Improved Building Energy Consumption with the Help of Modern ICT

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Kyoto process and the global combat against climate change will require more intensive energy saving efforts especially in all developed countries. Key for the success in building sector is the energy efficiency of the existing building stock. Reliable information on realised energy consumption is the basis for all kind of improvements. Monitoring and targeting systems based on modern information and communication technologies can support daily building operations and saving actions. Based on the internet technologies information and benchmarking services can be developed in order to improve the dissemination of best practices and the networking both on national and international level. Some results of the latest developments carried out at VTT in Finland (www.vtt.fi) will be discussed.

1. BACKGROUND

The problem of potential **global climate change** and the big risks it includes for the whole of human civilization (figure 1) is nowadays widely recognised by the majority of scientists, politicians, etc. The web site (http://www.ipcc.ch) of the Intergovernmental Panel on Climate Change (IPCC) can convince even the most sceptical about the need for improvements also in the building sector, which is responsible for a remarkably large proportion of greenhouse gas emissions.

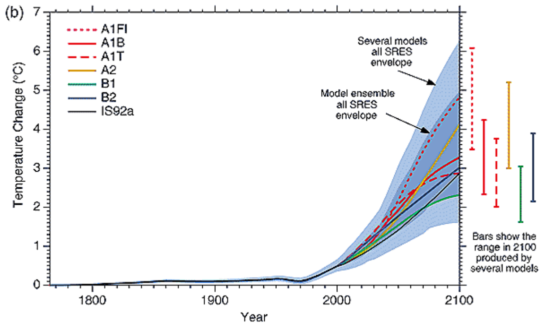

Figure 1. Historical anthropogenic global mean temperature change and future changes in the six illustrative SRES scenarios of IPPC /1/

The European Commission for example states in its Green Paper Towards a European Strategy for Energy Supply: "At present, greenhouse gas emissions in the European Union are on the rise, making it difficult to respond to the challenge of climate change and to meet its commitments under the Kyoto Protocol. Moreover, the commitments made in the **Kyoto Protocol** must be regarded as a **first step**; climate change is a long-term battle involving the entire international community … The European Union has very limited scope to influence energy supply conditions. It is essentially on the demand side that the EU can intervene, mainly by promoting energy savings in buildings and in the transport sector." /2/

Besides the big global risks mentioned, other more local reasons for improved energy efficiency can be easily found too. Health problems caused by burning of fossil fuels are becoming more and more important /3/. Scientific research on small particles produced mainly in burning processes of energy production predicts more than 100 000 premature deaths yearly in Europe alone /4,5/. Unnecessary energy consumption means also waste of valuable and unique raw materials and restricts the possibilities for future generations. At the same time it causes purposeless costs for private and national economies. The need for better energy efficiency is more than self evident but progress seems to be slow and especially electrical energy usage is going to increase in all building types. When planning actions for improvements it is important to remember, that **major potential** lies in improving the energy efficiency of the **existing building stock**.

2. ENERGY MONITORING FORMS THE FOUNDATION

" When you can measure what you are speaking about … you know something about it; but when you cannot measure it … your knowledge is of a meager and unsatisfactory kind" *Lord Kelvin*

In other words: "what can´t be measured cannot be managed". This phrase is more than valid also when energy management is discussed. Without proper knowledge about energy used in buildings and their processes no real management or improvement of current activities is possible. Good results in energy conservation in buildings depend decisively on the **attitudes and habits** of users on the one hand, and on the **motivation and know-how** of persons responsible for the operation and maintenance of buildings (foremen, service personnel etc.) on the other. Both groups mentioned can be strongly influenced by consumption monitoring and effective feedback.

The impact of monitoring and targeting cannot be overestimated. These activities form a basis for the planning of repair and improvement measures (retrofits). Without reliable information on the energy and water consumption saving activities cannot be **directed** properly, not to mention the **estimation of influences or economic viability** of measures already completed. Advanced monitoring and targeting is also an excellent **tool for training and motivation**, through which operations and maintenance personnel can receive concrete and "objective" feedback on the successfulness of their work. Proper feedback can also influence users' **attitudes and habits –** the so-called **human behaviour,** which often has a significant impact on the success of saving activities. Monitoring data based on reliable and up to date consumption figures also creates an important **feedback channel** for repairs and new building work, making it possible to evaluate the impacts of new energy saving technologies, new design solutions, etc. Reliable information on baseline and post-installation consumption is the prerequisite for performance based contracting and verification too.

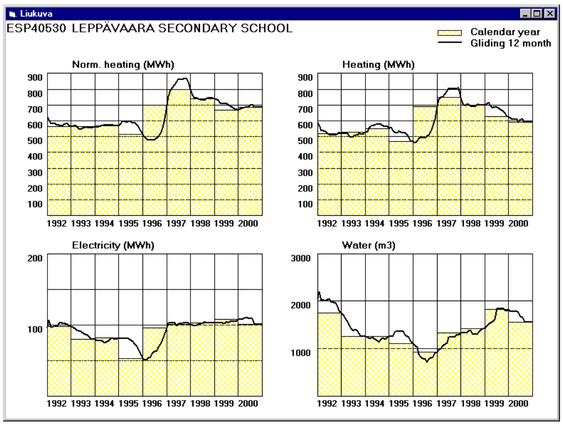

Figure 2. Short and long term variations in energy and water consumption in a school building

Accurate enough information on realised energy use is also necessary for the **validation and verification of** more or less theoretical **calculations** and **simulations** used in design phase and product development. In energy efficiency actions it is very easy to lose hold of a comprehensive perspective and concentrate on some kind of sub-optimisation, where just a part of the whole energy consumption of the building is taken into account. Continuous monitoring, based on existing meters can, by minor work, provide important whole building information, which helps in focusing on the most essential and visualises the real – expected or unexpected - impacts of implemented measures.

The first step in the way of better energy efficiency in buildings is the continuous and regular recording of actual use of energy and water. Comparing the yearly, monthly or daily consumption to the respective previous period gives already a lot of information about how the energy efficiency is varying and developing with time. When any changes in daily operation or maintenance routines are made the impacts should be observable in consumption figures too. Conversely, remarkable changes in consumption figures lead us to search for the probable reasons if they are not self-evident. Based on this kind of feedback information offered by monitoring, the energy behaviour of the building can be understood better, and operational routines can be directed in a right way. In many new buildings this is at least partly done by modern building automation systems or BEMS but when considering the whole existing building stock these kinds of systems are still exceptions.

On the basis of the information received in this way the functions of the building and it´s technical systems can be controlled. Simultaneously also feedback from the influence of users as well as from the quality of operation and maintenance works can be achieved. At intervals **-** especially when problems have been discovered - also more accurate "medical" checking and investigations will be needed in the form of energy auditing, retrofit planning, etc.

Figure 3. Existing meters can offer valuable data

3. EXISTING UTILITY METERS – AN UNDERVALUED SOURCE OF DATA

When aiming at improved energy control and management in the majority of existing buildings, installation of new sensors, meters, automation systems etc. is not a realistic short-term option because of high costs. Existing utility meters (figure 3) can offer a sound basis for the development of monitoring activities however. Actually the **information needed for basic energy management activities is already available for**

almost every building. Until now this existing data source has been almost forgotten or at least undervalued. Compared to invoices, utility meters can be easily used to gather the information for energy control and saving actions. In addition to their wide existence (investments already done) another important benefit is that the accuracy and performance (maintenance) of utility meters is quite well guaranteed and controlled because of the economic interests of both the utility companies and the customers.

For most of the needs of basic energy management the data accessed from utility meters is sufficient. Actually in the basic control and management of energy use there is no need for the very accurate and short interval registration of consumption provided only by modern meter technology or proprietary equipment (dataloggers etc.). The so called **whole building approach** gives already enough information to achieve most of the important benefits of monitoring mentioned before. The main disadvantage of this approach is that it actually does not quantify the energy performance of the building itself, but rather the sum total of the quality of construction and the behaviour and decisions of the occupants, building owners, operating personnel etc. From the point of view of environmental targets this can even be an advantage however. And the whole building consumption figures can always be **complemented with** temporary **in situ measurements,** when more accurate data is needed for auditing, verification or commissioning for instance. In many cases the installation of new "sub meters" is justified too in order to get more accurate information.

4. SMALL (AND SIMPLE) CAN BE BEAUTIFUL ALSO IN ENERGY MANAGEMENT

Effective utilisation of existing meters is not possible without supporting tools. Practice has shown that monitoring activities can not be carried out as manual paper work only. The modern version of pen and paper – the PC – offers a solution to this problem. Because PC´s are nowadays common in every organisation, it is possible to develop simple calculation and monitoring tools and offer them for the use of a very big audience. By utilising them energy control of buildings can be improved essentially by minor work and at a small cost. At the same time the awareness of end users of energy can be raised, which in many cases is prerequisite for further improvements.

One example of this kind of supporting tool is the “Kulu” software (http://www.vtt.fi/kulu) developed by the Technical Research Centre of Finland (VTT). Kulu can be easily used for monitoring and targeting in individual buildings, companies and other consumers like households

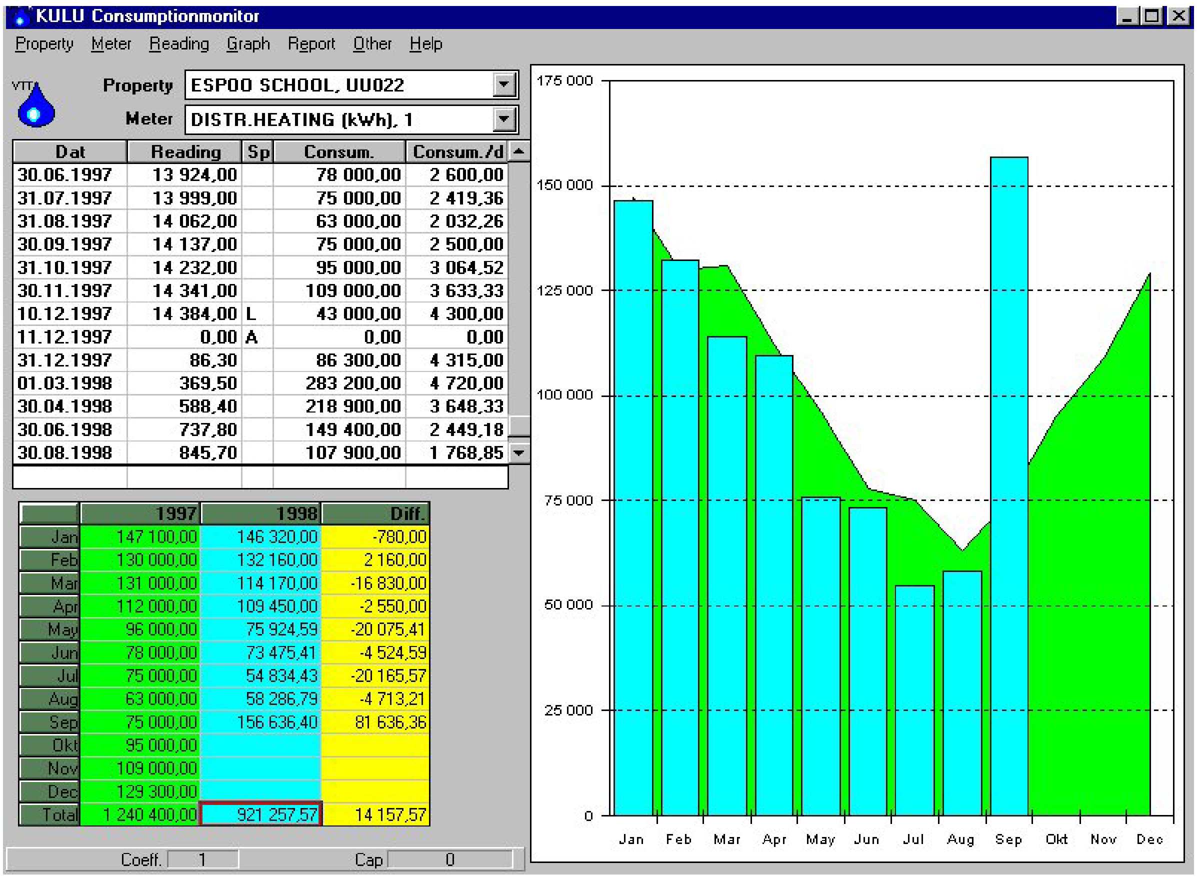

Figure 4. User interface of Kulu including all the main functions for monitoring and targeting

for example. Caretakers, service personnel, even inhabitants who directly influence energy consumption can track the development of their own use of energy and water as well as find possible failures and confusions. The standard version of KULU is in this type of use in dozens of Finnish swimming halls and other sports facilities, housing companies, small municipalities etc.

Figure 5. Deputy Head Master of Real Kooli in the city of Tallínn, Estonia monitoring the energy consumption of the school building

In standard version basic monitoring routines have been made as **user-friendly** as possible, to enable people with little or no experience about computers to use Kulu without any special training. In the figure 4 the user interface of the software can be seen. On the same display, all monitoring activities can be performed from updating of meter readings (or consumptions, outputs, etc.) into numeric and graphical summaries. Among other things the user can freely choose the time span of monitoring (e.g. daily, weekly, monthly, yearly cycles) and the type of graphic presentation (bar, area, line, pie). Besides consumption also information about the costs of energy etc. use can be easily produced. "Meters" can be set up also for other things than energy and water. In this way outputs and services, which the energy is used to produce can be monitored too and the amount of products, served people, used hours etc. which have influence on energy use can be controlled as well.

Based on sequential meter readings given by the user Kulu calculates always values for monthly consumptions and makes so called degree-day corrections for the heating energy figures. Comparison with the respective month of the previous year can be seen immediately in table and graph. The previous year automatically gives some kind of reference **target or yardstick** for the current year and remarkable changes in consumption/graphs (see e.g. figures 4 and 6) give a warning/alarm when something extraordinary happens. The accumulated sum for the previous year (or month in the case of the daily graph) provides a yardstick for the consumption for the current year. In the figure 6 the increase of electricity usage in the Real School in Tallinn can be easily noted in the graphical presentation. One reason is the new computer classroom taken into the use in the beginning of 2003. Instead of using the previous year's figures it is also possible to use values derived e.g. from energy calculations as a yardstick. It is essential that the **actual energy consumption is recorded regularly** and it is **compared against some "target"** or **"yardstick"**.

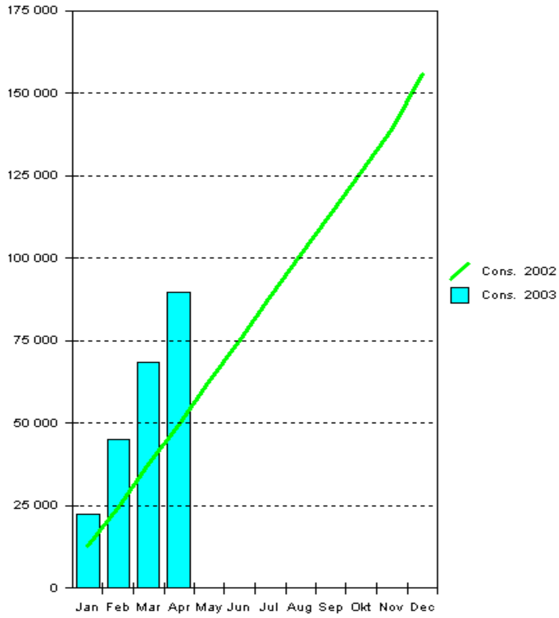

Figure 6. Cumulative monthly consumption of electricity (kWh) in the Real School of Tallinn

The standard version of Kulu can be easily delivered by email or on a single diskette and its use requires only a PC with Windows. In addition to English support for many other languages like Swedish, German, French, Italian, Polish, Czech, Estonian is already implemented and new language versions can be produced with a minor amount of work. Part of the translations are made in the project of International Energy Agency (IEA) called "Retrofitting in Educational Buildings, Energy Concept Adviser for Technical Retrofit Measures" (for more information see http://www.annex36.bizland.com).

In summary, the software mentioned provides the **basic tools for energy control and management**. It is particularly suitable for energy end users like households, O&M personnel of buildings etc. but for small companies and organisations as well. Of course the same can be done using spreadsheet programmes like excel but this requires much more knowledge and effort on the part of the user and the software licence as well. Running in the background of Kulu there is a real database, which offers many advantages for further processing and analysis of the user´s data. In this sense the software will be utilised simultaneously in several countries participating in the IEA Annex 36 mentioned above. Coherent data about energy consumption in schools and universities (case buildings) will be collected for the needs of this collaborative action in order to make international comparisons and to assess the real impacts of saving measures implemented in different countries.

5. PROFESSIONAL CONTROL NEEDS PROFESSIONAL TOOLS

In principal the standard version of Kulu doesn´t set any limitations on the number of monitored buildings and their meters. However, in practice organisations with a large building stock or meter base need more powerful tools. For them the professional version of Kulu offers one alternative. It includes many tools for comprehensive reporting and analysis as well as providing efficient maintenance of meter data. For example, a pocketsized handheld computer and bar code scanner can be used for meter reading (figure 7). Every meter will be recognised automatically by its bar code and the reading can be typed into the memory of the device. On the display the previous reading directs the reader and an alarm voice can be heard if the reading is smaller than previous one.

Figure 7. Handheld computer and bar code scanner helps to read consumption meters efficiently and correctly

Meter readings can be collected speedily and efficiently without errors and they will always match the right building and meter. In addition to the traditional consumption meters also data from other meter types like running ours of a boiler, ventilation system etc. can be collected at the same time. This kind of information can help explain variations in consumption.

Utilising these kind of semi-automatic meters reading systems data from thousands of meters can be collected in a day or two. Via a docking station meter readings can be transferred into the database for further analyses in a fraction of a second. So-called ‘alarm’ reports can be produced immediately and big changes in energy and water consumption can be found easily. This reporting method sorts buildings (or other consumers) according to the changes in consumption. Numerous other reports are available for different kinds of analyses. Feedback information to all levels of the whole maintenance (or user) organisation can be produced. For example the Department of Defence in Finland controls monthly energy usage in thousands of it´s buildings in this way.

6. NEW ICT OFFERS A LOT OF NEW POSSIBILITIES

The ongoing fast development of information and communication technologies (ICT) is rapidly changing all societies and many of their activities too. Internet is already now the main platform for many public and private information services, business applications, entertainment etc. It offers several possibilities to develop new type applications for energy control and management as well.

Figure 8. In the near future buildings and their equipment will be networked over Internet

As very first example many utilities have been enabling city residents (consumers) to submit their energy or water meter readings over the internet. Typically also some consumption reports and information on saving techniques or new energy efficient products are disseminated via web sites established by utilities, consumer organisations etc. One example is Motiva, the Finnish Information Centre for Energy Efficiency (for more information see www.motiva.fi).

Also at VTT, the internet has been used for the development of a new type of monitoring, targeting and diagnostic tools. **"WebKulu"** for instance offers in principal the same functions as the standalone software tools described before but it can be used over internet. It makes monitoring possible via standard web browsers and no installations are needed any more on user side - only access to internet and username with password will be needed. After login all the basic routines of monitoring like updating of meter readings, calculations, weather normalising, analysing, reporting etc. can be carried out from browser. New features including comprehensive benchmarking etc. are under development in collaboration with big property management companies, big cities and state organisations.

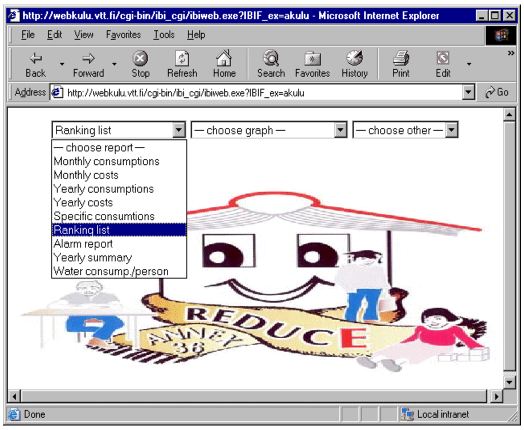

Figure 9. Preliminary user interface for web based reporting services in IEA Annex36 project

By utilising web based solutions energy saving actions and services can be implemented in a new way. For example service men of buildings can update their own data whenever they want from different locations (and countries even). The data is immediately available for analysing, comparisons etc. for everybody having access to the system. Even building occupants, tenants, owners etc. can easily get feedback not only on their own energy consumption but from other similar cases as well. In this way e.g. energy and water consumption in hundreds of buildings owned by the city of Helsinki are controlled and monitored (figures 10, 11). Janitors and other servicemen can get continuous feedback for their daily building operations. This information is available also for the users like e.g. the principals of schools.

Results of the web based development will be tested also on the international level during the IEA Annex36 project mentioned before (figure 9). Internet based applications can offer sound basis for the simultaneous and coherent data collection in several countries. Everybody will have immediate access to the latest data and common analysis, reporting and benchmarking can be carried out.

7. TOWARDS AUTOMATED DATA COLLECTION AND DIAGNOSTICS

Besides more or less manual updating of meter readings also more intelligent and automated data acquisition can be utilised using Internet, LAN/WAN and wireless or wired phone networks. Modules and equipment (I/O Servers) manufactured by Finnish high-tech companies like Comsel System (http://www.comsel.com) and Lonix (http://www.lonix.com/en) for example can be connected to the system. In this way consumption data can be updated daily or hourly and automated meter reading solutions can be realised. In case of modern electricity meters even rate of sampling of milliseconds is available and data for R&D of so called NIALM-tools and methods (Non Intrusive Appliance Load Monitoring) can be collected and quality analysis for electricity can be carried out as well. In near future data analysis and diagnostic routines can be carried out on the background automatically and alarm, summary, etc, reports will be generated and sent as short messages to mobile phones or as emails. Latest consumption figures, benchmarking reports, etc are always available whenever needed (e.g. in meetings) by the management, service companies, etc.

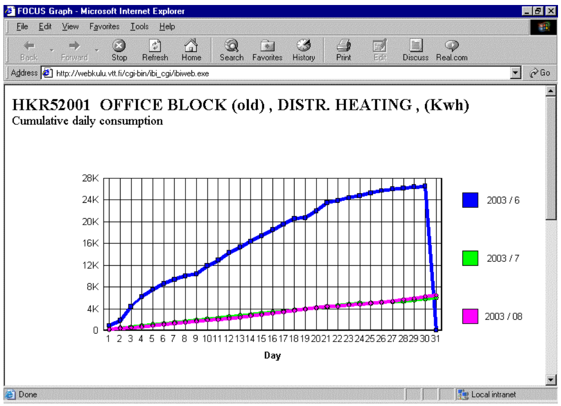

Figure 10. The influence of the exceptionally cold June 2003 can be seen in the heating energy consumption of an office building in the city of Helsinki, normal consumption is on the same level as that in July and August

These kind of new solutions based on internet and other ICT will be developed further as part of International Energy Agency´s project called IEA Annex 40, Commissioning of Building HVAC Systems for Improved Energy Performance (for more information see www.commissioning-hvac.org/). One target in the Finish sub project is to create methods and tools, which could be applied in the different commissioning tasks (initial, re-,

retro- etc. commissioning) for new and retrofitted buildings but for the existing buildings as well.

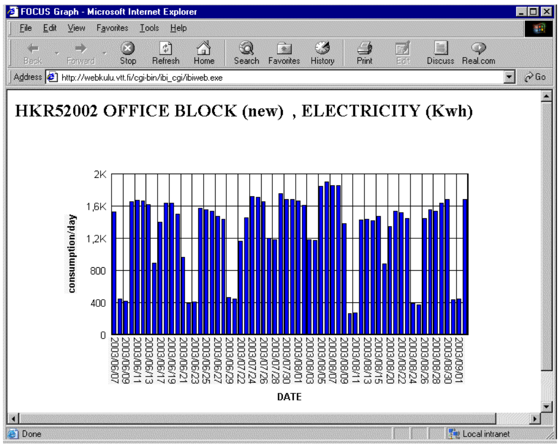

Figure 11. Daily use of electricity in an office building of the city of Helsinki

The R&D part will be done in collaboration with several research institutes of VTT and Tampere Technical University. Many big private and public building owners will be involved too as well as construction and building service companies, which will test the solutions in the practical building operations.

8. BENCHMARKING CAN OFFER VALUABLE INFORMATION

As already mentioned in the near future access to the internet will be commonplace for the majority of people in industrialised countries not only via computers but also via new generation mobiles, digital television, etc. This will offer a sound basis also for the development of new type of energy efficiency services. One example of the use of the internet is the ENERGY STAR® Label for Buildings developed by the US Environmental Protection Agency (EPA) and the US Department of Energy (DOE). An essential part of this labelling scheme is the basic information on building characteristics and the actual monthly energy consumption submitted over internet by the building owners, managers, etc. As part of the Energy Star web services (www.energystar.gov) a special web based **benchmarking tool** is available for the users as well.

Internet based benchmarking tools and services are under development also at VTT, where similar kind of approach will be tested as one alternative for the implementation of the energy performance certification and labelling system. The European Commission proposed already in 2001 a new Directive on the Energy Performance of Buildings, which after some processing became European Law in the beginning of 2003. The main objective of the directive is to promote the improvement of the energy performance of buildings within the European Union. Measures of the directive include:
- Methodology for calculating the energy performance of buildings;
- Application of performance standards on new and existing buildings;
- Certification schemes for all buildings;
- Regular inspection and assessment of boilers/heating and cooling installations.

Certification schemes for new and existing buildings must be implemented by all member states within the coming 6 years. This means, that suitable energy rating systems and certification schemes must be established quite fast and accreditation and training of sufficient personnel undertaking the energy performance assessments must be organised as well. The US Energy Star approach can offer one interesting model. It could be even developed further by putting more emphasis on the consumption data itself.

The effective management of building energy use requires the ability to set and review cost and consumption targets, to monitor performance against the targets and to communicate the building performance to others. As mentioned monitoring, targeting and benchmarking is one of the most effective means to improve overall energy awareness and energy saving motivation. **Continuity is key** for success in energy efficiency because motivation can easily fall off and all conservation technologies have the tendency to loose their impact because of poor installation or maintenance, failures, etc.

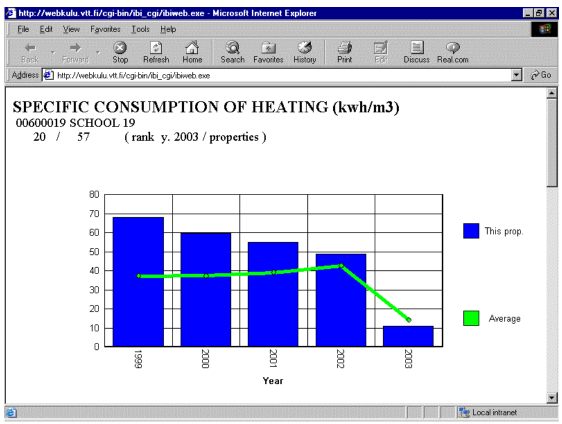

Figure 12. Heating energy consumption of a school compared to 56 other schools in the city of Helsinki

As mentioned previously, the best approach to monitoring and targeting is some form of comparison within the building itself, i.e. some kind of self-benchmarking. This can be complemented by benchmarking with other more or less similar cases, which of course can offer valuable information on new saving possibilities and keep up interest and motivation in the longer term. In this way new dynamic (”competition”) and informative aspects can be added to the certification whilst keeping the system simple enough to be applied to the majority of buildings.

In one school building owned by the city of Helsinki savings in the heating energy have been achieved during the last four years especially if compared to 56 other similar type of schools (figure 12). At the same time the use of electricity is almost double compared to the average of the others (figure 13). Reasons behind this fact should be investigated of course.

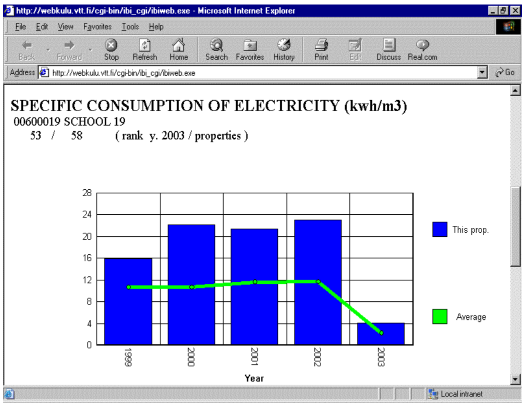

Figure 13. Electricity consumption of a school compared to 56 other schools in the city of Helsinki

9. ENERGY PORTAL FOR MUNICIPAL BUILDINGS

As a first step, the web based benchmarking services will be implemented as part of an energy and environmental portal for municipal buildings. Mainly monthly data on energy and water consumption will be collected and updated regularly into a central web based datawarehouse from about 150 municipalities of Southern Finland. Based on this data, benchmarking, analysis and reporting services will be developed and made available on the same web server. Reports on monthly consumption data from the last 2-3 years (when available) as well as longer term development based on yearly consumption figures will be available.

Reference data based on a larger number of similar types of buildings can be produced giving every user information about the variation of energy and water consumption in similar buildings in general and information about his own position in the whole sample. This kind of comparative information can also show graphically, the energy saving potential which can be realised by utilising the most efficient techniques and best practices. Besides kWh´s, m^3´s, etc, cost information can be produced too, as well as information on typical emissions of greenhouse gases.

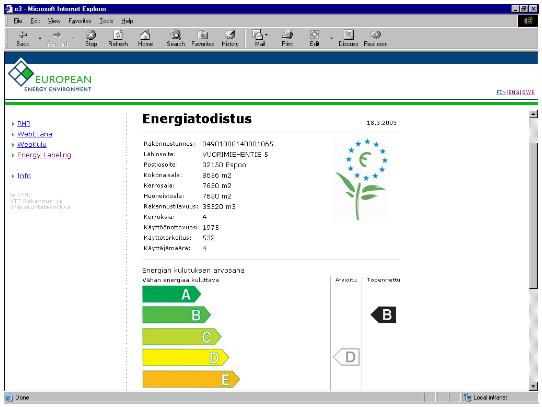

Figure 14. Draft for an "*e*Certification" including both the calculated and measured use of energy

In addition to the consumption data also information on energy saving technologies and products can be accessed. Simple calculation routines for the analysing of the energy performance of building will be included as well as results from the realised energy audits. Possibly the energy performance certification can be produced and updated over internet too. This kind of electrical "***e*Certification**" (figure 14) could be implemented by minor resources and at least the realised consumption figures would be up to date all the time.

Besides labelling via the portal also energy saving ideas and good housekeeping practices could be marketed to the municipal decision-makers and to the persons having responsibility for the daily building operations. After testing the concept first in the Southern Finland it will be extended to the whole country. If successful the similar concept can be later applied in other European countries too.

10. CONCLUSIONS

Modern ICT offers lot of possibilities for the development of new type applications and services, which can help to improve the energy efficiency of buildings. Remarkable progress can be achieved already with quite simple tools and information based on the existing utility meters. Automated techniques for data collection will increase the available information dramatically. Effective tools for analyses will be needed. In the near future new generation services and applications will be seen and internet will be the main platform for the development. When aiming at environmentally friendly and energy efficient buildings technology can be just one part of the solution however. Main challenges will lie in the field of awareness, motivation and human behaviour.

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