Monitoring Electricity Consumption in the Tertiary Sector – A Project within the Intelligent Energy Europe Program

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Abstract

The electricity consumption in the tertiary sector in the EU is still increasing and a further increase is expected of more than 2 % per year during the next 15 years. This sector includes companies and institutions of public and private services with heterogeneous economic and energy-related characteristics. Building managers and decision-makers are not enough informed about the electricity consumption structure and electricity-saving potentials.

Within the EU Intelligent Energy project EL-TERTIARY an overview of existing studies showed that the availability of disaggregated data on electricity consumption and its use by purpose (lighting, office equipment, ventilation, air conditioning, etc.) is poor. The methods of determining the types of end-uses are weak; most studies are based on calculations and estimations, only a few on measurement. In addition, many of the results are not published.

EL-TERTIARY developed an internet-based methodology for monitoring electricity consumption. It was applied in more than 120 case studies in 12 EU countries. They cover various types of buildings: offices, schools, universities, kindergartens, hotels, supermarkets, and hospitals evaluating more than 900 technical systems.

On the background of ongoing activities on EU level, such as directives, research and implementation projects the paper illustrates the concept of EL-TERTIARY, the newly developed methodology for the documentation of building audits and monitoring as well as selected results.

Background

Electricity continues to gain an increasing share of final energy use in all EC countries. Its use places an extra burden on the energy economy and the environment. In the past the consumption increased by 15.6 % in the period 1999–2004 (Bertoldi & Atanasiu 2007) and a further increase of more than 2 % per year during the next 15 years (European Commission 2006). This long-term development makes it necessary to initiate increased measures to save electricity and to use it efficiently. Southern EU countries tend to show a much higher increase in electricity consumption and an alarming occurrence of summer peaks with precarious impacts on the stability of electricity grids.

Together with the overall increase of the tertiary sector due to structural changes, the development of technical equipment, e.g. air condition, information and communication technologies, is a key factor for the increase in electricity consumption.

Reported experiences of consultants show that they were able to find high potentials for a more efficient electricity use in most companies and buildings (Jochem/Gruber 2005). However multiple types of significant barriers to energy efficiency improvements exist (e. g. Sorrell et al. 2004; de Canio et al. 1998; de Groot et al. 2001). They are mainly caused by socio-economic framework conditions in the sector, but also market failures, transaction costs, or imperfect information as well as market barriers on the supply side. Especially public organisations and companies which are not profit-oriented are characterised by a high level of barriers (Schleich/Gruber 2007). In individual companies energy costs absorb only a small part of the total budget or income of the companies and institutions in this sector. For this reason, energy saving is not commonly a financial or management priority in the tertiary sector. One of the main important barriers is the lack of information about the patterns of energy consumption. This is partially due to missing metering devices and partially to organisational deficiencies such as failing to clearly assign the responsibilities for energy management and energy costs. Transaction costs including the costs of collecting, assessing and applying information on energy savings potentials, investments and organisational measures, as well as the costs of negotiations with potential suppliers, consultants or installers are prohibitive (Ostertag 2003). Another problem is the shared responsibility between different departments, e.g. operating and purchasing departments. There is also a lack of sufficient market structures and access to energy service companies, energy consultancies, energy agencies, etc. Finally the end-users, i.e. the employees who do not pay the energy costs, are not usually motivated to save energy.

The tertiary sector is a heterogeneous area. It includes subsectors such as all kinds of public and private offices, hotels, restaurants, shops, supermarkets, schools, universities, kindergartens, hospitals, swimming pools and various other services. Many types of buildings are represented which vary with regard to size, technical standard, building age, equipment, etc. For efficient electricity-saving measures it is necessary to have detailed and reliable know-how of the electricity consumption structure, the condition of the energy-relevant equipment and saving potentials. Due to the heterogeneous types of buildings in the tertiary sector the general availability of disaggregated data concerning electricity consumption and its use by purpose – e.g. lighting, office equipment, ventilation, air conditioning, etc. – still is poor (Bertoldi & Atanasiu 2007).

Activities on EU level

Improved data about electricity end-uses and saving potentials in tertiary buildings help to design and implement adequate energy efficiency policies and programmes both at national and EU level, e.g. the Green Building Programme, the Green Light Programme, the Motor Challenge Programme, the Directive on Energy Efficiency for Lighting, the Eco-Design Directive for energy using equipment, the Directive on the Energy Performance of Buildings, and the Directive on Energy Efficiency and Energy Services (ESD), as well as the negotiations on the Energy Star and voluntary initiatives such as the Codes of Conduct on energy efficiency of selected electronic equipment, the EICTA agreement with producers, and the Group for Energy-Efficient Appliances (GEEA).

In order to support theses activities at the EU level, the EU-funded programme “Intelligent Energy Europe” co-finances European projects for the promotion of energy efficiency and the use of renewable energies. It covers implementation aspects such as capacity building, spreading of know-how, exchanges of experience, policy input, awareness raising, education and training. In this context EL-TERTIARY (Monitoring Electricity Consumption in the Tertiary Sector) is part of a set of projects which include metering and analysis of electricity consumption. Some of these projects in the area “Energy-efficient equipment & products” concentrate on technologies such as pumps, motor systems, boilers, or lighting, others on certain sectors, such as EL-TERTIARY, ENERinTOWN (municipal buildings), or REMODECE (private households). Other projects like ODYSEE-MURE or EMEEES have a broader view and include all end-use sectors and a couple of products and technologies.

ODYSSEE-MURE EU-27 is a project on the "Monitoring of Energy Demand Trends and Energy Efficiency in the EU" (www.odyssee-indicators.org; www.mure2.com). The project is co-ordinated by ADEME and carried out by energy efficiency agencies or their representatives in the 27 countries in Europe plus Norway and Croatia.
ODYSSEE relies on a comprehensive database that contains, on the one hand, detailed data on the energy consumption drivers in the main energy demand sectors (households, tertiary, industry, transport) by end-use and sub-sector and, on the other hand, energy efficiency and CO2 related indicators. The network of national teams updates the data regularly. The present data situation in the tertiary sector is worse than for the other energy demand sectors which means that there are a lot of data gaps in the ODYSSEE database with regard to energy consumption by end-uses and sub-sectors. Projects like EL-TERTIARY could contribute to an improvement of the database in future.
MURE provides information on energy efficiency policies and measures that have been carried out in the countries covered and enable the simulation and comparison at a national level of the potential impact of such measures. The MURE database is constructed in five sections which contain the energy efficiency measures, statistical data and a simulation tool for the four main energy demand sectors and general cross-cutting measures. The network of national teams guarantees the continuous updating of the database. As in the case of ODYSSEE, the EL-TERTIARY project could provide additional data for the MURE database and reduce the exisiting data gaps in the tertiary sector.

The EMEEES project deals with the "Evaluation and Monitoring for the EU Directive on Energy End-Use Efficiency and Energy Services” (www.evaluate-energy-savings.org). The project is carried out by a consortium of 21 European partners and coordinated by the Wuppertal Institute for Climate, Environment and Energy. The project aims at the design of top-down and bottom-up methods to evaluate the energy efficiency measures implemented to achieve the 9% energy savings target set out in the EU Directive (2006/32/EC) (ESD) on energy end-use efficiency and energy services.
The data demands with regard to energy consumption by sub-sectors, end-uses, technologies and products both for the bottom-up and top-down methods are high. Projects like EL-TERTIARY can contribute to a considerable improvement of the existing data with regard to the tertiary sector and its sub-sectors and end-uses.

The objective and the methodology of the REMODECE project on "Residential Monitoring to Decrease Energy Use and Carbon Emissions in Europe" (www.isr.uc.pt/~remodece/) is very similar to the EL-TERTIARY project. The overall objective of the project is to contribute to an increased understanding of the energy consumption in the EU-27 households for the different types of equipment, including the consumer behaviour and comfort levels, and to identify demand trends and potential electricity savings. The availability of high quality data is an essential condition for the definition of policy recommendations to influence both the energy efficiency of the equipment to be sold in the next decade, and to influence the user behaviour in the selection and operation of that equipment. For that reason, measurement and surveying campaigns in a large number of households have been carried out within the REMODECE project in all 12 EU-countries (plus Norway) involved in the project.

The EU-funded programme “Intelligent Energy Europe” co-finances European projects for the promotion of energy efficiency and the use of renewable energies. It covers implementation aspects such as capacity building, spreading of know-how, exchanges of experience, policy input, awareness raising, education and training. In this context EL-TERTIARY (Monitoring Electricity Consumption in the Tertiary Sector) is part of a set of projects which include metering and analysis of electricity consumption. Some of these projects in the area “Energy-efficient equipment & products” concentrate on technologies such as pumps, motor systems, boilers, or lighting, others on certain sectors, such as EL-TERTIARY, ENERinTOWN (municipal buildings), or REMODECE (private households).

EL-TERTIARY

The project EL-TERTIARY (Monitoring Electricity Consumption in the Tertiary Sector; www.eu.fhg.de/el-tertiary) started in 2006 and was completed in 2008. Its objective was to promote a more efficient use of electricity by providing detailed and reliable know-how on the electricity consumption structure and its use by purpose (lighting, office equipment, ventilation, air conditioning, etc.) in various types of tertiary buildings (subsectors), such as office buildings, schools, hotels, and supermarkets. A standardised and pragmatic methodology for electricity metering, survey and analysis was developed and tested in 123 selected typical buildings in 12 EU countries involved in the project. In a further step, from the methodological point of view the results of the case studies were evaluated comprehensively with respect to quality of metering and data collection as well as an analysis and statistical approximation of the building stock. Methods and concepts for identification and effective use of electricity-saving potentials were developed.

Review of existing studies

In a first step, the project collected existing data in European countries and analysed methodologies used for gathering these data. This overview showed a heterogeneous picture concerning the methodology used, the number of cases involved and the split level of end-uses. Some studies present results of individual building audits, others calculate extrapolations for a whole subsector on national level.

The review reflected the heterogeneous structure of the sector and its buildings and showed many different approaches to analyse the electricity consumption. Most reviewed studies are of a regional or national nature. The analysis of existing data reveals that obvious problems exist. They are related to the existing studies and the technological status of the region, country or sample treated. Creating the technical and methodological foundation for a comprehensive and unified European wide database was the target of EL TERTIARY.

Methodology

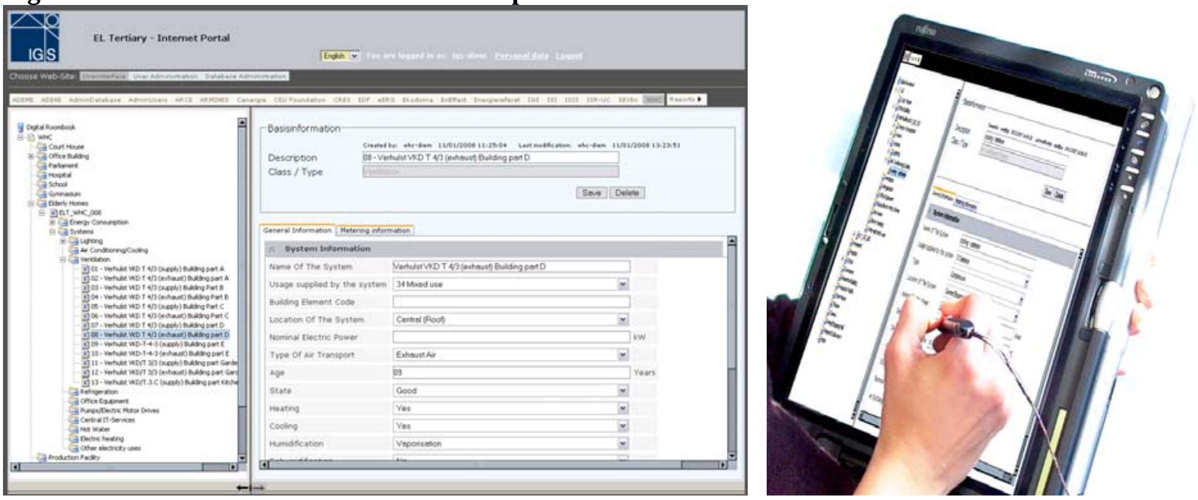
As a conclusion from the review the key features of the new methodology were
- Adaptability: The database can be improved continuously to be able to react on new technology or systems that have not been regarded in the first dataset.
- Flexibility: Since audits often cover only individual systems or parts of buildings due to time or budget limits the methodology has to work even when only selected parts of the building have been audited.
- Multi-user operability: The system needs to be used by multiple users in different countries
- Ergonomics: the system has to be as self-explaining and as easy to use as possible since it will be used by auditors with different backgrounds.

As a consequence the methodology avoided to use a model similar to the Swiss SIA or German EnEV that focus on the calculation of an overall energy balance. These models are often time consuming or intransparent regarding data, accuracy and evaluation strategy. On the other hand the methodology should gather more detailed data than e.g. the German energy certificates that only display a buildings specific annual energy consumption.

Instead EL TERTIARY uses a methodology that distinguishes between building audit (description of the building) and metering data. Buildings are described in a top down approach starting with general information on the whole building like owner, geometry, type, age etc. In addition all technical systems – lighting, ventilaton, AC/cooling, motor drives etc. can be described very detailed. To buildings and all systems the auditor can add metering results. The database allows to enter only absolute values (e.g. kWh) and no specific and thus calculated values (W/m²). For all metered values correlating absolute variables can be added (e.g. the supplied area, number of hotel beds). This is to avoid calculations by the auditor that can not be checked if not plausible.

Figure 1 shows an example of the input menu of the web-based tool used with a web browser on a tablet PC as used during an audit on a building site. The technical realisation was carried out by IGS in cooperation with ATD GmbH, Braunschweig, using a Microsoft SQL Database and ATD's VISIONTREE software .

Figure 1 EL TERTIARY database input menu

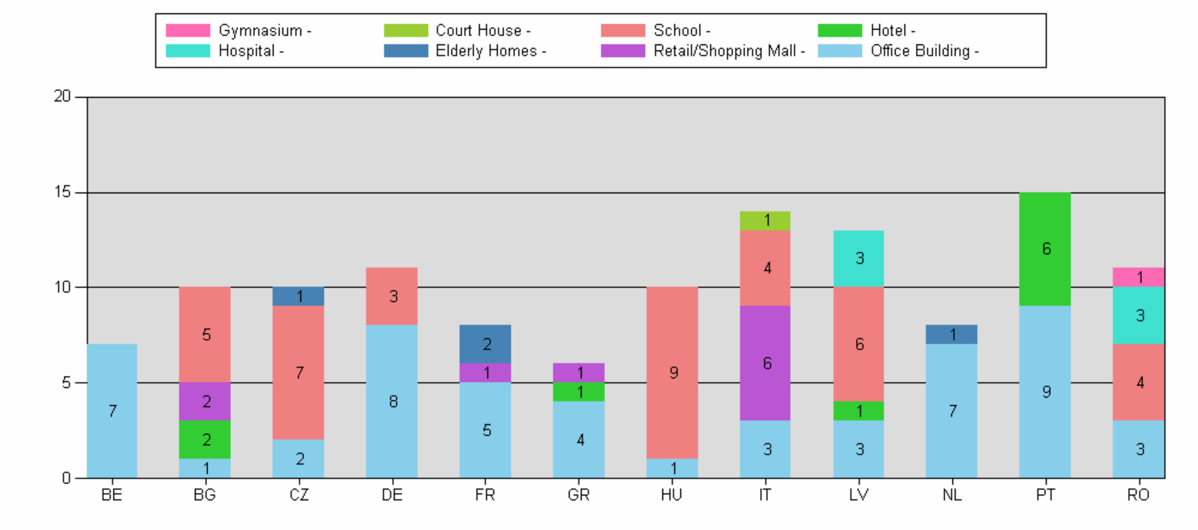


Data can be exported using flexible reporting systems for all variables in different data formats with options to select by various variables.

Results

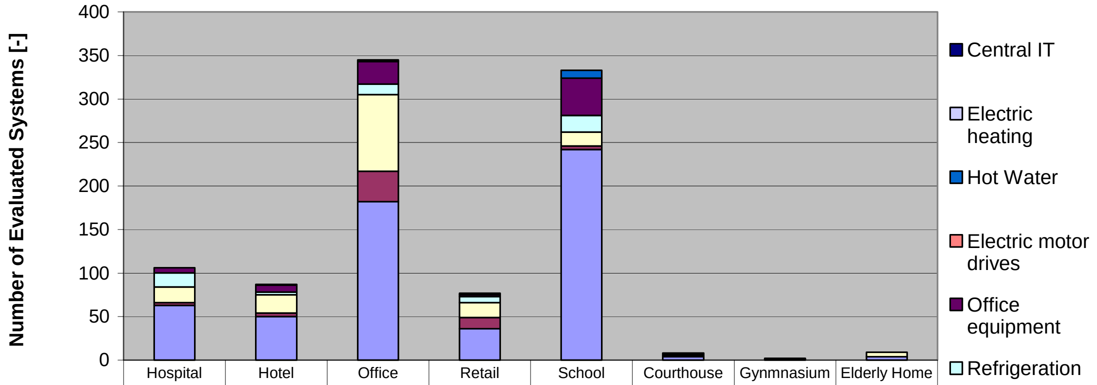
The project has been carried out between 2006 and 2008 in 12 EU-countries. Within the project the partners form all countries evaluated 123 buildings of 8 different types and 967 systems. Most of the buildings were office buildings (53) and schools (53). 59 building were located in atlantic central and 41 in continental climate. About half of the sample had been built after 1984. The sizes ranged from smaller than 2.000 m² (23) to more than 50.000 m² (3 with most buildings between 5.000 and 10.000 m², see Figure 2.

Figure 2 Types of Buildings in the EL TERTIARY Sample by Country



Lighting systems have been audited predominantly (582) followed by ventilation systems (165), office equipment (88) and Air conditioning / cooling (60), see Figure 3.

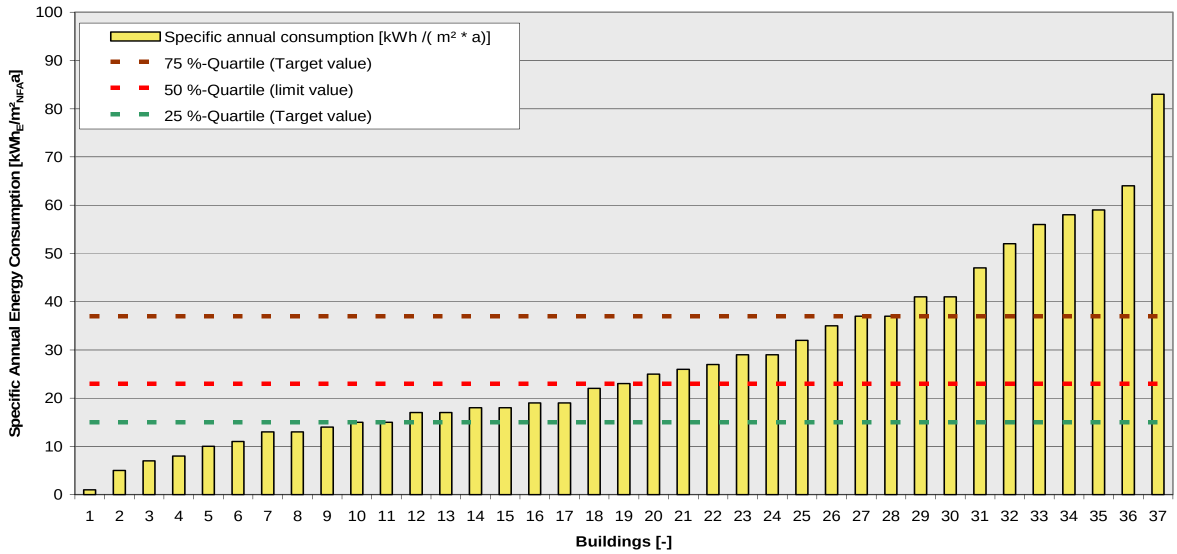
Figure 3 Evaluated Systems per Building Type



	Hospital	Hotel	Office	Retail	School	Courthouse	Gymnmasium	Elderly Home
Central IT	0	0	0	0	0	0	0	0
Electric heating	0	0	0	0	0	0	0	0
Hot Water	0	1	2	2	9	1	0	0
Electric motor drives	0	0	0	0	0	0	0	0
Office equipment	6	8	26	2	43	2	1	0
Refrigeration	16	3	12	7	19	0	0	0
Ventilation	18	21	88	17	16	0	0	5
Air Condition / Cooling	3	4	35	13	4	1	0	0
Lighting	63	50	182	36	242	4	1	4

The data allows several types of analysis regarding the energy efficiency of the building stock. At first the specific annual consumption of electrical energy can be calculated. The sample has been large enough to generate subsamples for different buildings types as shown for schools in Figure 4. The quartiles of the sample have been used to generate benchmarks for the different building types, see Table 1. The samples have not been large enough to make further distinctions for age, type or climate. Yet the benchmarks provide already plausible data especially for schools and office buildings. In addition the different quartiles indicate the spread within the sample and overall saving potentials for the building types.

Figure 4 Specific Annual Energy Consumption of School Buildings
(kWh_E = final energy [1]; NFA = net floor area)



[1] The paper gives final (site) energy instead of primary energy since the factors for conversion were not known in all cases. The factor to convert electrical site energy into primary energy for Germany is 3,0 (DIN V 4701-10:A1 2006-12)

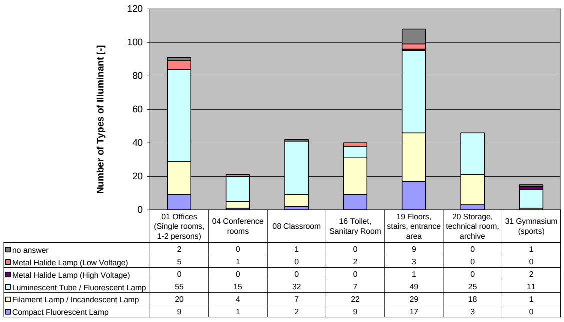
Table 1 Benchmarks for the Specific Annual Consumption of Electrical Energy for Different Building Types

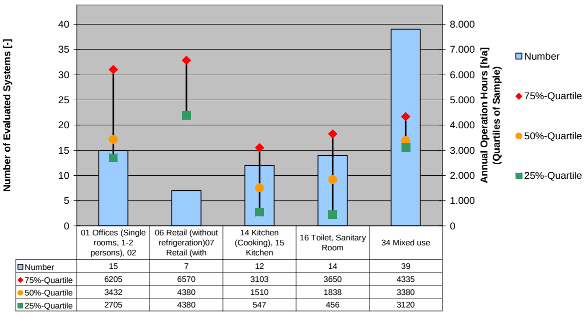
	Number of buildings [1] [-]	25% Quartile [2] $[kWh_E/m^2_{NFA}a)]$	50% Quartile $[kWh_E/m^2_{NFA}a)]$	75% Quartile $[kWh_E/m^2_{NFA}a)]$
Office	51	55	84	156
School	26	15	23	37
Retail	10	264	503	643
Hotel	10	61	70	108
Hospital	5	29	35	44
Elderly Homes	4	67	108	141
Gymnasium	1	15	15	15
Courthouse	1	66	66	66

Benchmarks for the overall energy consumption of buildings are rather easy to collect. They can be well used for statistical extrapolation or to set priorities for further analysis in a large group of building. Yet it is difficult to deduct specific saving potentials since the building stock is very heterogeneous and the data does not indicate specific savings. Therefore the methodology audited individual technical systems. The web-tool offered a conventional data input for an energy balance in which auditors could enter the total annual energy consumption for different types of systems e.g. the total consumption of the lighting system or the office equipment in one building. In the data analysis the consumption of all individually metered systems was subtracted from the buildings overall consumption and described as "consumption of other systems" to avoid "adjustments" to the total. The methodology proved the fear stated above: the analysis of the subsystems is very intransparent and selective. The auditors usually looked at those systems they were able to analyse and left out other systems. Furthermore it was not possible for the analysis group to check the way consumptions have been metered which is quiet difficult e.g. the consumption of all motor drives within a building.

Therefore it was very helpful for the determination of saving potentials to analyse the auditing data of the systems evaluation. The systems have been described mainly by visual assessments and analysis of the building documentation. In addition meterings have been carried out but were not mandatory. For lighting systems (meaning: the lighting system in one room) the database asks for size and supplied usage, type of lamp, illuminants, ballast and motion sensors, the height of lamps, use of daylight etc. These aspects can be used to determine the energy efficiency of a system fairly well. At the same time the audit is very easy to do. Figure 5 shows selected results for lighting and ventilation systems.

Figure 5Types of Illuminants per Room Type; Annual Operation Hours of Ventilation Systems per Supplied Room Type





The target of EL TERIARY was to create a methodology for comprehensive and detailed supervision of the European building stock. The application of the web-based tool proved to work with good results. The sample of 123 building was obviously not large enough to carry out a representative analysis of the building stock but enabled the authors to test the potential for data gathering and detailed analysis.

After the successful initial application a version 2.0 of the tool will have additional features. In addition to systems it will also be possible to describe facades and rooms to gather all building and operation related information relevant for energy efficiency. To evaluate energy savings it will be possible to enter data on implemented measures to improve energy efficiency and continuous annual data on energy consumption. With this data it will be possible to determine the effect of political strategies and technical or service measures to improve the energy efficiency and to continuously supervise the development of the energy consumption of the building stock on a large scale.

The method and web-based tool will be applied in further building audits to support conclusions for policy measures on EU and national level and further activities on a large scale. The authors will use the tool to create a national data base on the German building stock within the R&D program *EnBop – Energetische Betriebsoptimierung* (“Optimizing energy efficiency in operation”) funded by the German Ministry of Economics and Technology.
It is intended to integrate the database in European and international activities that are currently in preparation. Results can be used for energy management and benchmarking purposes by facility managers, consultants or ESCOs. Conclusions for support of the EU and national policies will be drawn, e.g. use of monitoring methods in the certification process of buildings, recommendations for standards for equipment, information campaigns etc. In addition, using a model developed in the MURE project, the effect of some important policy measures will be calculated for the years 2010 and 2015. The findings of this analysis, together with the data collected in the EL-TERTIARY project, will permit to calculate and set up the electricity consumption structure by subsector and final end uses for the forecasting years and to evaluate measures for optimized building operation.

Auditors’ view of electricity-saving potentials in the individual case studies

After the audits the results were presented to the facility owners or managers together with recommendations of energy efficiency measures. These recommendations were collected and evaluated. Together with specific electricity consumption data and the consumption structure per end-use the efficiency gaps are an important basis for policy conclusions. The following paragraphs give some examples.

Almost all auditors found potentials in the lighting area. Most frequently a replacement of lamps was recommended: incandescent and halogen lamps by CFLs and T12 or T8 by T5 lamps. Motion control systems should be installed, at least in rooms not very often used (sanitary rooms, floors, stair cases, garage). In other cases daylight sensors are considered the best solution. In some cases too much power per m2 was installed, lamps were on at night or the use of daylight was unnecessarily limited (dark wall painting, window shading, windows too small). Part of the lamps or covers were dirty and therefore lighting not efficient.

The second main area of potentials was office equipment. The large majority of recommendations refer to user behaviour: the computer equipment should be switched off completely when leaving the office after work, which means that this measure is by far not common in offices. The same was said for TV sets in hotel rooms. Another recommendation was to replace CRT by LCD monitors and in general to replace old equipment as soon as possible by the most energy-efficient one.

If air-conditioning/cooling is installed in a building almost in all cases energy-saving potentials were found. There was a variety of measures: external protection of rooms from overheating, increase of indoor air temperatures in summer, lower fan speed, better control of equipment (frequency converter), switch off during night, replacement of old equipment, insulation of pipes, heat recovery, and behavioural measures (closing windows and doors). For ventilation systems mainly heat recovery, replacement of old and inefficient equipment, switching off when rooms are not used, and automatic control were mentioned.

In office buildings and schools refrigeration is mainly used in small units. In many cases these refrigerators are old and should be replaced by at least A class equipment. Some are also too large or simply unnecessary. Another recommendation was to inform personnel about energy saving possibilities (use of equipment, maintenance).

In case of electric motor drives mainly heat circulation pumps with low energy-efficiency were found. Some are working all year 24 hours per day and could at least be turned off in summer or improved by the installation of automatic control.

Electric hot water production is used in part of the buildings. The main suggestions for improvement were to replace old equipment, to install or repair boilers or pipe insulation, to install timers or thermostats, and to use gas or solar energy instead.

Electricity saving potentials in the area of electric room heating was – with one exception – only addressed when additional small heaters are used. Generally it was recommended to improve or extend the main heating system so that electric heaters can be removed.

Various other electricity uses and saving measures were mentioned, e.g. switching off vending machines, replace old kitchen or laundry equipment or use it more efficiently, disconnect the power factor compensation during night, check the efficiency and the use of small appliances such as water heaters and coffee machines.

Generally, many auditors recommended information and motivation of employees about energy saving possibilities. The other measure very often mentioned is the installation of electricity meters to enable control of consumption and improved energy management.

The measures that have been described include modernization and maintenance as well as installation of building control systems and the enhancement of building operations. Many have a significant impact on the energy efficiency although they are quiet simple for an engineering point of view. Nevertheless they have to be part of comprehensive, cost effective and persistent improvements.

Outlook

All case studies in the EL-TERTIARY project are completed. The analysis will be continued for all relevant electricity consuming systems. Up to now considerable energy-saving potentials were found. In the last phase of the project a survey of building or company managers will be evaluated and the results will be combined with the technical findings of the individual cases. In addition, surveys with hotel managers and office employees have been carried out. The hotel surveys aimed at gathering energy-relevant data by interviews instead of audits; the evaluation is still ongoing. Interviews with office employees focus on comfort aspects. They indicate for example, that in many office rooms lighting can be reduced without loss of comfort or even with a gain in comfort, because employees work a large part of time at computers today, but lighting was not changed in the meantime. Common conclusions from the experiences of the case studies will also be available with respect to suitability of methodologies, quality of findings, applicability to meet the demand for these data, existing electricity-saving potentials, etc. They will provide starting points for the implementation of existing Directives and other EU and national programmes for promoting energy efficiency improvement. In addition, using a model developed in the MURE project, the effect of some important policy measures will be calculated for the years 2010 and 2015. The findings of this analysis, together with the data collected in the EL-TERTIARY project, will permit to calculate and set up the electricity consumption structure by subsector and final end uses for the forecasting years. Technical results will also be compared to existing studies (see Figure 2 and 3) and to findings of other IEE projects, for example ENERinTOWN and EL-EFF Region.

As the main objective of the project is to improve the information on electricity consumption and saving potentials in order to use this information for decision making and promoting activities, the dissemination of results is a substantial part of the project. A range of communication channels will be used for dissemination: Internet, leaflets and guidelines for target groups, workshops, e-mails to key persons, publication of the project report and of journal articles. Among other measures guidelines for energy managers in buildings and companies will be developed. They cover a concise methodology for electricity management, i.e. disaggregation of electricity consumption, measurement where necessary, recommendations for the decision-making process, highly profitable investments and changes in user behaviour.

References

A. Johnston, J. Hutchison, A. Smith, 2000. Significant environmental impact evaluation: a proposed methodology. Eco-Management and Auditing 7(4): 186-195.

Adnot, J. et al.: Energy Efficiency and Certification of Central Air Conditioners (EECCAC). Final Report, Vol. 2. Paris: Armines 2003.

Bertoli, P. & Atanasiu, B.: Electricity Consumption and Efficiency Trends in the Enlarged European Union – Status Report 2006. European Commission: DG Joint Research Centre 2007.

ENERinTOWN: Monitoring and control of energy consumption in municipal public buildings over the Internet. www.enerintown.org/home

EL-EFF Region: Boosting efficiency in the electricity use in 8 European regions. www.efficient-electricity.info

European Commission: European Energy and Transport. Trends to 2030 – update 2005. Luxemburg 2006.

Gruber, E.; Sofronis, I.; Dusée, R.; Plesser, S.: Detailed Analysis of Electricity Consumption in Tertiary Buildings as a Basis for Energy Efficiency Policies. ECEEE Conference, La Colle Sur Loup, June 2007.

Ostertag, K.: No-regret potentials in energy conservation – An analysis of their relevance, size and determinants. Technology, Innovation and Policy. Heidelberg: Physica 2003.

Sorrell, S., O'Malley, E., Schleich, J., Scott, S.: The Economics of Energy Efficiency Barriers to Cost-Effective Investment. Edward Elgar, Cheltenham 2004.

Weber, L.: Energy-relevant decisions in organisations within office buildings. In: Proceedings of the 2000 ACEEE Summer Study, 8.421-33. Washington, D.C.: American Council for an Energy-Efficient Economy 2000.

DIN V 4701-10:A1 2006-12: Energetische Bewertung heiz- und raumlufttechnischer Anlagen, Beuth Verlag, 2006