribute a large portion of the carbon dioxide that is driving up global temperatures and disrupting weather patterns worldwide. Even nuclear energy has been shown to be a carbon emitter when considering the construction and mining activities needed to build and run a facility. Reducing energy consumption therefore has many positive environmental aspects.

Because energy is seen as a key driver of economies, most attempts to bring down emissions (not to be confused with efforts made to survive short-term energy shortages) have traditionally focused on better means of production, including, for example, filters, scrubbers, and “carbon-neutral” energy sources. There is growing conviction, however, that energy efficiency (which includes eliminating wasted energy) should be seen as a “resource” in its own right, with its own measurement of “negawatt”, which is a kilowatt-hour (kWh) that was never produced in the first place (Rufo and Coito 2002). In this way, different abatement measures can be compared on equal footing.

Before efficiency measures can be assessed, however, there must be some knowledge of energy consumption totals and patterns of behavior. Is the office equipment in question, for example, consuming most of its electricity in an active or passive state? Are computers left on at night? Are power management features engaged? These types of questions can be best answered through direct study of a given place while looking at both equipment and behavior.

This study examines the data obtained from energy audits of seven schools in Hungary, primarily in the capital of Budapest and in one of its suburbs. These audits examined all aspects of energy consumption, but focused on electricity consumption, and the best results obtained came from the metering of information and communication technology (ICT) and other plug-in equipment. This thesis is primarily based on the data obtained from the metering of 330 such plug-in devices, and what possible energy savings are potentially there to be capitalized on. Although far from a representative sample for the entire country, some clear trends are detectable that will prove valuable in a field that has very little disaggregated data.

Terms

Different studies dealing with the energy sector on a macro-level use different terms to classify the buildings within the sector of non-mobile sources. The terms “commercial” and “services” sector are often used interchangeably with the term “tertirary”. Some of the differences in these terms are described in section two, but for our purposes the categorization is unimportant, since the sub-sector of “educational” buildings falls cleanly within all of these categories. In the literature review I tend to use the same term alluded to by the secondary source in question to avoid confusion if a reader wishes to look back on my sources. For the educational sub-sector itself in Hungary, my extrapolations will follow the paradigm of the Hungarian Statistical Office (Központi Statisztikai Hivatal). Table 1 on page 10 contains a convenient breakdown of the Hungarian school system.

My references to information and communication technology (ICT) and other plug-in equipment are straightforward. I avoid the term “personal computer” wherever possible, as some researchers use the term to refer to an IBM style computer, while others refer to a desktop computer and monitor together. Laptop computers are almost non-existent in Hungarian schools, as are Macintosh computers (with the exception of the American School of Budapest) so the term “computer” refers solely to an IBM-style desktop unless otherwise noted.

Monitors with liquid crystal display (LCD), on the other hand, are making inroads into Hungarian schools, and will therefore be referred to as LCDs or flat screens to differentiate them from cathode ray tubes (CRTs).

I use the terms “active use” and “in-use” consumption synonymously to refer to any device that is being used for its intended purpose. If a device has dropped into a mode that uses less energy than when in active use, I refer to that mode as “low-power” consumption, while if the device is on and waiting to be used, I use the term “standby”. For example, a printer rests in standby mode, waiting for a message for it to print. During this printing it is in active mode, or “in use”, as opposed to being in standby. In contrast, a computer that is not used for a certain length of time will go “to sleep” and consume a lower rate of electricity in its low-power mode. Although some devices (monitors, in particular) have different low-power modes, they do not generally have distinct low-power, standby and in-use modes.

Although the seven schools of the study can be seen in many different ways, there are some obvious groupings to be made. The first distinction is that three of the seven schools charge their students tuition. The tuition schools are the American School of Budapest (American school), the British International School (British school) — both of which have grammar and high school students, and even pre-school children in the case of the British school — and the Central European University Business School (Business school), a post-graduate institution. All three of these schools were established after the fall of Communism and are in located in modern facilities. English is the language of education in these schools. These schools are grouped together because their budgets for technology purchases would seem to be larger than for the other schools, and a first order of business will be to see how much of their data is reflective of the country’s schools on the whole.

The non-tuition schools can be further broken down into two groups: private gymnasiums (essentially university preparatory high schools) and public grammar schools. The former includes the Kölcsey Ference Gimnázium Budapest (Kölcsey), a French Hungarian bilingual school, and Baár–Madas Református Gimnázium, Általános Iskola és Diákotthon (Baár), a grammar school, gymnasium and bording school. The public schools are Hild József Általános Iskola (Hild) and Vajda Péter Ének-zene Testnevelés Tagozatos Általános Iskola (Vajda), both grammar schools and presumably possessing less money for equipment purchasing than the others.

Goal

The goal of this research was to gauge electricity demand and to establish the potential of selected energy saving techniques, particularly in regards to information and communication technology and other plug-in devices in the Hungarian educational sector.

Objectives

The objectives of this research include:

1. to inventory and measure the various forms of electricity consumption in selected Hungarian schools through metering, observation and document analysis;
2. to break down the electricity consumption of ICT equipment and other plug-in devices according to in-use, low-power and standby consumption;
3. to estimate the total consumption by ICT and plug-in equipment in the Hungarian educational sector for grades 1-12;
4. to explore the energy savings potential of no-cost changes and the technical potential of selected energy efficient equipment
5. to produce recommendations for school officials on cost-effective ways to save energy.

2. Background of the current study

The purpose of this chapter is to provide a context for the current study. After a quick look at why environmentalists are concerned with opportunities to reduce energy consumption, there is a brief overview of energy paradigms, followed by a look at total energy consumption in buildings. There is then an overview of the research into electronic equipment in the tertiary sector, mainly related to office equipment. This section is followed by a brief overview of energy consumption in Hungary, followed by a more detailed look at trends in the Hungarian school system that will affect the use of ICT equipment.

Energy and the environment

The relationship between energy production from fossil fuels and environmental ills such as air pollution and global climate change is well established. Reducing these effects in an efficient and effective manner, however, requires an in-depth understanding of how the energy is created, transmitted and consumed. Because curbing the supply of energy is not considered a politically viable solution, environmentalists instead look toward greater production and transmission efficiency, on one end, and toward curbing final consumption on the other. There is ample evidence to suggest that the 30-year trend of rising energy demand will continue unless a concerted effort is made to reverse it (IEA 2004).

Energy consumption paradigms normally divide usage into mobile and non-mobile sources, with mobile sources made up of means of transport, and non-mobile sources composed of different types of buildings and agriculture. Breaking down the group of non-mobile sources once agriculture has been removed usually involves separating living from working areas, and then by dividing working areas still further into industry and services.

In its study of the pre-accession European Union of 15 countries (EU15), the French Agency for the Environment and Energy Management (ADEME 2005), divided the service sector into administration; trade (wholesale and retail); (private) offices; education and research; health and social action; and others. Although common, this paradigm is not universally followed. A 1995 study in Greece referred to the “residential services sector,” which was set against “transport” and “industry”. The residential services sector was then divided into residential, commercial and public services — a similar end result to the ADEME paradigm — but the formulas applied to the different buildings were not differentiated (Mirasgedis *et al*. 1995).

Gauging and categorizing energy use in the services and education sector is particularly difficult because of the large number of different tasks being performed within buildings. Recording the energy use for any single building presents a number of challenges, and therefore requires a great deal of time and effort to carry out.

There has been little research on educational buildings in Central and Eastern Europe. One relevant research was performed in Slovenia by Butala and Novak (1998), who performed extensive energy audits in 24 Slovenian schools. Their research looked at architectural style, heating devices, temperature and power, types of regulation, and ventilation technique before concluding that considerable energy efficiency gains could be achieved. The study did not document any research into plug-in equipment. Mirasgedis *et al*.focused on overall consumption and CO_2 reduction potential, while Butala and Novak were particularly concerned about heat loss. ADEME tracks unit consumption per employee and per unit consumption per square meter.

In California, dispute over how to account for office equipment use has estimates ranging from 1% to 3% of total energy use of commercial consumption. Lighting is the major sector of end use, with Rufo and Coito attributing it to 39% of commercial consumption. Cooling, ventilation and refrigeration account for 15%, 11% and 8% respectively (Rufo and Coito 2002).

In the Hungarian educational sector, several variables may be of interest. Although Hungary’s population is declining and ageing, students are staying in school longer and information technology has been a focal point of recent educational reform. The government and educational experts alike have stressed the need to keep the "digital divide" — the fear that ICT skills will further separate rich from poor — as narrow as possible (Kárpáti and Fehér 2005).

Lighting

In its voluminous 2006 look at lighting, *Light's labour's lost*, the IEA singled out tertiary-sector buildings as using "the largest proportion of lighting electrical energy, comprising as much as the residential and industrial sectors combined." In OECD countries, a group that includes Hungary, lighting accounts for 34% of electricity consumption in tertiary buildings, as opposed to just 14% in residences (IEA 2006). Another relevant reference to Hungary in the book explained inertia was a major factor inhibiting the uptake of more efficient lighting:

> [...] within companies as well as among individuals — even given rapid economic changes, as has been evident in transition countries in Central and Eastern Europe — there is often a reluctance to move from known practice, even if purchasing energy-efficient lighting makes financial sense.

Although lighting is not a major focus of this study, its relevance in the overall scheme of electricity consumption, and the modest number of plug-in lamps found in schools, demands that we pay it some attention.

Plug-in electronics

Technology that draws power directly from an electricity outlet is not only a significant amount of total energy consumption in the tertiary sector, it is one of the most difficult to pin down. In chapter 7 of *Computers and the environment* (2003), Cole outlines the varying figures and discrepancies expressed by the energy community, particularly surrounding the role of the Internet in increased consumption. People are using computers and their peripherals at an ever growing rate, but what is more difficult to track is how much energy is being saved through the use of ICT.

One part of this equation is knowing how much energy is being consumed in the tertiary sector. Cole claims that the commercial sector consumes more than 70% of the energy used by office equipment in the United States, and then refers to a 1997 study by Mungwitikul and Mohanty that put this figure at 90% for Thailand.

According to ADEME, the education/research sector consumes 8% of the final energy consumed by the services sector in the EU15. Although the IT sector is pushing energy consumption higher, there are some indications that the overall electricity use in the EU15 sector is stabilizing or even declining (ADEME 2005). The ADEME report is quick to point out that the service sector is by far the least well known energy consuming sector.

There are two competing consumption trends related to electronic equipment: greater productivity, which generally requires more energy consumption than the device it renders obsolete, and greater efficiency, which reduces consumption for the same task. In general, the market can be trusted to drive productivity gains. As products mature, however, there are fewer and fewer productivity gains to be had. Unlike productivity gains, the market will often neglect energy efficiency gains until prodded by policy (for compelling examples demonstrating this point, see Weizsacker *et al*. 1997).

Computers demonstrate these duelling forces well. Cole (2003) pulls together numerous sources to show how efficiency gains caused by policy measures such as the Energy Star program and the demand for ever smaller products have gradually reduced power consumption by computers since 1985, only to have leaps in processing power drive consumption upward again. Computers in 2001 driven by a Pentium IV processor, for example, were consuming just slightly more than the 386 models from 1986. Since its appearance in 1994, standby (or low-power) consumption has also fluctuated. Any future estimates of energy consumption must therefore be made with caution when predicting the future energy demand of computers.

Power management is not always a one step process of putting a machine “to sleep”. According to Apple (2005), computer power management “controls backlighting, hard disk spin down, sleep and wake, some charging aspects, trackpad control, and some input/output as it relates to the computer sleeping.” In this way, the computer also controls monitor consumption, as well as its own. Cole adds that many computers allow the hard disc to continue sleeping while other functions awake.

Cole points out that monitor consumption rose steadily throughout the 1990s as larger, color models became more affordable. There is mounting evidence now, however, that monitor consumption has headed downward once more, with lower consuming LCD models gaining a foothold in the market. One estimate put LCD penetration in 2005 at over 68 percent worldwide, with higher figures in developed countries (DisplaySearch 2006).

Policies mandating power management features in ICT equipment have proven successful in the US, Switzerland, and Sweden (Cole 2003), but there is still some question as to whether computers, printers, monitors and other ICTs are properly configured to take advantage of their low-power capabilities. There is also a lack of knowledge as to how well users are turning off their equipment at night, and whether off truly means “off”, or electricity is pulled unbeknownst to the user. America’s program to support energy efficiency, the Energy Star program, requires all monitors, for example, to have a sleep mode of 2 watts or less, and an “off” mode of 1 watt or less (Energy Star website 2007).

Energy consumption in Hungary

According to the IEA’s 2003 (a) report on Hungary, consumers in the country do not pay a lot for electricity compared to other IEA countries, but they do pay a lot per GPD. Although the significance of this information could be interpreted in a number of ways, when combined with the country’s move toward more market-based rates for energy, it is clear that consumers in all sectors need to reduce demand or increase efficiency if they want to avoid the pinch of higher prices.

Hungarian schools

In the early 1990s there was an increase in the number of primary schools in Hungary before the number fell back to about where it was in 1989. The number of classrooms followed a similar trajectory, but is now below the level of 1990, while the number of teachers has been on a steady decline from 96,000 in 1990 to just under 90,000 in 2003. Although the number of students has dropped considerably during this period — from 1.1 million to 900,000 (Hungarian Central Statistical Office 2004) — Hungarian students have been staying in school longer and achieving higher degrees, as can be seen in Table 1 (Kárpáti and Fehér 2005).

Table 1. Highest school qualifications of those leaving the educational system, 1990 and 1998 (Kárpáti and Fehér 2005)

Highest qualification	1990	1998
University or college degree	10.6	17.8
Secondary school leaving exam	18.8	35.3
General secondary school (4 grades, student ages 14-18 years)	4.9	12.0
Secondary vocational school (4 grades, 14-18 years)	10.8	6.8
Post-secondary training (2 grades, 18-20 years)	3.1	16.5
Vocational training school (3 grades, 14-17 years)	33.9	25.8
Short vocational training school (3 grades, 14-16 years)	2.8	3.0
Primary school (8 grades, 6-14 years)	27.2	14.8
Primary education incomplete	6.6	3.3
Total sum (in thousands)	152.4	155.4
Percentage of qualified population	61.2	69.9

What this information suggests is that Hungary is undergoing a transformation of its of educational sector that may not lend itself well to increased efficiency, since the infrastructure in place, assuming it was well suited to meet previous needs, is now being challenged by changes in student attendance. Primary schools, for example, are experiencing a decline in attendance to the point that some are threatened with closure. Population figures for Hungary predict that declining birth rates will continue to age the population, putting more pressure on schools to attract students, with predictable consequences for schools with the least to offer.

The *World energy assessment* (UNDP 2000) cites office equipment as the largest growing energy consumer in the services and public sector in Western Europe. According to Hungarian educational policy, which repeatedly stresses the importance of ICT competence:

> In the same way as in the library, access to computers in the school's computer room must be ensured both in and outside class to facilitate pupils' independent learning. Computers should be available for other subjects/Cultural Domains, too. IT supported project work representing a higher level than conventional classroom activities must be also present in the school (Hungarian Ministry of Education website 2007).

In 1998, ICT became a mandatory part of the school curriculum in primary and secondary schools, with a minimum of two 45-minute lessons per week for children aged 12-17 (Tót 2002). Experts are pushing for more and earlier ICT education for children. The National Core Curriculum for 2003 dropped the first year of computer studies from grade 6 to grade 3, which means that more facilities will be needed and more computers will be in use. Among Kárpáti and Fehér's conclusions were that "PCs and their accessories in schools are too few and obsolete" (2005).

According to a PISA study quoted in the OECD publication *Education at a glance: highlights* (OECD 2006), in 2003 there was roughly one computer for every four to five students in Hungary, which was the fourth lowest (i.e. best) ratio in all OECD countries. Given Hungary's practice of handing down computers to needier schools upon obsolescence, it is safe to assume that the overall number of new units is outpacing the number of retired machines, and therefore a one to four ratio of computers to students is likely a conservative estimate.

The PISA project also interviewed school principals (OECD 2005) to gauge the number of additional computers needed for learning ("instruction is hindered by a shortage of computers"). According to school principals in Hungary, 28% of the country's students have their learning held back by a lack of computers. Although it is risky to conclude that these responses can be used as an indicator of how many additional units will be added to the total computer fleet in the coming years, it seems safe to say that educational decision makers welcome more ICT equipment.

3. Methodology

Overall research design

The research that forms the basis of this thesis was conducted under the project Monitoring Electricity Consumption in the Tertiary Sector, also referred to as “El-Tertiary”. Designed as a means to gather electricity consumption data on buildings in the tertiary sector, the original El-Tertiary methodology stressed the use of a combined top-down and bottom-up approach that relied heavily on visual observations, document research and interviews, as well as selective metering.

A choice was made by the Hungarian arm of the project to focus on school buildings and to invest in metering equipment in order to collect actual consumption data in three areas — lighting, plug-in electronic equipment, and large motors — to augment the other data collection techniques.

This thesis takes a mostly bottom-up look at the data gathered on plug-in devices to shed light on questions surrounding electricity use, consumption and savings potential in schools in Hungary. Although any conclusions will be tempered by the lack of representative data, the exploratory nature of the analysis should prove fruitful given the dearth of empirical data in the field.

Choosing schools

Before detailing the specific methodology of data procurement, a few words need to be said about the schools that were included in the study. The intense demands of the data gathering performed under the El-Tertiary project, as well as the limited amount of metering equipment, meant that only a small number of schools could be included in the survey. Because research this detailed could not hope to tackle a representative sample within the research period, schools were handpicked according to their characteristics and willingness to participate.

Given the short period of time and high level of documentation needed, only willing school administrations were recruited for the study.

Informational brochures were sent to 50 school administrations, mainly in Budapest, soliciting participation in the project. A small number of responses were received and followed up on, leading to two schools — Vajda and Baar — joining the study. The other schools were approached directly through personal contacts or "cold calling".

As wide a variety of schools as possible was sought in order to cover different aspects of school use. The Hild Joseph school in downtown Budapest, for example, is a good example of a school built in the 19th century that has not had a lighting retrofit since at least the second world war. The American International School of Budapest in the Budapest suburb of Nagykovacsi was recently constructed and contains all of the amenities one would find in an American high school, such as an Olympic style swimming pool, a gymnasium with retractable basketball hoops, and a theater that seats 350 people.

During the selection process, the project team was well aware that three of the schools likely had more financial resources at their disposal, which led to the inclusion of a school from a poorer district over one that prepared students for internationally respected degrees. A total of seven schools were selected for metering, but the results will be weighted during the extrapolation process in favor of the schools that more closely resemble Hungarian reality.

Methods of data collection and metering equipment

School schedules are mainly constructed in weekly blocks. The project team therefore decided to leave the metering equipment in place for at least two weeks (i.e. 14 days) to ensure that weekend consumption was properly taken into account. In my analysis I decided to work primarily with one-week totals, not only because of the way school schedules are designed, but also because the numbers are easier to compare in larger increments. Hourly consumption figures are provided wherever possible for individual pieces of equipment, both in low-power and active consumption. The in-use hourly consumption figures will be used to compare the plug-in equipment from different schools to see if there is a significant difference between the different categories of schools. Whether the equipment seems to be of the same generation of technology or not will be a factor in deciding which data to include in the nationwide extrapolations. The data from the four Hungarian-language schools will be assumed to be representative as long as there are no results that are completely at odds with widely accepted values as reported in the literature. Averaged data from the three tuition schools will be used for extrapolation purposes if they fall within the range of values collected from the other schools, but the extrapolations will be based on equipment ratios (e.g. per student, per teacher, etc.) according to the data from the four Hungarian-language schools.

Metering data for plug-in electronic devices was collected with Enertech wattmeters. These devices record electricity consumption pulled by a single plug in 10-minute intervals. In most cases, a single device (e.g. computer, microwave) was tracked by a single wattmeter, but from time to time a power strip with multiple devices was metered, usually due to a shortage of equipment, or when, for example, an entire cart of audio/visual equipment was tracked.

An initial walk-through and interview with a representative from the school administration (preferably the school's director) preceded the selection of equipment to measure. Although each school was unique, some trends were detected on sight. For example, it became apparent that ICT-based workstations for administrative staff was consistent at all locations, and that the desktop computer was omnipresent.

This equipment was metered at every location. Equipment was chosen that was either in use (by an employee present) or had signs of use (if no employee was present), in accordance with the El-Tertiary project methodology, rather than random selection. Meeting the criteria for representative data was beyond the means of the study due to the high percentage of the population that must be studied in such small universes. In a student lab of 20 computers, for example, a representative study would have called for us to measure 18. Photocopiers, scanners and other equipment were also metered in common areas.

Selected equipment was also metered in areas accessible by teachers and students, although this data was kept separate because yearly totals would need to be generated by using school-year factors, that is: by multiplying the weekly average by the number of school weeks, which was usually 37. In one case, one week of summer-holiday data was obtained, but these results are necessarily tempered by the fact that the school in question was much better than the others at ensuring that equipment that was not in use was not receiving any electricity. This phenomenon is detailed in the analysis.

All other types of plug-in equipment was metered whenever possible. Vending machines, for example, were metered in common areas. Notable (and regrettable) exceptions were found exclusively in kitchens, where limitations of the metering equipment prevented the metering of large coolers and other commercial appliances. Other efforts were made to elicit energy totals of kitchens through the mains. Industry data was also consulted to complement the data obtained.

Data analysis

An inductive approach was taken toward analyzing the data obtained as much as possible. For each school, a set of dates was chosen to function as a period that could be used to acquire a one-week average that properly reflected the 5-2 ratio of school days to weekends (holidays were carefully avoided). Once downloaded from the metering equipment using Oscar software, the individual data files were examined individually. The data was first converted into spreadsheet form in Microsoft Excel and vetted for irregularities. I then searched the data for signs of detectable differences in consumption that suggested active consumption, standby consumption, low-power consumption, and “off” consumption.

Because the Enertech wattmeters only provided consumption data in 10-minute intervals, there were some gray areas as to whether the equipment had merely been switched off — and perhaps on again — or the machine had truly dropped into a power-saving mode. The distinction here is important because low-power settings save energy when the machine is left on but is idle. To preserve a conservative estimate of low-power savings potential, I decided that a device must show at least 40 minutes of low-power consumption to be counted as being in standby or low-power mode.

In most cases, a low-power or standby consumption pattern was easy to detect. A one-hour sample was taken during a period of obvious low-power/standby consumption to distinguish it from active use. Table 2 is a good illustration of how the data was analyzed. From 9:00 to 9:50 the device was off. At some point between 9:50 and 10:00 the machine was turned on. It was in active use until it entered a low-power mode between 10:30 and 10:40, where it stayed until called to life between 12:40 and 12:50. At some point around 13:30 it was turned off. One hour of low-power consumption was determined to be 2.8 watts. If a device was left on overnight, a larger sample was used to determine the one-hour average, but this level of accuracy serves little purpose in any practical sense because the differences in the two samples were minimal.

A similar procedure was performed to gauge the active level of power consumption, although this sometimes called for greater sampling, depending on the type of equipment. Unlike low-power modes, active use can vary considerably. For computers, different applications require different levels of power, while for printers and photocopiers the active use is difficult to extract using 10-minute intervals because user tasks often take little time. For these types of “short-burst” devices, focus is placed on weekly averages.

Table 2. Sample data reading of active versus low-power consumption

Date	Time	Electricity consumption (in watts)	Counted as low-power	Hourly average of low-power consumption
2007.09.02	9:00	0		
2007.09.02	9:10	0		
2007.09.02	9:20	0		
2007.09.02	9:30	0		
2007.09.02	9:40	0		
2007.09.02	9:50	0		
2007.09.02	10:00	1,2		
2007.09.02	10:10	10,5		
2007.09.02	10:20	10,5		
2007.09.02	10:30	10,5		
2007.09.02	10:40	7,8		
2007.09.02	10:50	0,4	0,4	
2007.09.02	11:00	0,4	0,4	
2007.09.02	11:10	0,6	0,6	
2007.09.02	11:20	0,4	0,4	
2007.09.02	11:30	0,4	0,4	
2007.09.02	11:40	0,4	0,4	
2007.09.02	11:50	0,6	0,6	
2007.09.02	12:00	0,4	0,4	2,8
2007.09.02	12:10	0,4	0,4	
2007.09.02	12:20	0,4	0,4	
2007.09.02	12:30	0,6	0,6	
2007.09.02	12:40	0,4	0,4	
2007.09.02	12:50	9,1		
2007.09.02	13:00	10,5		
2007.09.02	13:10	10,5		
2007.09.02	13:20	1,5		
2007.09.02	13:30	0,2		
2007.09.02	13:40	0		
2007.09.02	13:50	0		
2007.09.02	14:00	0		
2007.09.02	14:10	0		

A one-week average of both the active and standby/low-power consumption was determined for each device. Another total was made of how many times the particular device was left on overnight. These totals were then combined with other devices of similar nature and extrapolated for the total number of such devices in the school, with a distinction made, where needed, for equipment used by students or teachers, and full-time administrative staff. To extrapolate the energy consumption for the whole school, different areas of the school were considered individually and a formula was created based on the inventory of items found in the four non-tuition schools.

The sum of the standby and low-power consumption was declared energy savings that could be achieved by proper management of the equipment (i.e. shutting it down when not in use), while the active use was used to determine how much electricity could be saved by either shutting the equipment down (when no low-power mechanism was engaged) or switching to more energy efficient equipment.

With warming and cooling devices such as refrigerators, water heaters and microwaves, a clear cycle of electricity usage is detected. In these cases, however, all activity is active use in the sense that power management functions are employed.

Once the average consumption levels were obtained, the data was extrapolated based on the number of weeks of active use that were likely given the type of user: the averages for student and faculty devices were multiplied by 37 (weeks) to simulate a full school year of consumption, and a standby/low-power addition was made for the summer months based on the patterns of power management seen for the individual device.

Once these yearly averages were obtained, the averages of the Hungarian schools — and of the tuition schools where the consumption was similar for that particular device — were averaged together and multiplied by the number of devices likely to be in active use in a school of 400 students (a convenient number given the size of the schools in the survey). These formulas are written out clearly in the fifth chapter. This average for a 400-student school was extrapolated for all of Hungary based on the number of students in all elementary and secondary schools (1.5 million students) for a rough estimate of the total electricity consumption by the Hungarian educational sector for grades 1-12, divided into active and low-power/standby consumption.

The next analysis looks at how possible it would be to eliminate this standby consumption based on the power management observed at the schools of the study. The thesis then looks at the option of replacing computers and monitors with more energy efficient models. My analysis involves looking at the total energy that goes into producing new units (via life cycle analysis) versus the projected energy savings.

4. Analysis of electronic consumption

My first task is to look at the consumption figures of different pieces of equipment for the different schools. Some ICTs will be looked at in more detail to differentiate use by administrators, students and teachers. Where possible, the analysis will break down the average weekly consumption (total) into in-use consumption and standby or low-power consumption.

The in-use consumption average will allow us to compare the equipment used by the different schools, while the standby and low-power consumption will tell us about the schools' use of power management features and the equipment's ability to conserve energy on its own. As explained in the methodology, consumption is categorized as "low-power" if the machine is in low-power mode for 40 minutes or more. In short, the low-power/standby column shows the energy that could be saved by shutting off the equipment every time that device would be unused for 40 minutes. To complement this data, I list the percentage of times that the equipment was left on overnight.

Comparing these figures will give us a rough idea of whether or not the schools are using similar equipment and behaving in a similar manner, and thus whether or not the data from the different schools could be aggregated or should be kept separate. In the case of the American school, we only have aggregate readings for computer and monitor, mandating a combined analysis in that case.

Once the data has been examined individually, different aggregates will be chosen depending on the type of room, such as student computer lab, staff kitchen, etc., to get a larger view of how different areas consume electricity.

Computers

A total of 101 computers were metered during this research — more than any other piece of equipment. Only the CEU Business School had laptop computers — and then only two units — at a permanent work station. Although students, teachers and administrators may be using laptop computers intermittently or at home, it is clear that schools as buildings are home to traditional desktop computers and monitors.

All of the schools used IBM-style personal computers with one notable exception: the American school relies solely on Apple MacIntosh computers. Because the power cord of an Apple computer plugs into the computer, we simply metered the two together.

Due to time constraints, we did not look "under the hood" of the computers of the study for their specifications. Most of the computers seemed to be no more than five years old, with the lone exception of those in the computer labs at Vajda and Hild, which seemed to be a mix of older models.

Table 3. Weekly and hourly averages of all metered computer consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Low-power	Total	In-use	Low-power	Left on overnight (%)
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	2,401	323	2,725	65	2.1	100
Business	2,575	379	2,915	62	1.4	100
British	6,212	443	6,655	93	3.9	100
Hild	372	40	413	33	2.0	6
Kölcsey	1,685	437	2,122	57	3.3	91
Vajda	1,186	115	1,301	56	4.6	4

Several things are immediately apparent in this table. The most obvious conclusion comes from the column showing how often the computers were left on overnight. It is clear that Hild and Vajda — which are assumed to be the lowest funded schools — turn off their computers at the end of the day, whereas the others almost never do. This fact helps to explain why Hild and Vajda also consume less than the other schools in low-power mode every week.

Another interesting finding is how the average consumption of each machine while in use falls into increments of 30, with the Hild school at roughly 30, the other four “Hungarian” schools and the Business school at 60, and the American and British schools at 90. In low-power mode, that paradigm fails to keep its shape, with the Business school having the deepest sleep, and Vajda the highest low-power consumption rate, but all are under 5 watts per hour — considerable savings over the in-use rate in every case. In fact, one of the reasons that the British schools weekly average totals are higher than the others is that some of their computers failed to fall asleep overnight. An average British school computer in this case would consume 93 watts every hour instead of 4 watts — 23 times as much.

It is interesting that Kölcsey and Baár have similar results to the CEU Business School. The machines themselves seem to be indistinguishable, and the lack of any centralized power shut-off is common in all three schools. Moreover, and certainly less expected, judging by the actual consumption totals, the behavior matches up as well, particularly between Baár and the Business school. This connection will be addressed in the sections to come that deal with disaggregated data.

Table 4. Weekly and hourly averages of student computer consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	1,117	386	1,503	65	1.8	100
Business	2,934	59	2,993	71	0.5	100
British	7,033	368	7,402	80	3.7	100
Hild	354	8	362	30	1.9	0
Kölcsey	1,429	493	1,923	55	3.4	100
Vajda	657	51	709	53	2.8	1

For the most part, the “student” computers are those in the computer labs, with some also devoted to students in libraries. Here the power management of Vajda and Hild are in plain sight. These values strongly suggest that the power is being turned off centrally. Equally interesting is the fact that the computers in the other labs are never being turned off. The fact that all of the computers are being left on, without exception, seems to go past the point of carelessness and into the realm of intentional. The students may in fact be instructed to leave the computers on. After all, there is an obsolete belief that computers are harmed more by being switched off than simply being left on, as well as a common misconception that computers use more energy when they are switched on than they would have used had they been simply left on. Our data reconfirms that the latter is clearly a fallacy, while the former is disputed with regularity, with the added claim that the heat witnessed by the computer's parts during low-power mode is more likely to damage the internal parts than on/off cycling (see, e.g. Cole 2003, among others).

We again see that the average British school student computer consumes twice as much as the next highest average at the CEU Business School. This is indeed a surprise considering that the latter is a graduate level institution whose computer labs are open from morning until night, whereas the British school operates during normal school hours. Although the British school's student computers have higher low-power averages, the aggregate total of the low-power weekly average is a small part of total consumption — 5% for the British school and 2% for the Business school.

Table 5. Weekly and hourly averages of administrative computer consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	2,897	265	3,162	64	2.1	100
Business	1,857	1,019	2,877	45	3.2	100
British	5,337	484	5,821	100	3.9	100
Hild	493	11	504	33	1.9	0
Kölcsey	2,782	124	2,906	36	3.6	71
Vajda	2,141	192	2,333	65	3.1	7

The figures for the administrative computers follow the patterns set by the other categories. The one exception is the in-use average for Kölcsey, but that is more likely do to the small sample size in this case. Our team had decided to focus heavily on the student computer labs in this school, and therefore chose to collect aggregate data for computers and their peripherals elsewhere. This economizing allowed us to get a more accurate picture of the total consumption by electronic devices, but rendered the data inappropriate for disaggregated analysis.

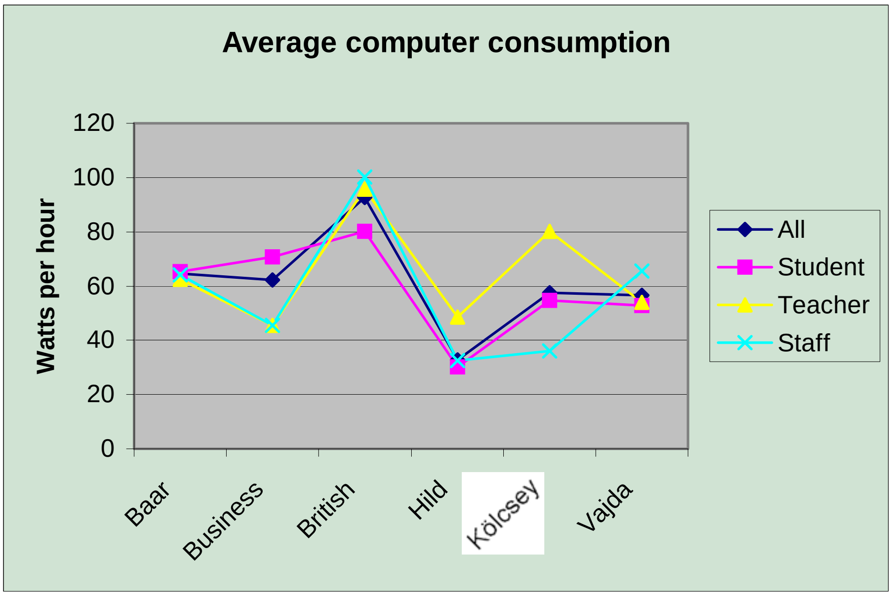
Table 6. Weekly and hourly averages of faculty computer consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	5,509	224	5,733	62	3.0	100
Business	1,857	1,019	2,877	45	3.2	100
British	6,244	463	6,707	96	4.0	100
Hild	120	324	444	49	2.8	62
Kölcsey	3,323	186	3,509	80	2.7	67
Vajda	1,603	222	1,826	54	11.6	14

In some cases, teachers have access to common computers, normally located in the faculty room, the library, the smoking lounge, or even the student labs. Table 6 shows only those computers that are distinctly provided for use by teachers. With the exception of Vajda, which only had one computer available specifically for teachers, all of the other schools left their faculty computers on more than 60% of the time overnight.

The British school’s computers are once again the high consumers, which suggests that there is at least some uniformity in the types of computers purchased by the school for different groups. Figure 1 takes a closer look the average consumption of the computers in use.

Figure 1. Comparing in-use computer consumption



What this graph suggests is that four of the six schools are purchasing the same computers for students, faculty and administrative staff indiscriminately. It is generally safe to assume that the computers with higher consumption have greater processing power, i.e. they're better computers. To some degree, better computers increase efficiency, certainly on the staff side, through, for example, faster computations or making it possible to run more advanced software.

As noted before, the low value for the Kölcsey staff computer average is likely the result of a small sample. The results of the combined computer and monitor averages for this school will be more revealing. The variation seen at the Business school is curious in that it is the only case where the students have the most potent computers. It could be that this school purchases ICT equipment in cycles, and that the student labs received more recent attention. There is also a much higher total number of computers in the Business school (300) than in many of the others, though the influence of this fact is difficult to speculate on.

Another interesting fact is that teachers and staff at the Business school have computers that are among the weakest of the entire study. Although the small sample size could account for some error, it does not seem likely that the units chosen were of such low consumption that replacing them with units more indicative of the true average would pull the Business school's results out of the range of usefulness. In other words, the results from the Business school's computer metering are in line with the non-tuition schools metered, and these results are therefore valid for further extrapolation into the general Hungarian educational sector. The results from the British school, on the other hand, seem to be anomalous for computers, and are perhaps better suited as a predictor of what the next generation of computers will look like at the Hungarian schools.

The results for Vajda represent an unexpected finding, particularly for the student computers. While the computers in administrative offices looked like those seen in other schools (i.e. the houses were of similar appearance), the computers in the student labs looked like older models. Judging by their consumption, however, their performance seems to be on par with Baár's and Kolcsey's. As noted earlier, the research did not entail looking at computer specifications, but the data suggests that Vajda's computers have been upgraded internally to a standard seen in the majority of the schools. This topic will be discussed further in the section on conclusions.

Monitors

It is important to remember that a computer puts its monitor to sleep, not the monitor itself. Unlike computers, where the forces of efficiency and capability are pulling consumption in two different directions, technology is taking monitor consumption on a consistently downward trend. It is true that in the 1990s consumption rose for a while, but that was mainly due to the switch to full-color monitors (Cole 2003). With black and white monitors now obsolete, technological advance is toward models that take up less space and make use of liquid crystal displays, both of which use less electricity than bulky cathode ray sets. With this in mind, we should see less monitor consumption per unit in schools that have more money to spend on purchasing new monitors.

Table 7. Sample reading from a CRT monitor at Baár

Date	Time	Consumption (watts)
2007.04.21	11:40	0.2
2007.04.21	11:50	0.2
2007.04.21	12:00	0.2
2007.04.21	12:10	1.8
2007.04.21	12:20	9.8
2007.04.21	12:30	9.8
2007.04.21	12:40	9.1
2007.04.21	12:50	9.8
2007.04.21	13:00	9.1
2007.04.21	13:10	7.2
2007.04.21	13:20	9.1
2007.04.21	13:30	5.5
2007.04.21	13:40	0.3
2007.04.21	13:50	0
2007.04.21	14:00	0
2007.04.21	14:10	0
2007.04.21	14:20	0
2007.04.21	14:30	0
2007.04.21	14:40	0
2007.04.21	14:50	0.1
2007.04.21	15:00	0
2007.04.21	15:10	0
2007.04.21	15:20	0
2007.04.21	15:30	0
2007.04.21	15:40	0
2007.04.21	15:50	0
2007.04.21	16:00	0
2007.04.21	16:10	0.1
2007.04.21	16:20	0

Note Table 7 how the low-power mode for the monitor in question seems to be .2 watts per 10 minutes. The monitor is then woken up, and normal activity transpires. When it falls to sleep, however, it falls into a veritable coma of just .1 watts per hour. My initial inclination was to conclude that this lower consumption period was in fact a case where equipment was drawing power even though it was seemingly “off”. The problem with this theory is that is nothing from the other data acquired suggests that anything was ever turned off at this school. Monitors are particularly notorious for being left on, and the computer to which this monitor was connected was left on for 18 straight days. We are thus left to conclude that certain monitors have a deep sleep mode separate from the standard low-power mode, most likely related to the back lighting versus near complete shut-down.

As for the consumption in different schools, we metered roughly the same number of monitors as computers, with an attempt made to meter flat screens in proportion to their existence in the school. In most cases, student and teacher monitors were completely CRTs, while staff monitors were mixed. More information is available in the section on computer labs.

Table 8. Weekly and hourly averages of all metered monitor consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	904	74	978	47	0.7	100
Business	1,654	425	2,079	32	0.8	100
British	1,685	242	1,927	46	1.6	100
Hild	567	12	579	55	3.0	0
Kölcsey	948	261	1,209	51	1.8	87
Vajda	1,429	52	1,481	55	1.8	5

If we follow the assumption that the two lowest funded schools are Hild and Vajda, then it should come as no surprise that Hild's machines have the highest low-power value. It is encouraging from an energy conservation standpoint that the worst value on the table is only 3 watts per hour, and also illustrative that even with monitors four times as consumptive in low-power mode, Hild was able to keep low-consumption to less than 3% that of the Business school by militantly turning off their machines at the end of the day. Moreover, their monitors were nearly twice as consumptive while in use than the Business school's, and yet total consumption per week per unit was one fourth as high.

When two different values were found for the hourly low-power consumption, the greater value was used, mainly because of doubts as to whether the machine was simply consuming power while "off" or there was a deeper sleep mode. The values of the deeper sleep mode are used in the low-power weekly averages, but they are so low — less than .2 watts per hour, and sometimes less than .1 — as to have an indiscernible effect on the total, and becomes more of an academic question than one of relevance for power saving potential. It is interesting to note that with the sole exception of those at Hild, all of the schools' monitors meet the US Energy Star program standards for low-power consumption on average.

One interesting finding is that Vajda's weekly electricity consumption per monitor is third highest — 50% more than Kolcsey and Baár, even with their nearly perfect practice of turning machines off at night. Breaking down the consumption figures into different users helps to understand why.

Table 9. Weekly and hourly averages of student computer consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Low-power	Total	In-use	Low-power	Left on overnight (%)
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	739	60	798	53	0.6	100
Business	1,101	74	1,175	25	0.6	100
British	1,444	520	1,964	60	3.5	100
Hild	580	13	593	58	3.2	0
Kölcsey	803	304	1,107	56	1.9	92
Vajda	819	20	839	59	2.0	4

The most striking result found in this table is clearly the hourly in-use consumption, where all but the Business school has an average between 53 and 60 watts per hour. This result is an excellent opportunity to look at how behavior and power management influence electricity demand.

The first matter of note is how the Business school, which is the only school to stock its computer labs with LCD monitors (though a few were found in a smaller lab in Kölcsey), is reducing in-use consumption by more than half. Its low-power consumption per hour is also tied for the lowest, and yet it has the second highest weekly totals for total consumption. Even with the lack of overnight shut-off, the low level of low-power consumption means that the

Business school monitors only consume 74 watts per week each while sleeping. With no low-power consumption at all the school would still have the second highest consumption. The high consumption relative to the other schools is therefore purely a matter of greater use and should therefore be seen as a success of efficient technology purchasing.

Table 10. Weekly and hourly averages of administrative monitor consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	831	82	913	27	0.5	100
Business	1,984	133	2,117	56	1.1	100
British	1,423	231	1,654	44	1.6	100
Hild	608	14	623	61	2.8	0
Kölcsey	1,237	152	1,389	59	2.0	57
Vajda	1,808	20	1,829	41	0.7	7

This table again suggests that the data recorded for the Hild administrative personnel is too low. Although the three sets of results gave similar readings (a large sample relative to the other schools given the small number of staff at Hild), and is therefore not the result of a rogue variable, it is possible that the period of metering (January 25 – February 14) coincided with tasks that kept administrators away from their computers. It could very well be that the Hild staff continues to perform some tasks manually, and that there were extenuating circumstances during this period, but in any case it seems hard to believe that staff monitors are only in use for 10 hours per week on average. Table 11 shows the number of hours monitors in use.

Table 11. Hours per week of active use for administrative monitors

	Weekly average (watts)	Hourly average (watts)	Weekly use (hours)
Baár	831	27	31
Business	1,984	56	36
British	1,423	44	33
Hild	608	61	10
Kölcsey	1,237	59	21
Vajda	1,808	41	44

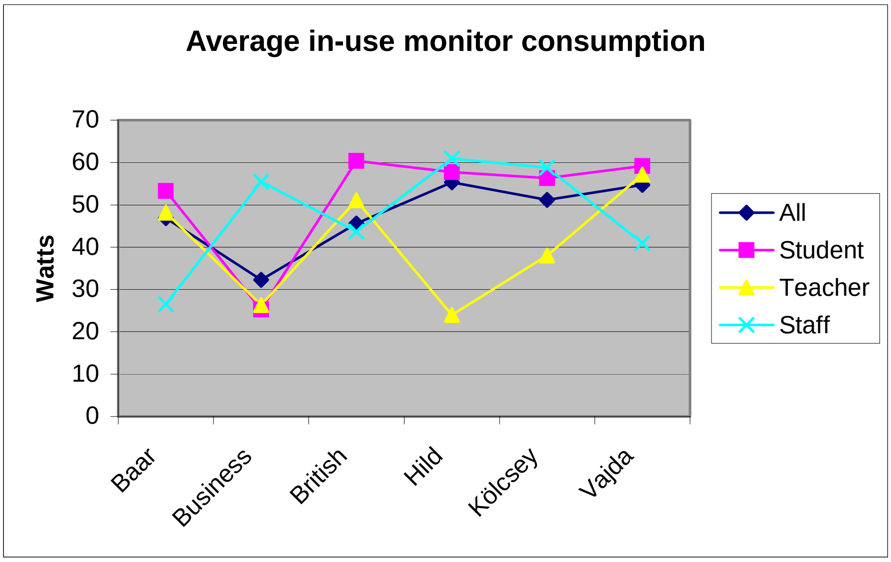
The school most resembling Hild is Vajda, and their monitors are in use for roughly 44 hours per week. The results are particularly disconcerting because the team's methodology called for metering equipment that should be in use. If anything, our results should err on the side of overestimating consumption. Kölcsey has also produced an unusually low number of in-use hours if we assume a 40-hour week, but as explained previously, that school's data is week for administrative units because of aggregated readings. A similar table can be found in the combined computer and monitor section.

Table 12. Weekly and hourly averages of faculty monitor consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	N/A	N/A	N/A	N/A	N/A	N/A
Baár	1,472	111	1,583	48	1.3	100
Business	986	34	1,020	26	0.3	100
British	2,062	41	2,103	51	0.3	100
Hild	368	0	368	24	unseen	0
Kölcsey	1,931	157	2,088	38	1.3	100
Vajda	2,572	166	2,738	57	2.8	4

As can be seen in Table 12 and Figure 2, average in-use consumption of teacher monitors is lower than the overall average, which suggests that teachers are getting newer monitors, and are being bad at turning them off. The value of updated technology is readily apparent in the in-use weekly averages, where Vajda's monitors are out-consuming the others, even in low-power consumption. Keep in mind, however, that Vajda and Hild had very few workstations available for teachers, which will be readily apparent in the section on common faculty rooms.

Figure 2. Average in-use monitor consumption



The most interesting thing that this graph illustrates is how closely the average consumption is to the student monitor consumption level. This finding should come as no surprise given the higher representation of student equipment in the sample population, but considering the actual ratio of student equipment to all others, a more accurate conclusion is to say that student equipment is much more homogeneous than that of staff and faculty. It would be an easy, yet careless assumption to make to assume that ICT purchases are made consistently, i.e. that a teacher's room will receive the same computer as the director's assistant and the student lab, and the library, etc. This graph clearly shows that schools do not purchase the same monitor over and over again, and they differ in who receives the newer models. On the other hand, computers and monitors seem to be purchased in bulk for student labs.

The exception to this rule, and a potential pitfall of this study, is where schools receive ICT equipment as donations. However, the school that seemed to have a mix of different computers and monitors, Vajda, produced consistent consumption data. The findings therefore suggest that student computer labs may be the best place to look for ICT equipment that gives a representative sample of a school's overall ICT consumption.

Computers and monitors

The tables in this section combine the averages of the computers and monitors metered in each school, which allows us to enter the data obtained from the Apple MacIntosh computers in the American school. It is also useful in showing the complete effects of the computers' power management ability because, as mentioned previously, the computer puts it to sleep.

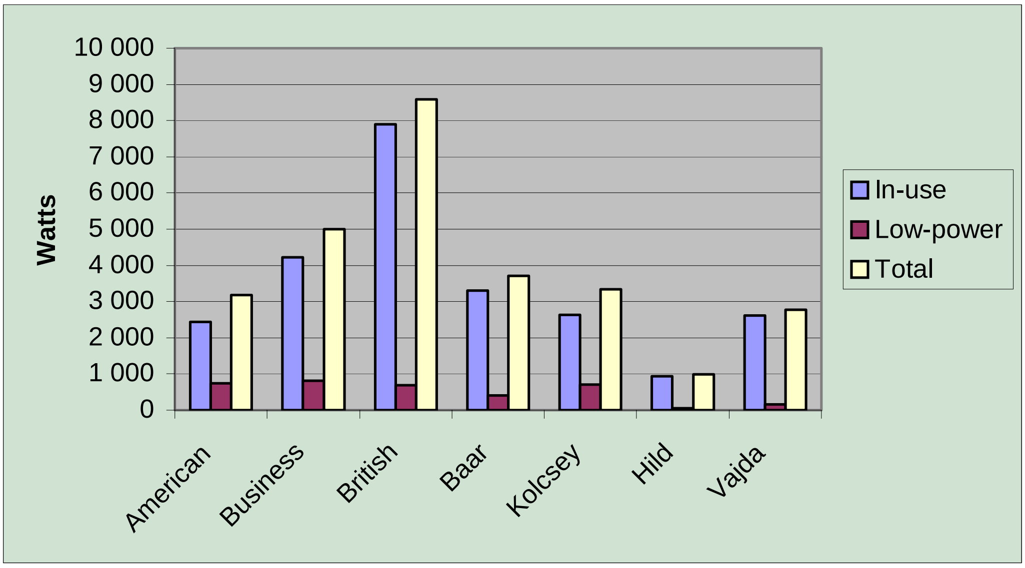
Table 13. Combined averages for all computers and monitors

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Low-power	Total	In-use	Low-power	Left on overnight (%)
American	2,442	743	3,185	85	5.9	93
Baár	3,305	398	3,703	111	2.8	100
Business	4,229	804	4,995	95	2.2	100
British	7,897	685	8,581	138	5.5	100
Hild	939	53	992	88	5.0	3
Kölcsey	2,633	698	3,331	109	5.1	89
Vajda	2,614	168	2,782	111	6.5	5

This primary goal of this table is to see how the American school's Apple computers and monitors compare to the IBM-style equipment found everywhere else. In this case, the Apples lived up to their reputation as efficient machines, as seen from the in-use hourly averages. In low-power terms, however, the MacIntoshes are not particularly impressive, but the G4 machines are not the newest generation, and are actually right in line with similar IBM models from other schools that are also a few years old.

The Business school clearly benefits from its use of flat screen monitors, while Hild likely has older computers that do not consume as heavily as the others, while for the British school the opposite is true. Baár and the Business school earn high marks for having low-power modes that consume half that of the others. On the other hand, the weekly low-power consumption shows that these advantages are quickly undone by leaving the machines on overnight, as evidenced by Hild and Vajda consuming just 53 and 168 watts per week, respectively.

Figure 3. Weekly average of computers and monitors, total consumption



Looking at the weekly average consumption in a bar diagram shows that of the three tuition schools, only the British school is far out of line with the other schools. The data from the American school is nearly identical to that of Baár and Kölcsey, schools with similar aged students.

The Business school's weekly low-power total is right in line with that of the other schools that left their machines on overnight, which again suggests that the higher weekly consumption by computers and monitors at the Business school is caused by greater use. This stands to reason when one remembers that the Business school is a graduate institution where more is demanded of the students, and where computer facilities are open to the students during evenings and weekends. Because the other "overnight offenders" leave their equipment on straight through the weekend, the Business school's low-power consumption ends up right in line with the others.

More speculation is called for to determine why Vajda's weekly consumption figures more closely resemble Baár and Kolcsey's than Hild's. Because we have already seen that Hild's staff consumption figures seem unusually low, I am inclined to believe that Vajda's figures are more indicative of a typical Hungarian school. With that said, it is important to point out that Vajda's equipment consumes more energy in use (111 watts per hour) than Hild's (88 watts per hour).

Table 14. Combined averages for student computers and monitors

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Low-power	Total	In-use	Low-power	Left on overnight (%)
American	2,273	871	3,145	87	5.5	90
Baár	1,856	445	2,301	119	2.4	100
Business	4,035	133	4,168	96	1.1	100
British	8,477	889	9,366	140	7.2	100
Hild	934	21	955	88	5.1	0
Kölcsey	2,233	797	3,030	111	5.3	96
Vajda	1,476	71	1,548	112	4.7	3

The most striking feature of Table 14 is how the consumption figures for the American school and Kölcsey are nearly identical, with the sole exception being the hourly in-use averages. This table also gives a strong impression that the British school's above-average consumption stems in a large part from the student computers, which display higher in-use hourly and weekly averages than the school's other users. Computer labs will be dealt with in more detail in the next chapter.

Table 15. Combined averages for administrative computers and monitors

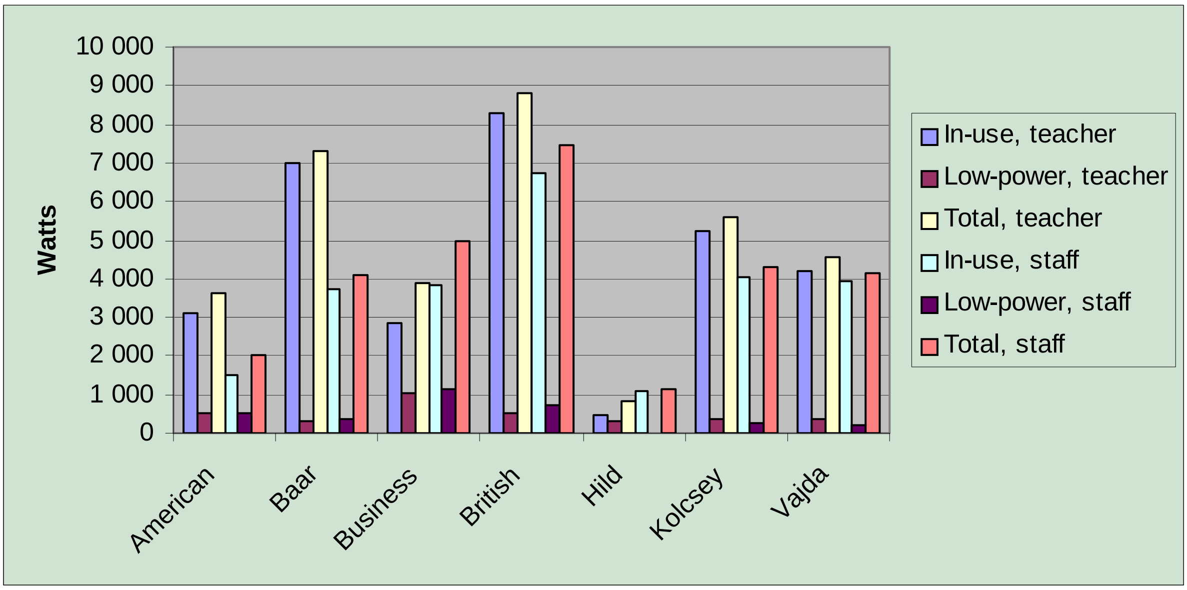
	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Low-power	Total	In-use	Low-power	Left on overnight (%)
American	1,519	508	2,028	59	2.3	100
Baár	3,728	346	4,075	91	2.6	100
Business	3,841	1,152	4,993	101	4.3	100
British	6,759	715	7,474	144	5.4	100
Hild	1,101	26	1,127	93	4.7	0
Kölcsey	4,019	276	4,295	95	5.6	64
Vajda	3,949	213	4,162	106	3.7	7

Table 16. Combined averages for teacher computers and monitors

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	3,115	499	3,614	88	7.9	100
Baár	6,982	335	7,317	111	4.3	100
Business	2,843	1,053	3,896	72	3.5	100
British	8,306	504	8,810	147	4.3	100
Hild	489	324	812	73	2.8	31
Kölcsey	5,254	343	5,597	118	4.1	84
Vajda	4,176	388	4,564	111	14.4	9

In most of these cases we see that teachers make greater use of their ICT equipment than administrative staff. This finding is slightly misleading because there is a much higher ratio of computers to administrative staff than computers to teaching staff, at least in the non-tuition schools. In the American school and the British school, there are computers in the classrooms themselves. The classrooms thereby become a de facto office for the teachers. The Business school is a graduate school, and therefore professors have their own offices. The other schools have common areas for the teachers that contain a few computer work stations. A graph comparing administrative and faculty weekly consumption totals is revealing.

Figure 4. Administrative and faculty weekly consumption for computers and monitors



There are several interesting things to take from this graph. First is the remarkable consistency in low-power consumption between staff and faculty equipment. This occurrence is no surprise in the cases of Hild and Vajda because there is so little at all. But in the other cases, it suggests that ICT equipment for faculty and staff is similar, which is something that should not be assumed. It might also reflect a central control over the power management features of the computers. Nevertheless, it is striking that the consumption totals fluctuate much more than the low-power consumption.

The graph also helps us to look at how different policies of assigning computer workstations affect electricity consumption, although it is difficult to draw conclusions. At the British school, where the teachers and staff alike have access to their “own” computers, teacher use is higher on average than for the staff. It should be noted that the British school teachers also have access to computers in the faculty area, where there are also two photocopiers. The American school likewise has computers in the classrooms, as well as in a common room, and consumption is higher than for administrative staff.

In the Business school, where faculty members have offices, there is less use on average by the teacher. Contrast these figures with those of Baár and Kölcsey, where teachers have no access to their own computers, but instead use those in common areas.

Printers and photocopiers

Printers and photocopiers are similar in many ways, particularly when examining their consumption data inductively. They have long periods of standby consumption that sometimes drops into low-power mode. The low-power consumption is easy to note, but the standby (i.e. non-use, non-low-power) average can be difficult to determine, and the in-use power is nearly impossible when given 10-minute intervals of data because these machines rarely run for a full 10 minutes, let alone the exact 10 minutes that has been recorded. Other

ICT peripherals also present this difficulty, including fax machines, shredders, scanners, adding machines, etc. Although performing spot checks of consumption levels may have added some information as to in-use consumption, it is unclear how this information could have been used to complement the metered readings. For this reason, in-use hourly averages are not presented for these devices. Instead, weekly total consumption will be the focus of the analysis, along with total standby/low-power consumption.

Table 17. Average of all printers by school

	Weekly averages (watts)			Hourly averages (watts)	
	In-use	**Standby/ Low-power**	**Total**	**Standby/ Low-power**	**Left on overnight (%)**
American	1,885	1,107	2,993	4.3	73
Baár	1,477	1,047	2,523	8.2	100
Business	471	1,408	1,879	7.8	100
British	416	566	982	3.5	100
Hild	51	50	101	17.5	0
Kölcsey	149	452	601	3.6	74
Vajda	809	181	954	3.7	10

The analysis of printers includes standby and low-power because, although they differ considerably in magnitude, both could be eliminated by switching printers off when they are not in use. As explained in the methodology, data was classified as standby or low-power only after 40 consecutive minutes in that state. It is also important to remember that printers and photocopiers rarely run for 10 minutes at a time, and therefore a much larger portion of the weekly "in-use" consumption could justifiably be moved into the standby column. In cases such as the Business school, where in-use consumption is already less than 25%, it is not hard to imagine that electricity consumption for printers could be reduced to almost nothing if technology could be developed that put a printer into a deep sleep after use.

As with computers and monitors, Hild's successful power management reduced presumably wasteful (judging by the high standby/low-power level) printers' consumption to almost nothing. Vajda as well used considerably less electricity than the other schools, despite having one of the highest weekly in-use consumption levels. Given the small sample sizes taken of printers (between two and four units per school), it is not worthwhile to look at averaged data broken down by user type. However, printers will appear again in the analysis of different room types.

Similar to printers, photocopiers show a wide range of consumption patterns and low-power features. Due to their large motors, however, they tend to consume a great deal of electricity, and are therefore worthy of examination.

Table 18. Average of all photocopiers by school

	Weekly averages (watts)			Hourly averages (watts)	
	In-use	**Low-power**	**Total**	**Low-power**	**Left on overnight (%)**
American	6,240	2,933	9,173	34.5	82
Baár	15,401	0	15,401	unseen	33
Business	1,385	858	527	3.6	100
British	30,275	1,945	31,572	51.1	71
Hild	N/A	N/A	N/A	N/A	N/A
Kölcsey	3,022	128	3,150	2.4	49
Vajda	5,378	1,332	6,710	21.5	7

It is very difficult to draw many conclusions, no matter how tentatively, from the data obtained on photocopiers. One interesting phenomenon is that schools that never turn off computers or monitors have a better record with their photocopiers. Judging by the nighttime values, the photocopiers at Baár, for example, would consume an extra 23 kWh every week each were it not for the nighttime switch-off. It is nearly impossible to say from our readings how much could be saved if that school could initiate some kind of low-power mode for their photocopiers, but looking at the consumption levels at the Business school, where the photocopier ran all night, and at Kölcsey, where they were left on every other night, it is clear that savings must be available, be it through low-power settings or new purchases. Certainly some kind of standby killer would benefit Baár and the British school. Different options are explored in the next chapter.

In the case of the British school, their photocopiers often failed to go into low-power mode at night. Of the three photocopiers examined there, one had a low-power mode of 10.4 watts per hour, another's was 91.8 (just over half of the standby consumption), and the third never fell asleep. At Kolcsey, five photocopiers were metered, four of which had an hourly low-power consumption of less than 5 watts.

It is beyond the scope of this thesis to factor performance into the value of ICT equipment. It could be that in some cases schools need to be able to rely on having photocopiers that can produce a certain number of copies per minute, or to run longer before needing to refill the ink, etc. However, schools similar to the highest consumers — ones that we would normally compare them to in our study — got by with much less consumption, which suggests that a great deal of energy could be saved in this area.

Digital projector

Although digital image projectors are primarily found in computer labs, they are also increasingly found in classrooms. The results of this transformation from analogue to digital media for classroom learning are detailed in the section on audio-visual equipment.

Table 19. Consumption by digital projectors

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	**Low-power**	**Total**	**In-use**	**Low-power**	**Left on overnight (%)**
American	537	145	682	117	11.0	27
Baár	764	705	1,470	177	4.4	100
Business	N/A	N/A	N/A	N/A	N/A	N/A
British	1,430	0	1,430	217	unseen	0
Hild	N/A	N/A	N/A	N/A	N/A	N/A
Kölcsey	516	679	1,195	154	4.2	100
Vajda	N/A	N/A	N/A	N/A	N/A	N/A

It is no surprise that the better funded schools are making greater use of digital projectors than the others, and it should be noted that these devices were in use at the Business school, most visibly in the large auditorium-style classroom, but not metered because of technical difficulties. Digital projectors are cutting edge technology coinciding with the increasing computing power needed to run larger digital media files. Their rise in popularity will likely put an end to any further purchases of analogue equipment, such as televisions, video players, DVD players that function through televisions, and perhaps even CD players.

Other peripherals

Other pieces of ICT equipment are found in schools, such as scanners, speakers, fax machines, shredders, and electronic calculators (also known as adding machines). Given their relatively smaller consumption levels and representations in our sample, they are listed here together in one table. These particular units do not feature low-power modes, but rather a consistent level of standby consumption while waiting to be engaged.

Table 20. Consumption of other peripheral ICT equipment

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Standby	Total	In-use	Standby	Left on overnight (%)
SPEAKERS						
British	0	521	521	unseen	3.0	100
Hild	0	131	131	unseen	2.4	0
Kölcsey	0	269	269	unseen	1.4	100
Vajda	0	222	222	unseen	2.6	11
SCANNERS						
American	13	585	599	unseen	3.6	100
Business	90	1,850	1 940	unseen	11.1	100
British	22	488	509	unseen	3.5	100
FAX MACHINE						
Kölcsey	0	470	470	unseen	2.7	100
ROUTER						
Kölcsey	930	19	949	6	1.5	100
SHREDDER						
Kölcsey	0	2,038	2,038	unseen	13.4	86
ADDING MACHINE						
Kölcsey	2,063	673	2,736	124	4.8	100

Speakers

Computer speakers are more often found in administrative areas of schools than in student computer labs. They are nearly always on and rarely used. In fact, our study did not turn up once instance of active use, though the speakers were often never switched off. It is tempting to conclude that perhaps the standby consumption level is the same as the active consumption, but we know from testing that speakers do consume more in active mode (as one would expect).

Fax machine and shredder

Similar to the speakers metered, the fax machine and shredder observed in the study turned up no discernable active use. The difference between the two pieces of equipment, however, is that a fax machine is justifiably left on to receive potential incoming facsimiles. Whether or not the fax machine needs to be left on overnight is perhaps a matter of debate, but at less than half a kilowatt per hour it is not a huge sum for one fax machine to be left on. The shredder, on the other hand, represents clear wasted electricity.

Scanner

Unlike the shredder, the scanners observed did receive some use. On the whole, however, 96% of the weekly average consumption by scanners went to standby power. Even for the most heavily used scanner, the total duration of active use spanned less than three hours over the entire two-week testing period.

Router

An important part of networked computers is the router, which distributes the Internet signal to grouped computers. Although the router is mainly in active mode, this does not mean it is being used, but rather that it is on call in case someone decides to use the school computer lab in the middle of the night. The small, but existing, level of low-power consumption is curious in that it represents about 25 hours of consumption over a two-week period. Why it dropped into low power on those few occasions is difficult to speculate on. Perhaps the network was down for two nights while the servers were tended to.

Adding machine

The adding machine in the accounting office of Kölcsey school was the only one of its kind seen, but is a common tool for accountants. They can also found in battery driven varieties. Obviously, the adding machine is being replaced by computers. It is extremely difficult to estimate how many Hungarian schools still have these machines in use, but given the fact that every financial office we observed had one computer workstation per employee, it is probably safe to say that they will not be around for long.

Audio/visual

The digital revolution is slowly making analogue audio-visual equipment obsolete. In classrooms, televisions, video players, and even DVD players designed to work through televisions, are being replaced by the digital projector.

Just a few decades ago, students viewed educational films via reel-to-reel film projectors. We found no trace of such equipment in any of the schools. We did, however, find televisions, video players, DVD players, cassette players and other stereo equipment in all of the schools. In most cases, this equipment was kept on mobile carts or locked up cabinets that allowed use but prevented theft. In the Hild school, televisions are mounted on wood platforms in the front corner of some classrooms, sometimes accompanied by video players.

In general, use of this equipment was negligible. Schools without digital display equipment should start budgeting for their inevitable purchase, unplug A-V equipment as a matter of policy, and begin thinking about recycling options.

Table 21. Television consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Standby	Total	In-use	Standby	Left on overnight (%)
American	215	0	215	40	unseen	0
Baár	379	135	515	63	5.7	25
Business	N/A	N/A	N/A	N/A	N/A	N/A
British	N/A	N/A	N/A	N/A	N/A	N/A
Hild	7	607	614	unseen	5	67
Kölcsey	N/A	N/A	N/A	N/A	N/A	N/A
Vajda	311	259	570	93	14.0	0

One place where Hild fails in their tightly regulated power consumption is turning off televisions. Most schools use carts to transport televisions and their playing devices to different classrooms. Hild features several rooms where the televisions are in permanent resting places within classrooms. The extremely low level of active use, yet not negligible sum of standby consumption suggests that they should adopt a similar scheme.

Table 22. VCR consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Standby	Total	In-use	Standby	Left on overnight (%)
American	5	78	83	unseen	3.5	0
Baár	17	316	83	unseen	1.1	58
Business	N/A	N/A	N/A	N/A	N/A	N/A
British	N/A	N/A	N/A	N/A	N/A	N/A
Hild	0	192	192	unseen	2.3	50
Kölcsey	N/A	N/A	N/A	N/A	N/A	N/A
Vajda	54	79	133	8	2.5	7

Video cassette players consume the majority of their electricity in standby mode. As a peripheral device, VCRs behave much in the same way as printers and speakers in that they are on all of the time, waiting for short moments of use. Their level of hourly standby consumption strongly resembles that of a printer.

Table 23. Other audio/visual consumption

	Weekly averages (watts)			Hourly averages (watts)		
	In-use	Low-power	Total	In-use	Low-power	Left on overnight (%)
CASSETTE PLAYER						
American	0	0	0	unseen	unseen	0
CD/CASSETTE PLAYER						
Hild	4	0	4	unseen	unseen	0
A/V COLLECTION						
Kölcsey	1,523	0	1,523	N/A	N/A	0
Business	1,489	2,183	3,672	N/A	N/A	14
DVD PLAYER						
Baár	0	574	574	unseen	4.4	50
Vajda	9	0	9	unseen	unseen	0

The Kölcsey and Business school audio/visual collections enjoyed some use, but it is hard to pinpoint what was used because of the cumulative metering. Considering that there are at least three devices in each bundle, the total is deceivingly high. It is also difficult to discern low-power/standby consumption in such a mix — for the Business school I was able to disaggregate in-use and standby consumption by seeking the endpoints of overnight consumption.

All in all, A/V equipment was barely used in any of the schools. In this respect, it is hard to conjure up any excuse for leaving these devices in standby mode.

Other plug-in equipment

ICT devices are not the only machines drawing electrical power through plugs in schools. Other equipment also consumes electricity, and in some cases quite a bit. Predictably, devices that are used for heating and cooling consume a great deal of electricity, and some of them, such as refrigerators, are common.

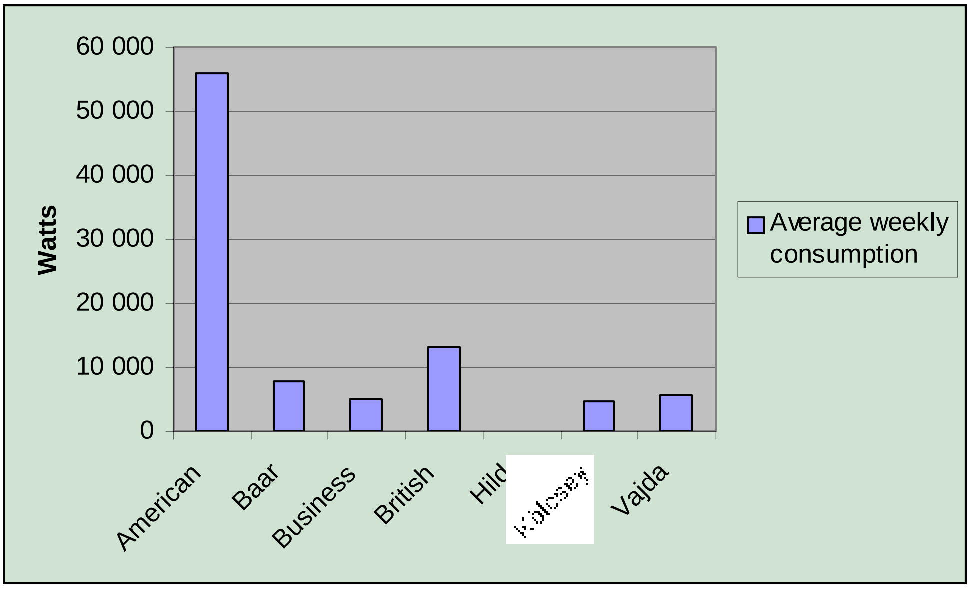
Larger coolers, such as those found in kitchens, were too large for us to meter with our devices, and can only be estimated. Given the large amounts of consumption associated with the refrigerators that were measured, however, it is easy to see how kitchens can become a major source of energy consumption, especially when large freezers are used to keep frozen goods. Of course, gas ovens also play a large role in kitchens, and this consumption is beyond the scope of this study.

Refrigerators and freezers

Cooling units represent a major source of electricity consumption. In the residential sector, for example, refrigeration and freezing accounted for 13% of total electricity consumption in IEA countries in 2000 (IEA 2003b). A major difficulty in estimating a figure like this for the educational sector is that some schools keep food on hand, and thus refrigerated, for school lunch preparation, while other order a service that brings in food daily.

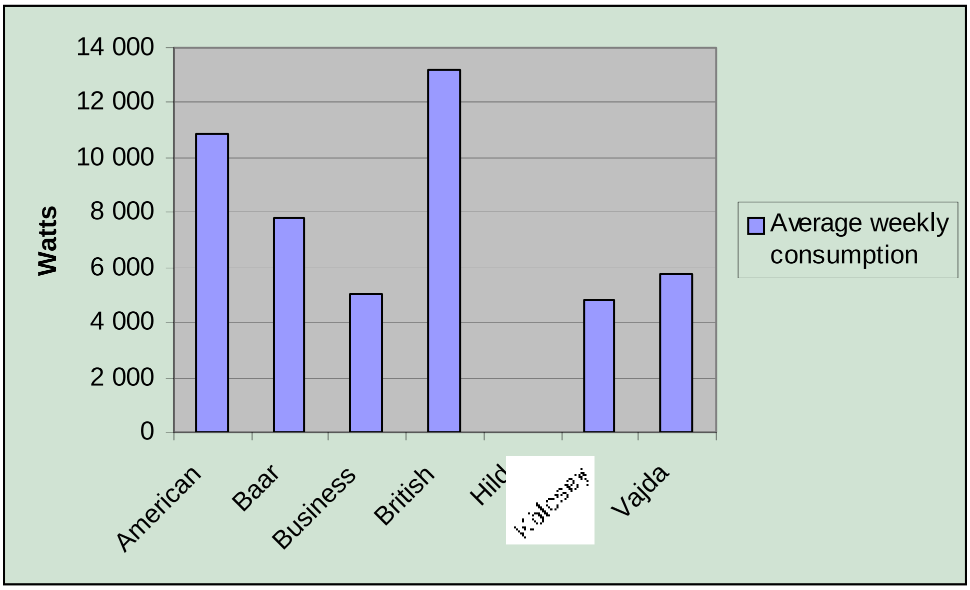
Of the schools in our study, Kolcsey and Vajda had prepared lunches delivered to the schools, where the food was warmed, if needed. The other schools had large coolers that were too large to meter. Attempts to meter the mains supplying these larger kitchen with power were largely unsuccessful due to failed metering.

Figure 5. Weekly consumption by refrigerators and freezers



Although refrigerators were noticed in the Hild school, none of them were metered. It should be noted that the average of the American units was pulled upward dramatically by the unit in the doctor's office. Because we did not meter a similar unit in the other schools, Figure 6 shows the American average without this unit.

Figure 6. Weekly consumption by refrigerators and freezers, no doctor's office



Although still twice as high as some other schools, removing the data obtained from the refrigerator of the American school's doctor's office, the American school's average is now much more in line with the other units. It is interesting to note that the American school and the British school averages are twice as high as the other schools, but the Business school is right in line. It could be that the Business school, which is located in what essential is an office building, simply does not have room for larger refrigeration units. The British and American schools were both constructed in recently, and their staff kitchens were noticeably larger than those of the other schools.

One item of interest is a freezer in the biology classroom at Baár Madaas, which ran day and night in the middle of a classroom although it was completely empty. Consuming 10 kWh per week, it is a perfect example of how electronic equipment in schools can be allowed to run unabated. Although an extreme example, refrigerators and freezers were found in every staff kitchen of every school, and were often filled far below capacity.

One large refrigerator-freezer in the British school was located in a student lounge area in a loft area of the school where the temperature soared during May and June, as seen in Figure 8, running near 30 degrees Celsius during much of the metering period. The entire unit was nearly empty, yet consumed over 17 kWh per week. A similar model in the supply room adjacent to a science classroom consumed half as much.

Figure 7. Simultaneous temperature readings for attic room and faculty room, British school

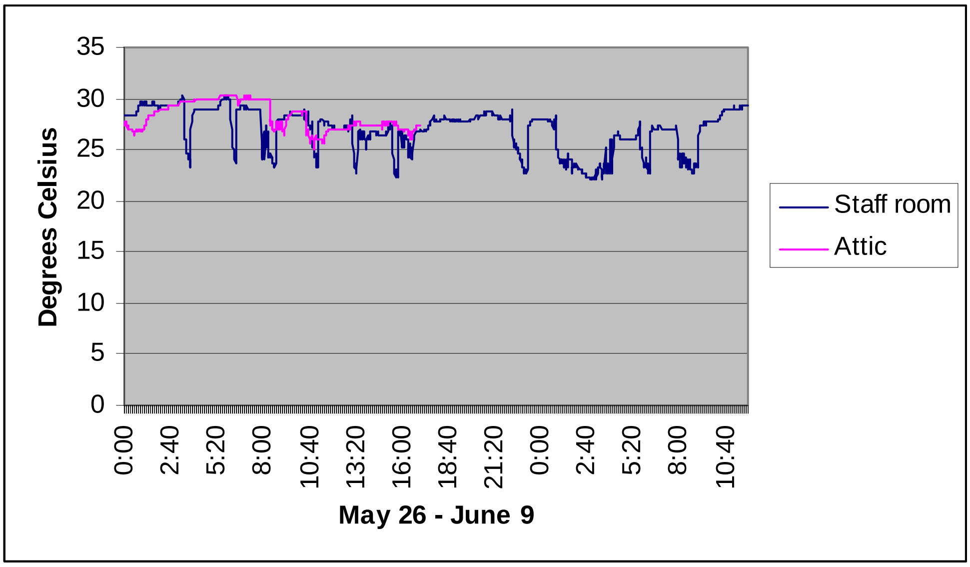


Figure 8. Consumption by refrigerator in British school attic student room

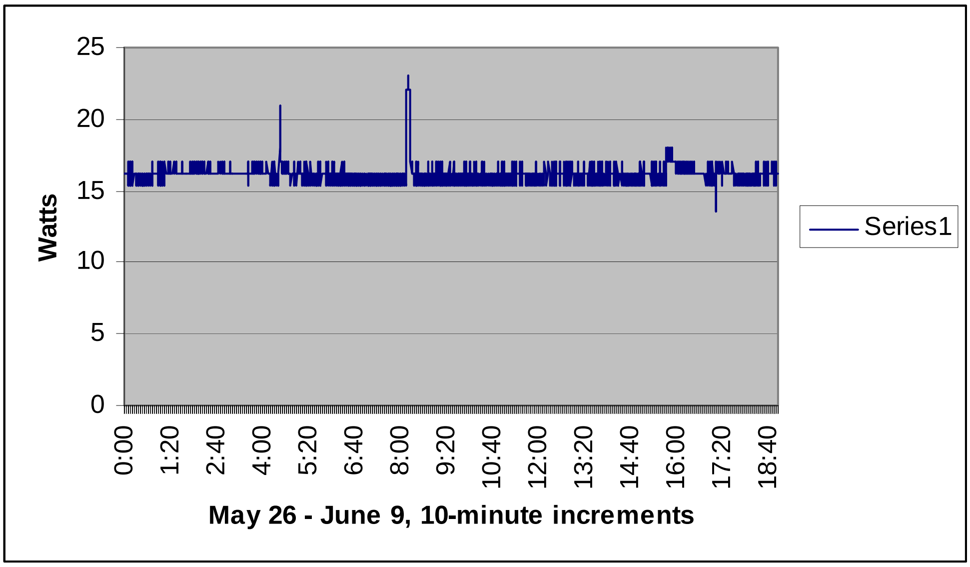


Figure 7 compares the temperature in the attic room with the temperature in the faculty room, which had air conditioning. Although the thermometer in the attic unfortunately stopped recording on June 2, the high ranges of the staff room, which are obviously periods without air conditioning, give us an idea of how the trend would have continued. It is worthwhile to mention that outdoor temperatures during May and June 2007 were unseasonably high: according to the Hungarian Meteorological Center (2007) temperatures in June were over 3.5 degrees Celsius higher than average.

Figure 8 shows the consumption of the refrigerator in the attic room during the metering period, which gives us a look at how room temperatures affect refrigeration units. According to the data, the refrigerator seems to be nearly immune to the temperature fluctuations of roughly 5 degrees seen in early readings, although there does seem to be some uptick in consumption as temperatures rose early in the measurement period. The spikes in consumption on May 29 and June 1 do not correspond to temperature spikes in the room, and were likely caused by either the door of the refrigerator being left open or the unit being filled with something.

In general, it is hard to think of a reason to have freezers at all in a school. As for refrigerators, with the exception of medical areas that must keep certain medicines cooled, refrigerators mainly serve to keep food and drinks from spoiling.

Other kitchen appliances

Because of limited measuring devices, the project team did not choose to do extensive metering of kitchen appliances. Most staff kitchens contained a microwave, espresso maker, and a refrigerator, with other devices occurring as expected in any kitchen. Some of the older kitchens, such as Hild, featured gas ranges in staff kitchens. There were some signs of use of these devices, but not many pots and pans, suggesting that they are used primarily to warm liquids — a function likely usurped faster devices like microwaves and electronic kettles.

Table 24. Weekly average of other kitchen appliances

	Weekly averages (watts)
MICROWAVES	
American	243
Baár	1,088
Business	486
Kölcsey	512
ELECTRIC KETTLE	
Business	1,466
WARMER	
Kölcsey	12,406
ESPRESSO MAKER	
Vajda	1,369

The one item that is clearly different from the others is the food warmer, which was used by the Kölcsey kitchen staff to warm soups. It is good here to distinguish between cafeteria kitchens and staff kitchens. As mentioned previously, the project did not manage to obtain data on consumption by larger kitchen cafeteria equipment, often referred to as commercial appliances.

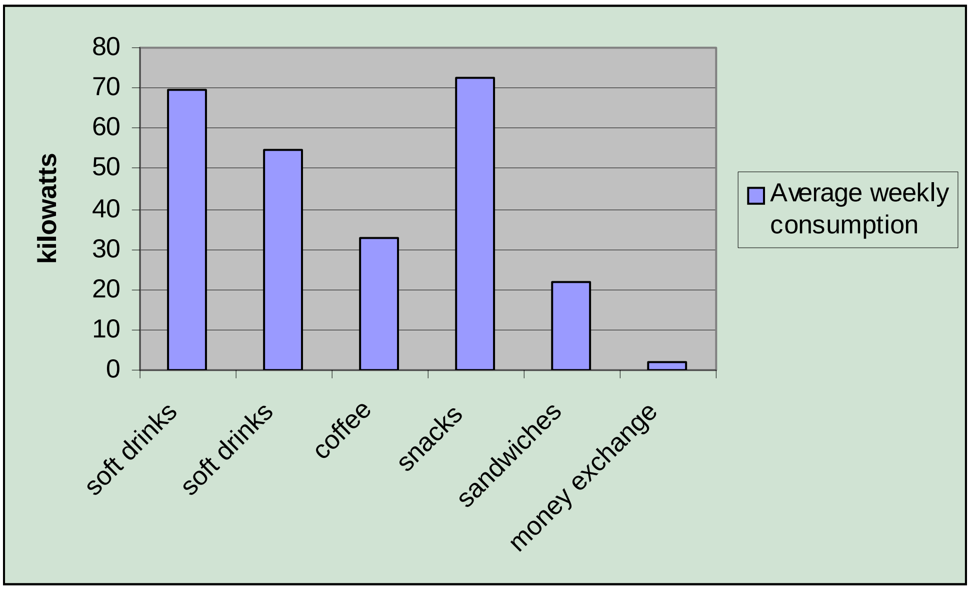
As for staff kitchens, it is clear that many different factors go into the use of these areas. For example, some schools, such as the American school and Hild, have a buffet on the premises. It would stand to reason that these facilities reduce the use of microwaves, coffee makers, and other appliances whose tasks are replicated in the buffet. Still another variable might be how many shops are in the vicinity of the school and how practical it is for staff and faculty are to leave. The American school, for example, is rather isolated in that it would be difficult to walk to an establishment during a normal lunch period. The Business school, on the other hand, is in downtown Budapest and, being a graduate school, the faculty have much greater freedom during the day, not to mention the students.

Vending machines

The project team metered six vending machines: five in the Business school and one at Kolcsey. The machines performed different functions in addition to dispensing items, including keeping drinks cold and keeping water hot, and therefore displayed a wide range of consumption. The average consumption for Kolcsey was 55 kWh per week, while for the Business school it was just under 40. Given the wide range of measurements, Figure 9 shows all of the metered machines.

Vending machines are a good example of hidden electricity costs. They run day and night, year round, keeping beverages cold and water hot, and shining light bulbs. In the case of both Kolcsey and the Business school, they account for roughly 5% of the total electricity consumption. According to sources at the Business school, the agreement with the vendors is that the machines can be there for free, and the vendors collect all of the profits. For its part, the school benefits from having food and drinks available.

Figure 9. Full list of metered vending machines, average weekly consumption (in kWh)



The main illustration of Figure 9 is how cooling drives up energy demand — the soft drinks and snack machines having twice the consumption level of the coffee machine, and more than three times that of the sandwich dispenser. Even the apparently lesser needs of the sandwich machine, however, amount to more than 20 kWh of electricity consumption every week. For comparison's sake, the average computer at Kolcsey consumes just over 2 kWh per week, meaning that one drink machine outconsumes an entire lab of computers.

Even the vending machine serving hot drinks consumes more than 30 kWh per week. Presumably, the machines only function is to dispense a measured amount of hot water and powdered drink, with enough light added to draw attention to its existence and allow the user to manipulate the controls. On any given night, the machine is drawing about 180 watts of electricity every hour.

The money-changing machine presumably allows customers to use the other vending machines, though it may serve visitors to the school who need to feed parking meters because there was no room left in the buildings underground parking lot.

Water heaters

Hungarian schools often feature individual boilers for heating water for sinks in common areas or bathrooms. All of the units observed as part of this study ran on electricity. Water heaters in two schools were measured: Kolcsey (7 kWh weekly average) and the Business school (4 kWh weekly average).

It is interesting to note that individual water heaters are often cited as ways to conserve energy. It is beyond the scope of this study to determine whether the schools would be better served by disconnecting their small water heaters and piping water directly from the gas water heaters. It could very well be that this water would not be considered potable. It is clear, however, that these heaters could be switched off at night, or models could be bought that improve efficiency or only heat upon demand, as opposed to the models seen in this study, which keep heated water on hand at all hours of the night.

Fans

The final device seen with any regularity was the fan. Because most of the metering was done before the weather turned warmer, only two schools were in the midst of summer temperatures: the British school and Vajda. The former made liberal use of fans in classrooms, where temperatures in late May and early June climbed far above the norms for those months.

Five fans were metered in all, with an average weekly consumption of just 600 Wh. In-use averages ranged from 30-40 watts, and they were left on overnight 17% of the time. For comparison's sake, the electricity needed to provide the computer lab — a room that is noticeably smaller than the classrooms — with air conditioning for a week was 2.8 kWh (a result that seems very low, and may be inaccurate considering the problems our team had with pulse meters). This is not to say that fans provide the same level of relief from summer heat; the students and faculty at the British school were complaining about the distracting discomfort. It is also important to remember that ICT equipment gives off a considerable amount of heat, and that the British computer lab equipment ran nearly non-stop. On the other hand, the computer lab had no windows, and the sun represented a considerable heat source in the classrooms, which featured large windows with no external shading.

Air conditioning was only seen in the three tuition schools, and is therefore unlikely to be a large factor in energy consumption in the Hungarian educational sector. The Business school was the only school of the three to have air conditioning in the whole building, which is because it is a converted office building instead of a purpose-built school.

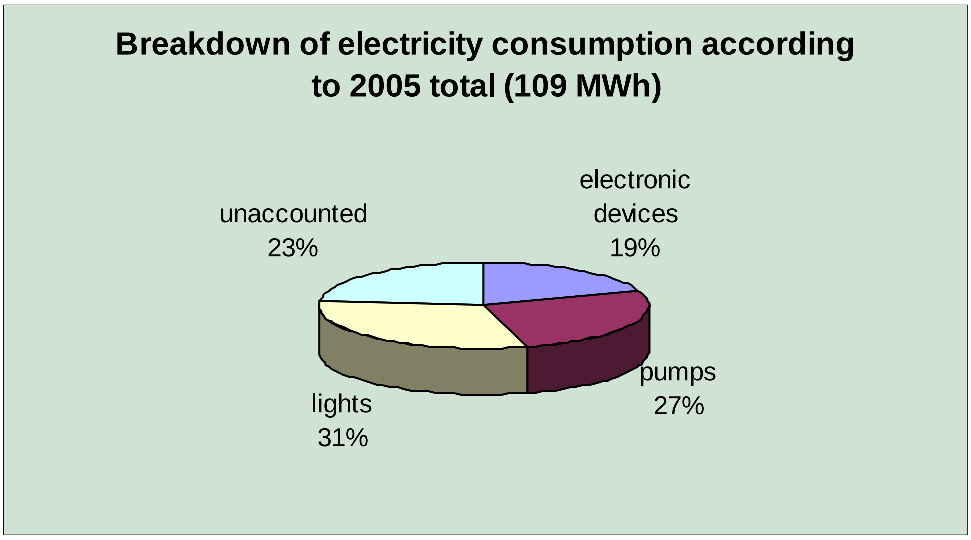
5. Aggregated consumption

Schools house a surprisingly wide array of electronic equipment. Although all schools are unique — especially in a country such as Hungary, where most schools are urban buildings from the 19th century rather than the sprawling American model — they have many common elements and, related to this, electronic equipment in certain areas. Every school, for example, featured a staff kitchen with a refrigerator. Every school had at least two computer labs, and so on. Electric lighting, as we see throughout the commercial sector in Hungary, is ubiquitous.

On the other hand, electricity consumption can be greatly affected by certain amenities that some schools offered that others did not. The best example, and one of the largest shortcomings of our research, was the fact that some schools had kitchens equipped to prepare and cook complete meals for students and staff, while others had food delivered to the kitchen, where the meals were merely warmed and served. The cooling and heating demands of large refrigerators, stoves. fryers, etc. must account for a significant portion of the schools electricity (and natural gas) consumption, but we were unable to meter this equipment because of the shortcomings of our devices, and were even thwarted in tapping into the electricity mains with our pulse meters.

In any case, aggregating and averaging the electricity consumption in different types of rooms should facilitate future auditing efforts and point out areas where electricity savings can be exploited. The most thorough and successful audit was conducted at Kölcsey, where successful pulse meter readings and lighting results allowed the project team to make a complete estimate of the total electricity breakdown. The results of Kolcsey's metering will therefore be highlighted in the analysis of electricity consumption by room type. Figure 10 shows an estimate of Kölcsey's electricity consumption by sector.

Figure 10. Kölcsey electricity break-down



Libraries have not been given a separate section because their relatively low consumption levels can be disseminated into other areas. For example, the librarian's computer can be included in the staff averages, while computers among the stacks can be considered student computers for the purposes of establishing computer lab levels. Their effect on aggregate totals is slight at most.

Summer consumption

Before looking at the aggregated consumption totals for different school areas, it is necessary to mention consumption during the summer holiday at the schools in question. It is tempting to believe that electricity consumption in student and faculty areas of schools drops to zero the day after the school year ends. Given the high levels of standby consumption that we were finding in the initials findings, however, we decided to leave our meters in place at Vajda for one week following the end of the school year.

We were surprised to find that the student computer labs and other areas remained active during this week. Because it was only one week — and the one directly following the end of the year, which means that there could have been unfinished business from the school year — I rejected the urge to read too much into this data. Nevertheless, these signs of life suggest that energy consumption does not come to a halt during the summer and other holidays in places primarily used by students and faculty.

Accounting for the summer months is done on an individual basis, primarily based on the patterns of power management during the metering period.

Student computer labs

By far the most concentrated number of ICT units was found in the student computer labs. These labs therefore received considerable focus during our metering activities. The most thoroughly metered labs were located at the Kölcsey school, where we received data on 17 computers and 15 monitors in the three computer labs — one of which was merely a work area, while the other two were teaching areas. It was the only school where we managed to meter the computer servers, which turned up an average of 26 kWh per week in electricity consumption. This consumption is 13 times higher than the average computer measured in Kölcsey's labs, which means that one computer server consumes more than half a lab of student computers, and more than eight computer and monitor pairs.

The two student labs used for classroom instruction had similar yearly totals of 246 kWh and 271 kWh. These totals were derived by multiplying the average consumption of the monitors, computers and peripherals metered by the total number of units. Peripherals included printers, digital projectors and a photocopier.

All tolled, the plug-in equipment in the computer labs at Kölcsey will consume roughly 7.6 MWh during 2007. The school as a whole consumed 109 MWh during the course of 2005.We did not assume any energy increase in for 2007 during our analysis, which would have increased the percent of unaccounted consumption, but we also assumed that summer consumption in purely student areas would be negligible — a bold assumption given the poor standby management witnessed in five of the seven schools, including Kolcsey. See the section on Summer consumption for more details.

Judging from the inventories of the four non-tuition schools observed, the following formula should give an idea of how much electricity an average student computer lab consumes:

$$E_T = (E_{SLCM} * 19) + (E_{TLC}) + (E_P) + (E_{DP} * .25) + (E_S) + (E_{SP})$$

Where:
E = Electricity in kWh
T = Total
SLCM = Student lab computer and monitor
TLC = Teacher lab computer and monitor
P = Printer
DP = Digital projector
S = Server
SP = Speakers

Taking the average of the averages of all the schools except for the British school (whose values were clearly higher than the rest) gives a total energy consumption per computer lab of 73 kWh per week. Over the course of a 37-week school year the yearly total becomes 2.7 MWh of electricity for a standard computer lab.

The combined standby and low-power consumption per week is 10.5 kWh, which amounts to 389 kWh per year. Schools that leave their computer labs running in standby for the duration of the summer could accumulate an additional 15 weeks of standby consumption, bringing the yearly total to 547 kWh of standby/low-power consumption for one computer lab. This additional consumption would bring the total lab consumption up to 3.2 MWh. On average, a school of 400 students would have two computer labs of this size, meaning that more than 1 MWh of electricity could be lost to standby and low-power consumption, most of which could be eliminated through simply shutting down unused equipment — a practice we see implemented successfully at both Hild and Vajda.

Taking our extrapolation to the Hungarian educational sector for grades 1-12 (i.e. elementary school through secondary schools of all kinds) — a total of almost exactly 1.5 million students (Ministry of Education and Culture 2007) — a rate of one standard computer lab for every 200 students amounts to 7,500 computer labs. If half of these labs are completely shut down for the summer, giving us an average of 3MWh of consumption per lab per year, we come to a total of 22.5 GWh of electricity consumption for Hungary's grade 1-12 computer labs. Of this total, roughly 3.5 GWh is standy/low-power consumption.

Obviously, these extrapolations are based on several large assumptions about which schools of this study the average Hungarian school more closely resembles. It could be that most schools are much more like Hild and Vajda than Baár and Kölcsey, in which case the standby totals are wildly off the mark. It could also be that the server consumption level is far above the norm given that we could only sample two servers, both from the same school.

On the other hand, it could very well be that the ratio of 200 students per computer lab is low. In a study conducted by Hungary's National Institute for Public Education (OKI), researchers exploring ICT use in education noted that "All of the schools we visited have an informatics classroom equipped with a multimedia-network and access to the internet . . . " (OKI 2005), and many of their case studies involved schools for young children and the disadvantaged. According to a study by the Programme for International Student Assessment (PISA) in 2003, Hungarian schools made more than one computer available to every five 15-year-old students, one of the best ratios in the world. This ratio is far better than my estimate of one for every 10 students grade 1-12, especially given the young age that Hungarian children are being introduced to computers in school. Granted, there are some computers available to students in libraries and some classrooms, but according to our research by far the largest number of computers available to students are in the computer labs.

Classrooms

The focus of every school is learning. The traditional didactic approach to teaching dominates the Hungarian educational sector, and classrooms are therefore the most common area. Although it is not directly part of my analysis, a few words about lighting help to give an idea of how much electricity consumption goes to lighting compared to plug-in devices.

Almost without exception, every classroom observed featured overhead, fluorescent tube light lighting of 36 or 40 watts each and natural lighting through large windows along one wall. Perhaps the only rooms that did not take advantage of natural lighting were the computer labs, which are often kept dark, probably to reduce glare and aid instruction, which often relies on digital projection. Most of the lighting ran in rows from front to back, and many classrooms had a separate, single row of tube lighting at the front of the classroom, apparently to light the board at the front of the room. Usually two or three switches allowed lighting to be turned on as needed, and the front row of lights was by far the least used. Our estimates for Kolcsey said that lighting accounted for over 30% of all electricity consumption.

Classrooms in older schools such as Hild often had televisions mounted near the front of the room, often accompanied by a video player. Our metering data showed this phenomenon to be an easy target for energy savings, as these televisions are rarely used but often left on. In the more modern schools, televisions and their accompanying devices are wheeled around on carts. Other audio visual devices were also seen in various classrooms, such as tape recorders, predictably in language and music rooms, or in general rooms for smaller children.

Fans were seen in many classrooms, particularly as temperatures climbed, but space heaters were not seen. This phenomenon clearly reflects the increased attention paid to heating over cooling in Hungary schools, as well as the structure of the school year, which pauses during the summer months. Classrooms in the British school are especially vulnerable to unseasonably high temperatures because the school’s modern building materials, tight fitting windows, relatively low ceilings and lack of external shading all drive up internal temperature and humidity.

Classrooms in the British and American schools featured computers, presumably primarily for the teacher, but also for classroom activities when needed. The Hungarian-language schools occasionally featured computers in science laboratories, and larger classrooms occasionally featured audio/visual equipment, as do foreign language rooms.

Taken as a whole, classrooms account for the majority of space in schools, but are rather empty in terms of ICTs and plug-in equipment. The occasional anomaly is seen, such as the aforementioned empty freezer in a Baár science lab, a fish tank or an outblowing fan.

According to our data, which probably metered a high percentage of the A/V equipment in the schools, a typical school of 400 students would have the following consumption for ICT and other plug-in equipment in its classrooms:

$$E_T = (E_{TC} * 3) + (E_{AV} * .5)$$

Where:

E = Electricity in kWh

T = Total

TC = Teacher computer and monitor, average

AV = Total metered classroom audio/visual consumption

This formula gives us a school average of 11.4 kWh for all classroom consumption from ICT and plug-in equipment. Of this total, 2.5 kWh is standby consumption for the A/V equipment and low-power consumption for the computer and monitor. In a full year, this amounts to 553 kWh, of which 129 kWh is standby/low-power consumption, assuming a summer of being switched on but unused, which I feel is a safe assumption. For Hungary as a whole, this amounts to just over 2 GWh, of which .4 GWh is standby/low-power.

As mentioned previously, audio/visual equipment should be removed from any permanent positions in classrooms and stored on rolling carts for occasional use. No further purchases of analogue equipment should be made and schools should start planning environmentally friendly disposable options for much of this equipment.

Kitchens and cafeterias

In all but two of the schools of the study, hot meals were prepared on site in large kitchens. These kitchens contained refrigerators, deep fryers, warmers, gas ovens, and various smaller devices such as slicers. They also often had separate ventilation units.

Because of the heavy equipment involved in refrigerating and cooking large amounts of food, however, we were unable to use the metering equipment at our disposal to measure the energy consumption. For different reasons we were also unable to measure the kitchens as a whole, normally because the mains boxes were too small to house our equipment. Another difficulty is that appliances such as ovens often run on gas, for which we had no metering equipment.

We were able to meter smaller equipment involved in warming food, as well as the lights in the cafeterias. Nevertheless, kitchens remain a large unknown in our study. The one item we managed to meter — a soup warmer at Kölcsey — consumed 12.4 kWh of electricity per week. This equipment was plugged into a normal socket. The commercial equipment seen in schools that prepare school lunches was often plugged into higher voltage outlets. To give some idea of what this equipment is consuming, Energy Star guidelines (2007) suggest that commercial refrigerators should consume no more than 14 kWh per week under test conditions.

Staff rooms and staff kitchens

Faculty and staff share facilities for storing and preparing their own food, drinking coffee and tea, accessing ICT equipment and relaxing away from the students. In some of the older schools, these can be designated smoking areas. They are similar in many ways to the faculty work areas, but usually contain refrigerators and coffee makers as well as computers and photocopiers. In the British school the staff room is air conditioned, while at Baár it is clearly a smoker's haven. These staff functions mean that in most cases these rooms witness year-round use, unlike the faculty work areas.

As for staff kitchens, the appliances found there were relatively consistent. The following formula provides a reliable estimate of the electricity consumption of ICT and other plug-in equipment:

$$E_T = E_R + E_M + E_E + (E_K * .5) + E_{WH}$$

Where:
E = Electricity in kWh
T = Total

R = Refrigerator

M = Microwave

E = Espresso maker

K = Electric kettle

WH = Water heater

Employing this formula with the data from the study gives us a total weekly consumption of 14 kWh. These items had no discernable standby power (with the exception of a tiny amount for the espresso maker). The yearly consumption of an average staff kitchen is therefore 742 kWh. For the Hungarian educational sector of grades 1-12, this works out to 2.78 GWh per year.

Faculty work areas

There are generally two types of rooms available for teachers to prepare their lessons: common areas and private offices. Private offices for faculty members are rare at any level of education below advanced learning. In the typical Hungarian schools of our study, it was common to see one large room with several tables grouped together in the center. This center work area was free of ICT equipment. Instead, computer work stations (with peripherals) were found lining the walls to varying extent. In every case there was room for more work stations, which suggests that these grouped work rooms will likely absorb more, possible many more, ICT work stations before units are retired, gifted or resold.

Vajda school, for example, had just one work station for the entire faculty. It is hard to imagine that this school, which may be the most characteristic of Hunagarian schools of any from the study, will not absorb a large amount of ICT equipment into this and other rooms. It is entirely possible that many of these computers will be handed down from other schools, all of which suggests that energy consumption by ICT equipment will surely rise.

Faculty work areas also contain photocopiers, desk lamps, phone chargers, and other small devices. Some even contain sinks with their own small water heater. These large rooms also feature a proportionately large number of light bulbs. Kolcsey has a particularly large faculty room, as seen in Figure 11. In the far back left corner there are two computer workstations with a printer and two photocopiers.

Figure 11. Kolcsey faculty room

The interesting finding related to these rooms is that something discourages people from shutting down equipment or turning off lights, and therefore electricity consumption in these rooms is high and constant.

The following formula will provide the total consumption on an average faculty room for a school of 400 students:

$$E_T = (E_{TC}) + (E_{TP}) + (E_{PC}) + (E_S) + (E_{SP}) + (E_{WH} * .25)$$

Where:

E = Electricity in kWh

T = Total

TC = Teacher computer and monitor

TP = Teacher printer

PC = Photocopier

SP = Speakers

WH = Water heater

The data from our survey provide a value of just under 12 kWh per week, of which 2.4 kWh came from standby and low-power consumption. Factoring in a summer of standby consumption coefficient of 65%, which reflects the overnight percentage of the four non-tuition schools, the yearly average of total consumption in faculty areas is 2 MWh, of which 82 kWh is stanby/low-power consumption. For the Hungarian education sector of grades 1-12 this works out to 7.5 GWh total, and 308 MWh of standby/low-power.

Of all the components of the formula, the water heater is the most conspicuous. It is true that only the two Kölcsey faculty rooms featured water heaters, but for schools as a whole these units were far from rare, and I therefore do not consider them an anomaly on par with, for example, the fish tank in the Baár biology lab.

Administrative offices

Administrative work stations in Hungarian schools seem to be the same as what you would find anywhere in the commercial sector, and certainly the same as what you find in municipal buildings. They work according to normal work schedules with standard ICT equipment, including computers, monitors, speakers, printers, fax machines, photocopiers, and even shredders. Their lighting resembled what you would find anywhere in a similar building in the commercial sector. There were desk lamps, but very little evidence of their use in task lighting in lieu of overhead lighting.

Because administrators resemble normal office workers, they work more throughout the year than teachers and students. Equipment in these offices should therefore have greater consumption and potential for savings. Because they work through the summer months, and Hungarian schools (at least none of the schools of our study) do not tend to offer summer courses, there is a greater need for cooling in these offices. The British school, for example, has air conditioning for its administrative offices, but not for its classrooms (with the exception of the computer lab). Older Hungarian schools rely on fans. Behavioral changes should therefore lead to energy savings in many cases at no additional cost.

The follow formula should generate a reasonably accurate figure for administrative staff consumption in a school of 400 students:

$$E_T = (E_{AC} * 7 * .9) + (E_{AP} * 5) + (E_{APC} * 2) + (E_{SP} * 5) + (E_F * 2)$$

Where:
E = Electricity in kWh
T = Total
AC = Staff computer and monitor
AP = Staff printer
APC = Staff photocopier
SP = Speakers
F = Fax machine

With the data from the research, this formula produces a weekly total consumption of 42.6 kWh, of which 13.2 is standby/low-power consumption. For the weekly total, the formula contains a slight modifier for holidays for staff computer and monitor usage because in most cases we took care to select work stations where the employee would be actively working during the metering period. This modifier of .9 reduced the weekly consumption by roughly 2.5 kWh per week. The yearly total for administrative staff electricity consumption from ICT and plug-in equipment came to 2.2 MWh. For the educational sector of grades 1-12 as a whole, this translates into 8.3 GWh per year, of which 2.6 GWh is standby/low-power consumption.

Hallways, entrances and stairwells

The most apparent overuse of lighting takes place in hallways and entrances. In both the American and British schools, joint faculty-student teams suggested reducing considerably the amount of lighting in hallways, for example. In both cases, the lights are controlled centrally, and left on all day. In the case of the British school, the central and hallway lights needed to be on before one could turn on lights in a classroom. According to the building manager, this system was designed by the building constructors and was not a request by the school itself.

The American school has a centralized lighting system that can be controlled centrally or locally. Lighting in central areas, hallways, stairways and bathrooms is turned on early in the morning for the early arriving cleaners and left on all day. The American school's Green Week coincided with the third week of our monitoring, and efforts were largely related to turning off unneeded lighting. The results can be found in the section on behavioral change.

Both the American and British schools largely use compact fluorescent bulbs, often in pairs, in hallways. The American school uses built in tube fluorescents in their entrance way, while the British school used compact fluorescents.

In three of the four older schools — Kolcsey, Vajda, and Baar — lighting in hallways has been changed to tube fluorescent. Vajda's lighting was updated at the beginning of the 2006/07 school year. It uses curved fluorescent tubes in the large rooms that connect the stairways to the hallways, and in some hallways.

Only Hild has not upgraded the lighting in its hallways, although the school's director said that renovations were being planned. Hild uses hanging, single-bulb incandescent in its hallways, with a mixture of 40- and 60-watt bulbs. Along its wide, main stairway there is an array of different lumiares with incandescent bulbs.

For the most part, these areas are free of ICT or plug-in equipment with the exception of photocopiers and vending machines. Photocopiers have been worked into the consumption totals of administrative staff, which leaves vending machines.

Based on the findings of the non-tuition schools, an average school of 400 students would have likely have one soft drink vending machine and one warm drink vending machine, for a total of 92 kWh of weekly consumption, and 4.8 MWh of yearly consumption. These numbers may seem like overestimates until one considers that schools without vending machines very likely have buffets with glass door coolers that closely mimic this consumption. For the Hungarian educational sector of grades 1-12, this translates into 18 GWh.

As mentioned previously, electricity consumption from vending machines can quickly add up to be a large portion of a school's total consumption, especially in relative terms to the value that it adds to education. The inefficiency of vending machines has become a topic of interest in the United States, where the Energy Star program (2007) has released guidelines that call for low-power modes for both the lighting and refrigeration aspects of vending machines. Assuming that schools are essentially active from 8 AM to 6 PM (allowing for extracurricular activities) for 37 weeks per year (administrative staff represent a small fraction of a schools population), these vending machines could reasonably fall into low-power mode for 14 hours per day for 37 weeks per year and 24 hours per day for 15 weeks per year, or roughly 36 total weeks per year in low-power mode. In other words, vending machines in schools could easily spend more than 70% of their existence in low-power mode, even if they never fall asleep during a school day.

6. Conclusions and recommendations

According to the data obtained from this research and the extrapolations detailed in the previous section, total yearly consumption of electricity by ICT and plug-in equipment in the Hungarian educational sector, grades 1-12, is 61.1 GWh for the 2006/2007 school year. As explained previously, this figure does not contain commercial appliance consumption in kitchens.

Table 25. Consumption by plug-in equipment for Hungarian schools, grades 1-12 (GWh)

School area	Total consumption	Standby/ low-power
Student computer labs	22.5	2.5
Classrooms	2	0.4
Staff kitchens	2.8	0
Faculty work areas	7.5	0.3
Administrative offices	8.3	2.6
Hallways	18	0
Total	61.1	5.8

As seen in Table 25, of the 61 GWh of consumption, nearly 6 GWh can be classified as either standby or low-power consumption. The definition I used to classify standby and low-consumption allows us to say that this 5.8 GWh of consumption could be completely eliminated by turning off all equipment that will not be in use for 40 minutes or longer. This period is much shorter than many experts claim is practical or even cost effective. Cole's 2003 article sites a work by Koomey et al. from 1993 that claims that shutting off a computer for several hours is not cost effective. They claim that even 15 seconds of extra attention per day spent powering the computer up and down costs an employee and entire hour per year. I would counter that an hour per year per employee is a worthy investment in shaping power saving behavior.

The 2.5 GWh of standby/low-power consumption in student computer labs is in one sense a success in that the computers of our survey showed consistent low-power management. On the other hand, the successful centralized power management by Hild and Vajda illustrate that nearly all of this total could be eliminated.

Replacement potential

Reducing the amount of energy consumed is not as simple as buying a new piece of equipment and retiring its predecessor. Electronic equipment, like all industrial goods, require a great deal of energy to produce. Calculating this embedded energy consumption requires a life cycle analysis.

Life cycle energy analysis, computers and monitors

Any analysis dealing with replacing electronic equipment for energy savings must take into account the energy embedded in the production process of new units. Williams and Sasaki (2003) compared different types of life cycle analysis to determine the amount of energy present in the ICT "backpack". They settled on the input-output life cycle assessment as the most accurate method, which gives a value of 5,600 MJ per computer and monitor, which converts to 1,555 kWh. In other words, any computer and monitor purchase (assuming they are carried out at the same time) must recover 1.5 MWh to merely break even from an energy conservation perspective — assuming, of course, that we are concerned with reducing the total amount of energy consumed globally, since the lion's share of the electricity consumed in the production of these items likely takes place far from Hungary.

To put this number in perspective, the highest weekly average of combined consumption for computers and monitors belonged to the British school at 8.5 kWh per week, which was twice the sum of the second highest school. Even assuming that this value holds throughout the summer (which it surely does not), the average computer-monitor set-up consumes 442 kWh per year. At this rate, a new computer and monitor would need to wipe out nearly four full years of consumption simply to break even from a total energy consumption perspective. If we assume that the new set-up provides 50% efficiency gains, the electricity consumption breakeven point comes eight years in the future — well past the typical obsolescence date for personal computers — for even this extreme example.

Although cost savings might eventually be recovered by a school from upgrading its computers and monitors, the goal of dual benefits — energy and cost savings — from new purchases of more efficient computers and monitors must be abandoned in this particular instance. Calculating potential cost savings derived from energy savings thus becomes an irrelevant point from an environmental perspective, and perhaps counter-productive to boot. Moreover, if we conclude that the higher in-use hourly consumption of computers seen at the British school (nearly 200% higher than Hild's) is due to the fact that the British school has newer units, the purchase of new computers signals more energy consumption, not less. Therefore, the average Hungarian school that purchases new computers would almost certainly increase their total electricity consumption, or at the very least, offset the gains achieved by the purchase of more energy efficient monitors. Although productivity may very well increase after the purchase of new computers, it is hard to conceive that this would translate into energy savings high enough to offset the increases in consumption.

The other environmental downsides of new purchases of ICT equipment is related to the vast amounts of water consumed during the manufacturing process and the chemical pollution. Williams (2003) estimates that 1,500 kilograms of water are needed to make one desktop computer and 17-inch CRT monitor, and that "hundreds or even thousands of chemicals, many toxic, are used to produce a computer."

Upgrading computer equipment also carries a surprisingly high embedded energy value of 1,750 MJ, or 486 kWh (Williams and Sasaki 2003). Although relatively small parts, computer microchips require a great deal of processing to manufacture, and are a much larger cost than other components of a computer relative to their weight. Nevertheless, technology marches on, and institutions are forced to keep up, especially in a competitive environment for students such as seen in Hungary currently. Assuming upgrading can be carried out effectively, Williams and Sasaki (2003) estimate that upgrading is a 12 times more effective life cycle option than recycling in terms of energy consumption. As mentioned previously, there are strong indications that the schools of our study are upgrading their machines, particularly in the case of Vajda.

Power management

Even if we allow a long enough recovery period to justify the purchase of more efficient electronic equipment for energy conservation purposes, attention must still be paid to minimizing energy consumption. In fact, many believe in the rebound effect, whereby more efficient equipment leads to even greater consumption. As Smil (2005) puts it: “the historical evidence is clear: higher efficiency of energy conversions leads to higher, rather than lower, energy use, and eventually we will have to accept some limits on the global consumption of fuels and electricity.” If we accept that ICT and other plug-in equipment is becoming more efficient, and that newer purchases are more efficient in the energy they use, then the power management record of the schools of our survey would seem to support the general principle of the rebound effect as described by Smil.

On the other hand, two of the three tuition schools — the American and British schools — are both taking active measures to reduce their energy consumption. Besides being willing participants in our survey (which was common for all seven schools), the American school held a green week to raise environmental awareness and reduce electricity waste in the school. During this time they managed to halt the increase in energy consumption, if not reduce it. The British school formed an environmental club that drew up recommendations for the school’s management to consider. The school is also working to incorporate green features into an extension of its premises. Perhaps awareness of the rebound effect is the first step in combating it.

It could also be that the rebound effect is actually an illusion. Perhaps the public grammar schools of our study conserve energy so well because they simply cannot afford to waste money in their budgets. In other words, increased consumption is not a result of feeling complacent about energy savings after purchasing more efficient equipment, but rather a sign that better funded institutions are rich enough to both purchase new equipment and to be careless about consumption.

More than anything, successful power management in schools seems to be the result of a commitment to saving energy and managed routine. Vajda's and Hild's computer labs are clearly turned off centrally — a top-down power management approach. Likewise, computers, photocopiers, and other machines with low-power modes must be programmed by administrators to fall asleep after a certain length of time.

Recommendations for school officials

1. Put someone in charge of managing electricity use in the school. This person should ensure that all low-power functions are enabled and functioning properly and that equipment in areas such as computer labs are turned off completely at the end of the day.
2. Encourage employees to turn off computer peripherals such as printers and speakers when not in use, or invest in standby killers, which turn off peripherals automatically when the computer is shut down.
3. Purchase refrigerators without freezers, which serve no real purpose in a staff kitchen.
4. Unplug superfluous refrigerators, especially during summer months.
5. Reconsider the agreement to allow vending machines in the school, and insist on energy efficient varieties that have low-power options. Consider having vending machines removed or unplugged for the summer months.
6. When new monitors are to be purchased, choose flat screen LCD monitors. They not only consume half as much energy as CRT models, but also conserve space and reduce eyestrain.

7. Spread the word that shutting down a computer is in fact better for the computer than leaving it on, and that there is no spike of electricity use when computers are turned on.

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