IEA ECBCS Annex 36:

Retrofitting of Educational Buildings – REDUCE

Energy Concept Adviser for Technical Retrofit Measures

Energy Audit Procedures

DECEMBER 2003 *EDITOR: JAN DE BOER*

INTERNATIONAL ENERGY AGENCY
Energy Conservation in
Building & Community
Systems Programme

RESUMÈ

Energy audits are the key procedure to identifying energy saving potentials in buildings to be retrofited. They can underline the necessity to start the retrofit process and can give indications which measures to focus on.
Recorded energy performance values can then serve as reference to which retrofit measures the savings can be related to.
Moreover, audits can be used during commissioning and after completion of the retrofit process to validate the implemented measures and to track building performance over the whole building life cycle.
This document covers a wide band of practical and useful methods, from monitoring the energy behaviour of whole schools or campus sites, down to the behaviour of single systems or just single components.

Preface

This working document is part of the work done within the project of the International Energy Agency (IEA): Energy Conservation in Buildings and Community Systems Programme (ECBCS), “Annex 36: Retrofitting of Educational Buildings – REDUCE. Energy Concept Adviser for Technical Retrofit Measures.”

International Energy Agency (IEA)

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an international energy programme. A basic aim of the IEA is to foster co-operation among the twenty-four IEA participating countries and to increase energy security through energy conservation, development of alternative energy sources and energy research, development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems (ECBCS)

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings and community systems, the IEA is sponsoring various exercises to predict more accurately the energy use of buildings, including comparison of existing computer programmes, building monitoring, comparison of calculation methods, energy management systems as well as air quality, studies of occupancy and in depth evaluation of impact on energy consumption of the building enclosure.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial. To date the following projects have been initiated by the Executive Committee on energy conservation in buildings and community systems (completed projects are identified by (*)):

Annex 1: Load Energy Determination of Buildings (*)
Annex 2: Ekistics and Advanced Community Energy Systems (*)
Annex 3: Energy Conservation in Residential Buildings (*)
Annex 4: Glasgow Commercial Building Monitoring (*)
Annex 5: Air Infiltration and Ventilation Centre
Annex 6: Energy Systems and Design of Communities (*)
Annex 7: Local Government Energy Planning (*)
Annex 8: Inhabitants Behaviour with Regard to Ventilation (*)
Annex 9: Minimum Ventilation Rates (*)
Annex 10: Building HVAC System Simulation (*)
Annex 11: Energy Auditing (*)
Annex 12: Windows and Fenestration (*)
Annex 13: Energy Management in Hospitals (*)
Annex 14: Condensation and Energy (*)
Annex 15: Energy Efficiency in Schools (*)
Annex 16: BEMS 1 - User Interfaces and System Integration (*)
Annex 17: BEMS 2 – Evaluation and Emulation Techniques (*)
Annex 18: Demand Controlled Ventilation Systems (*)
Annex 19: Low Slope Roof Systems (*)
Annex 20: Air Flow Patterns within Buildings (*)
Annex 21: Thermal Modelling (*)
Annex 22: Energy Efficient Communities (*)
Annex 23: Multi-zone Air Flow Modelling (COMIS) (*)
Annex 24: Heat, Air and Moisture Transfer in Envelopes (*)
Annex 25: Real time HVAC simulation (*)
Annex 26: Energy Efficient Ventilation of Large Enclosures (*)
Annex 27: Evaluation and Demonstration of Domestic Ventilation Systems (*)
Annex 28: Low Energy Cooling Systems (*)
Annex 29: Daylight in Buildings (*)
Annex 30: Bringing Simulation to Application (*)
Annex 31: Energy related Environmental Impact of Buildings (*)
Annex 32: Integral Building Envelope Performance Assessment (*)
Annex 33: Advanced Local Energy Planning (*)
Annex 34: Computer-aided Evaluation of HVAC System Performance (*)
Annex 35: Design of Energy Efficient Hybrid Ventilation (HYBVENT)
Annex 36: Retrofitting of Educational Buildings – REDUCE

Annex 37: Low Exergy Systems for Heating and Cooling of Buildings

Annex 38: Solar Sustainable Housing

Annex 39: High Performance Insulation Systems

Annex 40: Building Commissioning to Improve Energy Performance

Annex 36: Retrofitting of Educational Buildings - REDUCE

Educational buildings such as kindergartens, schools, training centres and universities display many similar design, operation and maintenance features in many of the IEA countries. Because of the level of similarity that exists within this building sector, experiences gained in developing different approaches to combat similar problems, especially during retrofitting, can easily be transferred to other countries. The two main similarities amongst these building types are the high energy consumptions and the necessity to retrofit many buildings within this sector. However, studies have shown that during retrofit energy saving measures are only rarely applied, because of a lack of knowledge by the decision makers regarding the investments and the efficiency of potential energy saving measures. Due to the lack of information, in many cases decisions are made that do not accurately take into account energy saving aspects. There are no “rules of thumb“ to enable a quick and easy estimation of the levels of required investment, before an analysis of the building structure in detail. Therefore the development of an energy concept adviser for economical retrofit measures would be useful during the planning and realization phase, on the one hand to help the investor to find the most energetically and economically efficient energy saving measures and also to avoid exaggerated expectations. The adviser should be applicable during the entire retrofitting phase to ensure that both the calculated energy savings and the economic success will be achieved after retrofitting. This annex therefore aims to develop such a tool. The energy audit procedures report is part of this.
The Fraunhofer Institute of Buildings Physics in Germany is, on behalf of the Forschungszentrum Juelich, coordinator of the Annex 36. The ten countries participating in this project are: Denmark, Finland, France, Germany, Greece, Italy, Norway, Poland, United Kingdom and the United States of America.

This document has been edited by Jan de Boer, Germany. The chapters are written by individual authors and participants of the Annex 36. A special thanks to **XXX** for reviewing the document.

Stuttgart December 6, 2003

Hans Erhorn
(Operating Agent of Annex 36)

Content

1. Introduction

Energy audits are the key procedure to thoroughly identify the energy saving potential of buildings to be retrofitted. They can numerically prioritise the need to start the retrofit process and can give indications about which measures to focus on. Recorded energy performance values can then serve as reference for the savings of the planned retrofit measures. Moreover, audits can be used during commissioning and after completion of the retrofit process to validate the implemented measures and to track building performance over the whole building life cycle.

The document targets the group of decision makers and their technical staff in municipalities. It shall trigger awareness for existing energy audit procedures by informing on their possibilities and by providing indications of potentials on employing them. It nevertheless does not claim to provide a complete overview of all methods available and applied in energy audits. These may vary country and problem dependent. The document tries to cover the range of methods practically required from monitoring the energetic behaviour of whole school or campus units down to the “low-level” behaviour of single systems and/or and components. Contributions from the different participating countries describe methods:

- to analyse the building envelope as an overall system down to air leackage tests and component analysis using thermography. Longterm and short-term based approaches are presented,

- to analyse, commission and surveil HVAC system behaviour, on short-term and long-term basis,

- to analyse lighting electricity consumptions and identify appropriate potential savings,

- to perform remote energy survellance for larger numbers of buildings, belonging either to companies or municipalities, allowing for instance to obtain almost real time overview of consumptions and to compare the behaviour of similar units; and

- to labell monitored consumption according to defined ratings. These procedures are so far country specific, but nevertheless might be applicable to other projects as performance indicators.

Most methods presented stick to a fixed format. The methods are introduced by briefly specifying the general monitoring approach. A more detailed description provides closer insights, followed up by an indication of the financial effort to perform the audit. References are given for further reading.

2. Overall Building Performance Analysis

2.1 Short Term Monitoring procedures

2.1.1 Building Envelope (by Jan de Boer)

2.1.1.1 Purpose and Monitoring approach

Detailed monitoring campaigns normally last two years or longer. They require a large number of sensors. The price paid for the possible detailed parameter and system analysis and accurate information on user behaviour are high installation, maintenance and evaluation costs. Projects with this high level of detail can only usually be performed by nationally funded institutes. Mainly the cost and linked to this the time needed are the obstacles to not making energy monitoring for practioners as common as for instance blower door tests. To overcome these obstactles, many diverse approaches have tried to confine the time for monitoring to a short term period like a week or only a couple of days, while still being able to obtain substantial information on the thermal and energetic building characteristics.

2.1.1.2 Description

These short-term methods normally do not require more than a portable data aquisition system (i.e. a laptop computer) and of the order of up to 25 sensors. Figure 2.1.1 gives a small overview of selected methods. Some of them only deliver static builiding characteristics, others are able to go much more into detail by estimating and identifying the different energy flows using a dynamic building model, which then can be directly taken for prediction (for instance for the whole heating period). As the level of accuracy, also the testing protocols are diverse. The most simple ones rely only on energy bill readings, other methods imprint special thermal conditions on the buildings. Using electric heaters the thermal zone of interest is for instance put into a *constant heat stage*. From this period the steady state heat loss coefficient can be deduced. To obtain information on the dynamic building characteristics a so called *cool down test* can be used. The heat generator and all internal heat inputs are set to zero after a constant heat phase, so that the thermal effects of the building mass can be determined. Solar gain behaviour is estimated at daytime intervals. Figure 2.1.2 illustrates an exemplary test protocol.

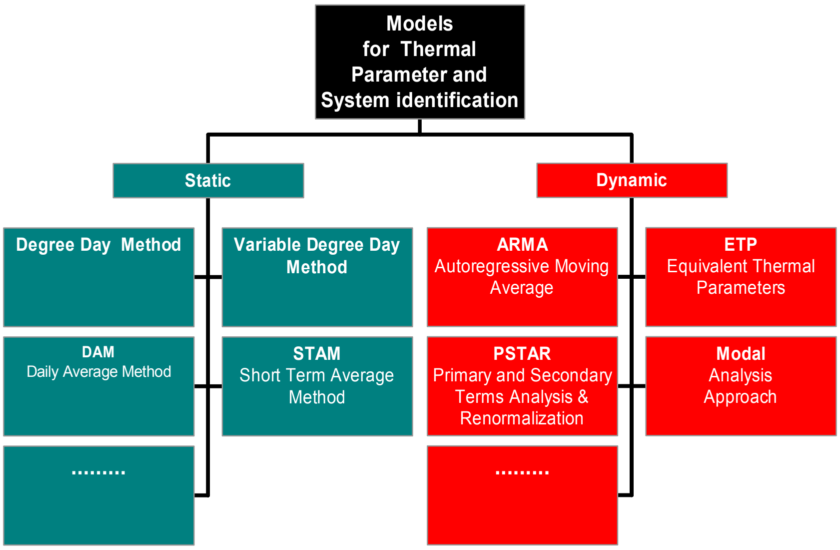

Figure 2.1.1: Selection of a number of different methods used for energy prediction of dwellings and non-residential buildings on short term basis [2.1.1].

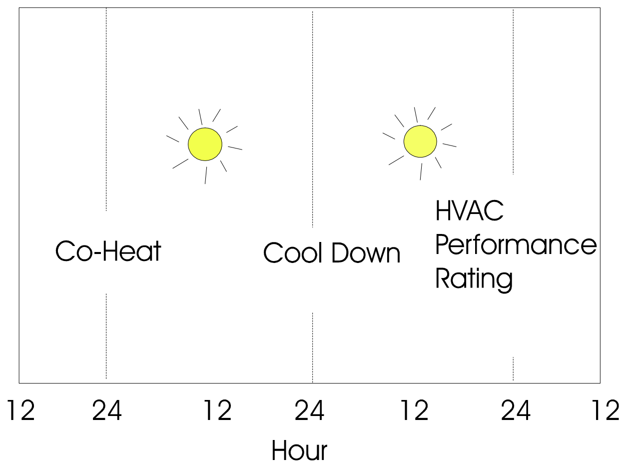

Figure 2.1.2: Example of an intrusive test protocol used for the estimation of steady state as well as dynamic building characteristics in a three day monitoring period.

The thermal building model can be obtained using a variety of methods, like the use of equivalent thermal networks depicted in Figure 2.1.3, parameter estimation of differential equations describing the energy balance as shown in Figure 2.1.4 [2.1.3] or frequency domain analysis for the calibration of an audit model as depicted in Figure 2.1.4 [2.1.2].

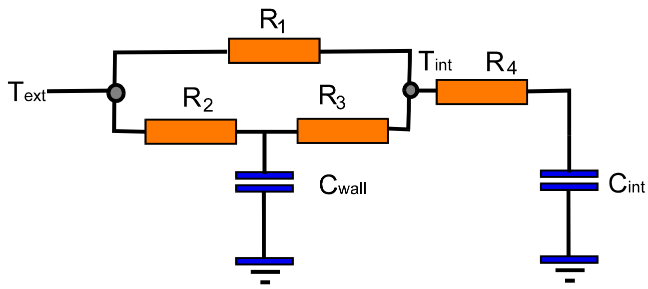

Figure 2.1.3: Example of a simple thermal network. R_1 can be understood as the thermal resistance of a window. R_2 and R_3 together with C_{wall} are roughly representing the behaviour of a wall.The branch R_4 and C_{int} describes the thermal coupling with internal masses. From short term monitoring these simple building parameters can be estimated. Parametrized thermal networks can then be taken as simple dynamic building models, allowing for long-term (annual) heating demand.

$$\sum_{k=0}^{N_{int}} a_{int}(k)\, T_{int}(n-k) - \sum_{k=0}^{N_{ext}} a_{ext}(k)\, T_{ext}(n-k) - \sum_{k=0}^{N_{aux}} a_{aux}(k)\, Q_{aux}(n-k) - \sum_{k=0}^{N_{sol}} a_{sol}(k)\, Q_{sol}(n-k) = 0$$

Figure 2.1.4: Basic discrete differential equation used for parameter estimation with the ARMA (Auto Regressive Moving Average) method (n: discrete time step, k: index, $T_{int}[n]$: internal temperature at time step n; $T_{ext}[n]$: external temperature at time step n; $Q_{aux}[n]$: internal heat gains at time step n, including electric heater; $Q_{sol}[n]$: solar heat gains at time step n, N_{int}, N_{ext}, N_{aux}, $N_{sol:}$: number of parameters describing dynamic behavior of corresponding variables, a_{int},a_{ext}, a_{aux}, $a_{sol:}$ corresponding parameters to be estimated).

The overall accuracy of the methods described can be considered good. Compared to simulation methods the models obtained– depending on the methodology chosen - are often closer to reality since they are directly developed from reality, i.e. the existing building.

2.1.1.3 Costs

Depending on the method chosen, the required monitoring equipement adds up to a laptop computer, a small data-logging system, up to 25 sensors (temperature, radiation, etc), an electric heater system to allow thermally independent control of the zone. The more complex short-term campaigns can be performed in a week by one person.

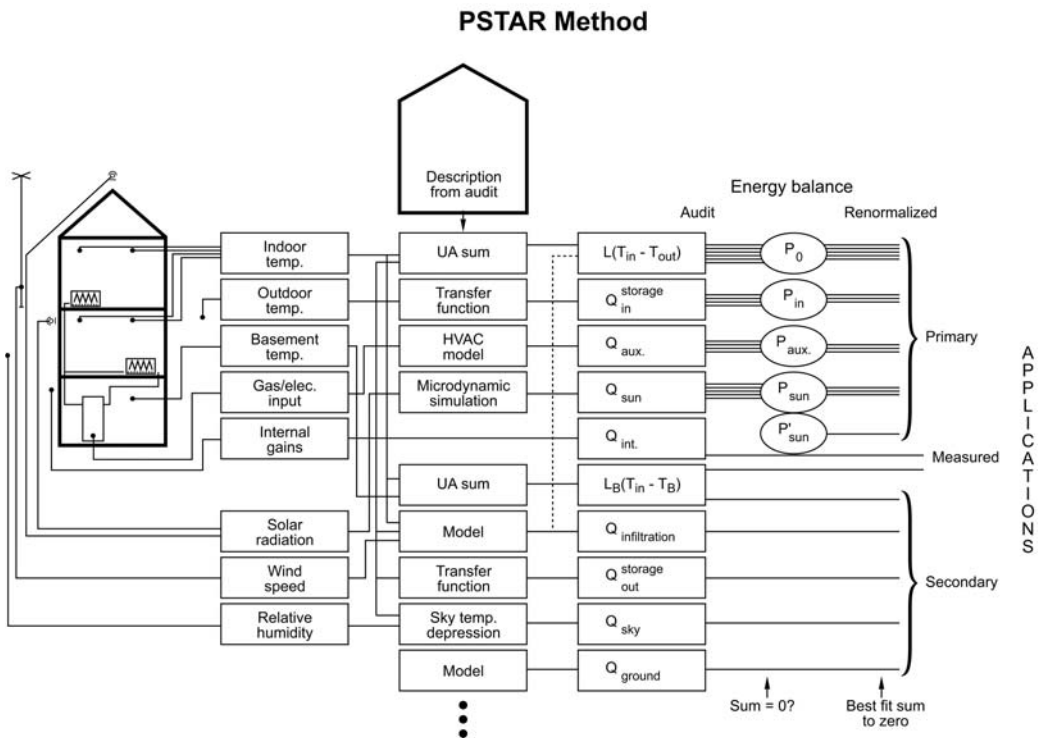

Figure 2.1.5: *Principle of calibrating the main heat fluxes in an audit model (Grey-Box-Method) according to [2.1.2].*

2.1.1.4 References

[2.1.1] De Boer, J.; Erhorn H.: In situ Kurzzeitmessverfahren, Qualitätssicherung wärmetechnischer Massnahmen an Gebäuden, Internal Report Fraunhofer-Institute of Building Physics, Stuttgart, Germany, 2001.

[2.1.2] Subbarao, K.: PSTAR - Primary and Secondary Terms Analysis and Renormalization: A Unified Approach to Building Energy Simulations and Short-Term Monitoring. TR-254-3175, Solar Energy Research Institute, Golden, CO (1988).

[2.1.3] Klein, C.: Kurzzeitmeßverfahren auf Basis thermischer Analogiemodelle zur Bestimmung thermischer Gebäudekenngrößen mittels einfacher elektrischer Netzwerke. Diplomarbeit, Fraunhofer-Institut für Bauphysik, Stuttgart.

2.1.2 HVAC Systems (by Fritz Schmidt)

2.1.2.1. Contribution of HVAC Systems for the rational use of energy in buildings

We have seen in section 2.1.1 how the building envelope influences the *demands* for heating and cooling energy and how we can determine these influences by monitoring. If we are interested not only in demands but also in energy consumption we have to consider the HVAC system of the building and its operation too.

The actual usage of the building and the meteorological conditions under which it is operated determine how much heating and cooling energy will be *needed*. The *primary energy necessary* for providing the required heating and cooling energy is determined through the HVAC system and the way it is operated. Therefore we have four possibilities to influence primary energy consumption

1. Influence the user awareness concerning energy consumption

2. Adapt system operation to the actual user requirements

3. Provide an HVAC system which supplies the required heating and cooling energy with a minimum primary energy effort

4. Reduce the transmission losses and ventilation heat losses of the envelope

To quantify the consequences of possible actions a new approach to evaluate buildings and their HVAC-systems was developed in. It follows the development of requirements from the building with its usage, internal loads and the climate (the ideal minimal energy demand called Q_0), through the room system (heat, cooling, conditioned air), distribution and the heating and cooling generation systems. Since none of these systems – room system, distribution and generation systems –work without any losses, some additional energy input is necessary at each stage (characterised by efficiency numbers e). This in connection with the typical reference load requirement for the building and its use gives the total load requirement to be supplied by the generating system ($Q = Q_0 * e_1 * e_2 * e_3 = Q_0 * e$ see also figure 2.1.6).

Heating systems are evaluated by comparing benefit and expenditure as it is done in other technical systems. The benefit of a heating system is to maintain comfortable thermal conditions in the rooms for the occupants. The requirements of the occupants for their thermal environment are independent from the heating system. Usually they specify their demands with nominal temperatures for the room air and for the inside surface temperatures of the walls. These temperatures depend on activity and clothing. A further task of a heating system is to warm up the incoming air from outside, which is necessary because of comfort, health, hygiene and building physics. The delivery of the benefit by the heating system is called „room system". The planning tasks for a good room system consist of suitable selection, dimensioning and arrangement of the room heating and ventilating systems.

It is possible to determine the heat load which must be transfered to a room in order to supply exactly the existing demand, this is the heating load. The time dependent integral over the heating loads – the ideal minimal energy demand Q_0 – is an energetic value to compare subsequent processes which satisfy the demands (room system, heat distribution, heat generation). DIN EN 832 [2.1.4], DIN 4108-6 [2.1.5] or VDI 2067-11 [2.1.6] contain the description for calculating the building-specific load requirements of heated and air-conditioned buildings.

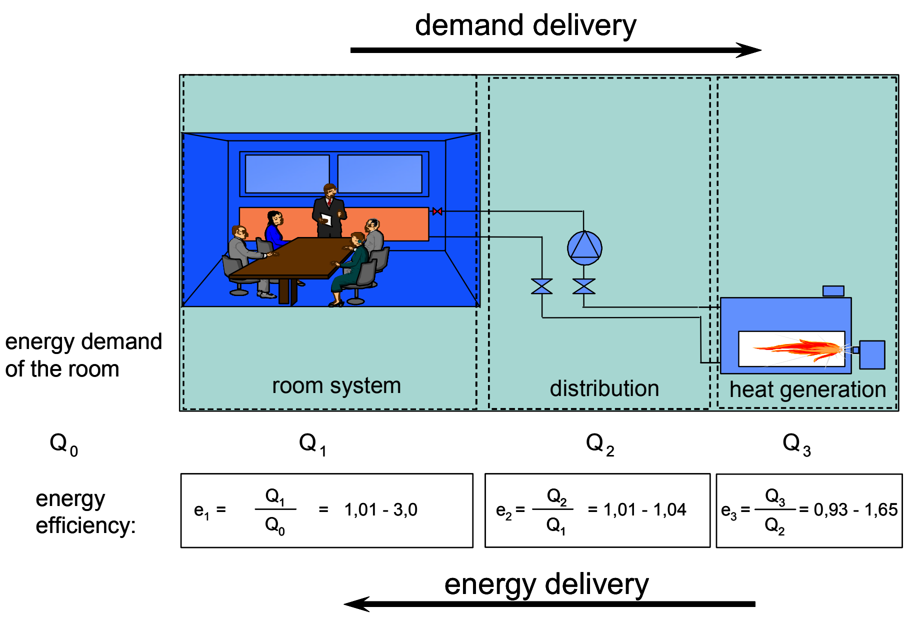

Figure 2.1.6: Demand and energy delivery.

Fig.: 2.1.6 gives the direction of the demand development in a building. Starting from the building itself, its planned usage and the climatic influences we distinguish three levels:

- the first level is the room system,
- the second level is heat distribution and
- the third level is the heat generation system.

Technical systems cannot be implemented in a perfect way, therefore additional energy is necessary to fulfil the demand (The energy Q_1 is required for the room system to satisfy the ideal minimised energy demand Q_0). An energy efficiency factor e_i can be defined relating Q_i with Q_{i-1} ($e_i = Q_i / Q_{i-1}$). This will be used as an energetic evaluation value to evaluate the alternative technical solutions. Therefore the minimal energy demand Q_0 multiplied with the energy efficiency factor e_i of each subsection gives the total yearly primary energy demand that it is needed by the heat generation system. DIN 4701-10 [2.1.7] provides methods to calculate primary energy efficiency factors for different heating-, ventilation- and domestic hot water systems. In Fig. 1 typical ranges of energy efficiency numbers of modern heating systems are given. The lower values of e_3 can be reached if heat recovery is applied. The high values of e_1 are due to inadequate operation and usage. Table 2.1.1 gives typical energy efficiency numbers of historical heating systems.

Period	Default systems: Description	Energy efficiency factor e^*_{system}
Before 1960	Steam heating	2,0.....1,7
1960 - 1970	Hot water heating, 95°C, gravitational force	1,8.....1,6
1970 – 1980	Pump hot water heating, 90/70°C	1,7.....1,4
1980 - 1990	Pump hot water heating, 80/60°C	1,6.....1,4
1990 - 2000	Pump hot water heating, 75/65°C and lower	1,5.....1,3

Table 2.1.1: Energy efficiency of default system.

In most operating systems energy consumption is higher due to inefficient operation of the heating systems. Therefor the adaption of an existing system to the actual demand is one of the first benefits from an audit. If we correlate this to the four possibilities to influence primary energy consumption we can state

1. Indoor air quality can increase Q_0

2. Adaptation of system operation to the actual user requirements reduces e

3. Provision of an HVAC system which supplies the required heating and cooling energy with a minimum primary energy effort reduces e_3

4. Reduction of the transmission losses and ventilation heat losses of the envelope reduces Q_0

2.1.2.2 Measurement of system parameters

To improve system behaviour requires monitoring of the system and measurement of system parameters. Basic control and management can be achieved by simple tools and measurements. Data to be measured include consumption data as well as internal temperatures (measured by thermostats in the most simple way) and occupancy. In connection with simple statistical tools such data can be evaluated and used for basic energy management, which is sufficient for most schools and gives a good impression of the energetic behaviour of more sophisticated educational buildings as we may find it at universities. Experience shows that the effect of such measurements on energy savings can be increased if their results are made accessible to the users of a building in an understandable form.

If the HVAC system includes air handling units a more sophisticated approach to HVAC systems performance might be desirable. Such an approach was undertaken in the frame of ANNEX 34 "Computer-aided evaluation of HVAC System performance" [2.1.8]. The following text reports some of the results given there.

The goal of Annex 34 was to reduce energy and environmental costs by ensuring that the design (or retrofit) intent is achieved in the operation of buildings. As we did, they assumed that there are two basic reasons why the performance of a building is often unsatisfactory: poor design (influence measures 3 and 4 in 2.1.2.1) and inefficient operation (influence measures 1 and 2 in 2.1.2.1). The second cause of unsatisfactory performance is often neglected especially in sophisticated buildings, although in practice there is considerable potential for improvement. Improvements in design generally only affect new buildings (or possibly existing buildings through major refurbishment's), whereas improved operation can benefit the whole of the building stock to which the technology in question can be applied. In addition it is stressed in Annex 34 that costs associated with the operation of HVAC plants in buildings are not limited to the fuel and electricity consumed by the plant. Unnecessary wear, leading to premature component failure, increases costs through the embodied energy and material resources in the replacement of equipment and the indirect costs associated with the repair process (e.g. transport). Leakage of refrigerant or inefficient combustion gives rise to global and local pollution problems. All of which suggests the need for other indices, besides direct fuel and electricity costs, when assessing the performance of buildings. To handle such data more elaborate systems are necessary. They are known as building energy management systems (BEMS) and fault detection and diagnosis (FDD) systems.

Generally, there is a trade off between the number of sensors employed and the performance of an FDD method. In Annex 34 refrigerant leakage for a rooftop air conditioner having a fixed expansion device is given as an example. Table 2 shows how temperature measurements change with refrigerant leakage. A system with low refrigerant charge has a lower evaporating and condensing temperature, higher suction superheat and discharge temperature, lower air temperature differences for both the evaporator and condenser, and lower sub-cooling leaving the condenser. Although all of there measurements are sensitive to refrigerant leakage for the target system, not all of them are necessary for detecting and diagnosing this fault.

Fault	Evap. Temp. (T_{evap})	Suction Superheat (T_{sh})	Cond. Temp. (T_{cond})	Cond. Subcool (T_{sc})	Comp. Hot Gas Temp. (T_{hg})	Cond. Air Temp. Diff. (ΔT_{ca})	Evap. Air Temp. Diff. (ΔT_{ea})
Refrigerant leakage	decrease	increase	decrease	decrease	increase	decrease	decrease

Table 2.1.2: Effect of refrigerant leakage on temperature measurements.

It is further stressed in Annex 34 that all fault detection and diagnosis methods rely on data measured by sensors that are installed within the HVAC systems. Therefore, the reliability of each method is strongly connected to the reliability of the measurements, which are - in principle - no more than relatively accurate estimates of the measured quantity. The performance of FDD methods depends strongly on the quality and the reliability of measurements. Inaccurate or incorrect measurements will inevitably result in poor performance of the FDD methods in terms of

- failure to detect faults
- high rate of false alarms
- inconsistent system monitoring.

The validation of sensors is therefore a critical first step in the installation or commissioning of FDD systems. All of these findings confirm that FDD methods are still under development and should be applied by experts only.

2.1.2.3 References

[2.1.4] DIN EN 832: Thermal performance of buildings – Calculation of energy use for heating – Residential buildings; German version EN 832:1998, Beuth–Verlag, Berlin.

[2.1.5] DIN 4108-6: Thermal protection and energy economy in buildings – Part 6: Calculation of annual heat and annual energy use, Beuth–Verlag, Berlin, November 2000.

[2.1.6] VDI 2067-11: Economic efficiency of building installations ; Calculation of energy requirements for heated and air-conditioned buildings, Draft version, Beuth–Verlag, Berlin, June 1998.

[2.1.7] DIN 4701-10: Energy efficiency of heating and ventilation systems of buildings – Part 10: Heating domestic hot water, ventilation, Beuth–Verlag, Berlin, February 2001.

[2.1.8] A. Dexter et al. Demonstrating Automated Fault Detection and Diagnosis Methods in Real Buildings. Final Report of Annex 34 Computer-aided evaluation of HVAC System performance, ISBN 951-38-5726-3, Espoo 2001.

2.1.3 A Comprehensive Energy Audit Method (by Fionna Fanning)

2.1.3.1 Procedure / Monitoring approach purpose

The objective of this project was to provide a sector supported tool that would be used for detailed energy and water benchmarking in schools. The tool consists of the benchmarking tool (which has been developed using Microsoft Access) and the paper based audit. The tool includes the identification of the important factors that define energy and water consumption, and the common and consistent definitions of terminology.

This bottom up assessment developed by the Building Research Establishment in the UK determines how and where energy and water is being used in schools and looks at benchmarking per pupil and per unit area. It has set up a detailed means of describing the facilities that a school has and the times of day that the school is being used (including community use out of school hours). In the future it is hoped that by removing the energy and water that has been used outside normal school hours that comparisons can be made between a number of schools to give realistic benchmarking figures. Also, comparisons can be made between the end uses between the different facilities for energy and water use. For energy it will also be possible to calculate the carbon produced.

This tool will assist a school to estimate (without having to install submetering) where and when the energy (and water) is being used (or wasted) to achieve the optimum in energy (and water) conservation.

2.1.3.2 Description

The project draws on Building Research Establishment (BRE) experience gained in developing a similar approach to the energy consumption of offices that led to a consistent Energy Assessment and Reporting Methodology (EARM) for offices. This method has subsequently been adopted in the CIBSE Technical Memorandum TM22 [2.1.9] and the ongoing series of PROBE studies [2.1.10]. It also forms an essential part of the background to the Carbon Performance Rating method included as part of the current edition of Part L of the Building Regulations [2.1.11] as a means of assessing new office design.

When addressing the similar problem for offices, for example, it was necessary first to define a “core” office activity and then to find ways of removing, or otherwise accounting for, the "unusual" activities and energy uses that were present in some offices before useful comparisons could be made.

In schools it is likely that such unusual factors could include the use of school facilities out of hours, where it will be important to be able to quantify the extent to which this requires heating, lighting and other equipment to be used. Such use might take place outside normal school hours, at weekends, or outside term time. Where this involves simply the use of teaching accommodation it is likely that energy use alone would be affected, and the effect would depend on the time of year. Where such use involves the use of sports facilities, then both energy and water consumption are likely to be affected.

It is equally important to ensure that benchmarking uses a common framework of descriptions and definitions so that the method can be applied consistently and unambiguously. Again taking the example of offices, the apparently simple performance measure of kWh per square metre per year actually requires considerable explanation:

- What sort of office? Naturally ventilated or air conditioned, normal office activities or a prestige headquarters building?

- kW of what form of energy? Gas, oil, solid fuel?

- Per square metre of what? Several measures of area are commonly in use, including gross floor area, "treated" area (ie, gross area less plant rooms and other unheated spaces), net lettable area (the usable accommodation area on which rent is paid).

- Per year? Is it accurate enough to use annual billing records? What happens if the annual meter readings are taken only 350 days apart, or 375 days apart? Or where oil or solid fuel are delivered in bulk?

Similar questions were asked in order to define schools and their energy and water consumption, with additional factors likely to include indoor and outdoor sports facilities, laboratories, computer based learning facilities and catering arrangements.

The form of the benchmark itself is important. In offices the benchmark of energy use per square metre per year has proved sufficient, provided the unusual "non-office" activities are removed. These include dedicated computer suites, restaurants and kitchens. In schools it is likely that a component of energy and water consumption would be related simply to the building area of the school, and to the type of school, and another component would be related to the number of pupils that make use of certain school facilities. A detailed means of describing categories of school and the facilities they offer, and a two-part benchmark related both to area and to numbers of pupils, seems to be required to make the necessary comparisons of performance.

The benchmarking tool consists of a Microsoft Access database where data is input and analysed and the paper based audit. The tool includes the identification of the important factors that define energy and water consumption, and the common and consistent definitions of terminology. Ultimately it is proposed that the resulting assessment method would be made widely available for subsequent use in developing more detailed energy and water benchmarks for schools.

To carry out the audit it is necassary to survey the school and note, in the paper based audit form, all energy and water using equipment, including:

- its rated consumption (the power that is drawn under normal operation (Rating Plate is normally marked with this value) or the volume of water that is drawn for a single use),

- its rated consumption correction factor (Correction factor relating rated consumption to actual metered consumption),

- how many hours a day it is used or how may times a day it is used

- when it is being used eg during school time, after school hours.

The data in then entered into the database which will calculate the total energy and water used, and the energy and water use by facility (eg general teaching, science), end use (eg energy for catering kitchen, water for hygiene), or excluding out of hours use.

For Form sheets for the comprehensive energy audit and a copy of the database (which is still in development format) to analyse your data, please email Fiona.Fanning@DfES.gsi.gov.uk.

2.1.3.3 Costs

It has been estimated that, depending on the size of the school a full detailed energy and water audit could take up to a week, depending on the amount of information that the owner already has.

2.1.3.4 References

[2.1.9] Energy Assessment and Reporting Methodology: Office Assessment Method, CIBSE Technical Memoranda TM22: 1999. The Chartered Institution of Building Services Engineers, DETR and BRE, London, February 1999.

[2.1.10] Reference for probe website

[2.1.11] Building Regulations 2002 Approved Document L2. Conservation of fuel and power in buildings other than dwellings (2002 edition). DETR, London, TSO, 2001.

2.2 Long Term Monitoring and Surveillance Procedures

2.2.1 Single buildings: Building envelope (by Jan de Boer)

2.2.1.1 Procedure / Monitoring approach purpose

Long Term Monitoring of the thermal behaviour of the building is performed to collect detailed information on the quality of the building envelope, to aquire information on the user behaviour and therefore the user impact on the building's energy behaviour. High installation and maintenance costs normally restrict these monitoring campaigns to research projects.

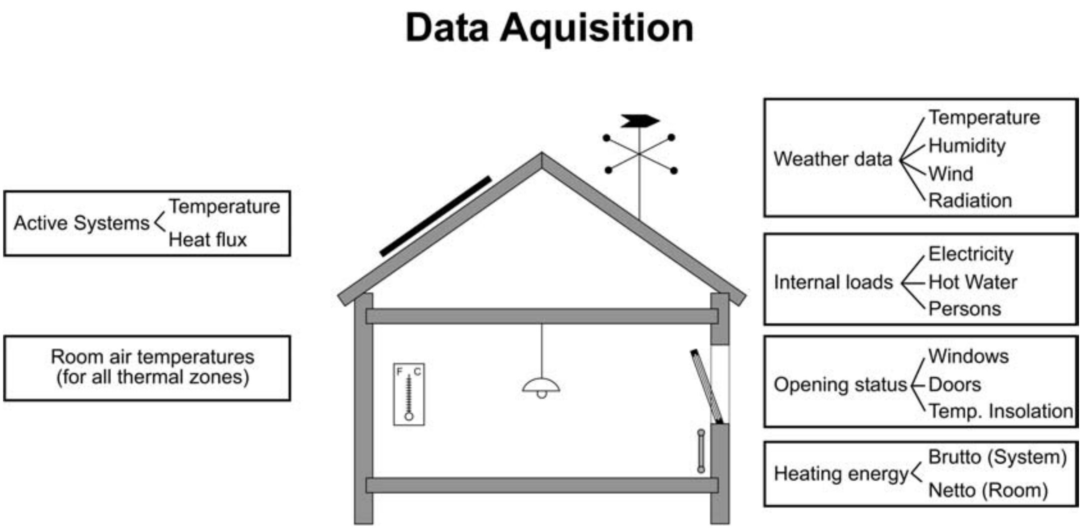

Figure 2.2.1: Quantities recorded for detailed analysis of the thermal building behaviour.

2.2.1.2 Description

The monitoring equipment is selected and integrated into the building such that it is possible to obtain complete energy balances at intervals of generally one hour for the whole building or specific zones of interest:

$$Q_H + Q_I + Q_S = Q_T + Q_V$$

where: Q_H Heating gains
Q_I Internal gains
Q_S Solar gains
Q_T Transmission losses
Q_V Ventilation losses

The gains in a considered zone which heat the indoor air are passive solar gains, internal loads and the heating system. Heat losses result from transmission and ventilation losses to the outside.

Gains from the heating system Q_H

Q_H specifies the gains that the radiators actually provide to the room or considered zone. In long term monitoring campaigns they are monitored with heat flux sensors, which have to be installed into the heat pipes. Figure 2.2.3 shows an example installation.

Internal Gains Q_I

The internal gains Q_I come from heat sources like persons, hot water and electrical appliances like lighting and computers within the considered zone. They are not explicitly intended to heat the space, but can contribute significantly. To estimate these gains, mean occupation schedules (number of students and time when they are in) have to be set up. Hot water gains can be monitored using heat flux sensors, electrical appliances by installing electrical energy meters.

Passive solar gains Q_S

Passive solar gains through the windows into the zone are computed using calculation models like the program “SUNCODE-PC” [2.2.3]. The measured radiation data, the geographical site, obstructions, the orientation, and the physical and geometric properties of the window including framing are considered in this procedure. If patterns on the use of potentially existing shading systems exist, these should be employed as well.

Transmission losses Q_T

The Transmission losses are calculated on an hourly basis from the sum of the losses through the construction elements separating the different thermal zones. The following equation applies:

$$Q_T = k \cdot A \cdot \Delta\vartheta \cdot t$$

where:
- Q_T Heat loss [Wh]
- k U-value of construction element [W/(m²K)]
- A Heat exchanging area of element [m²]
- $\Delta\vartheta$ Temperature difference between considered and neighbouring (outside) zone [K]
- t Time [h]

Outside temperatures are recorded on an hourly basis by the weather station. Indoor temperatures are monitored zonewise, also on an hourly basis. For heat tranmission into the ground, local average ground temperatures have to be used (consult the local weather station).

Ventilation losses Q_V

Ventilation losses cannot be monitored directly. However, they can be deamed accurately from occupancy and CO_2 concentration. Since all other portions of the energy balance can be determined, the ventilation loss can be estimated by :

$$Q_V = (Q_H + Q_S + Q_I) - Q_T$$

Natural ventilation losses through the windows are the difference between the overall ventilation losses and the losses from a mechanical ventilation system For cross-checking the obtained natural ventilation profile should be correlated with the users patterns to open the windows. The window status can be monitored with reed switch contacts.

From the ventilation losses the air exchange rate can be calculated. The air exchange rate describes the ratio of exchanged air volume to the volume of the specific space in a considered hour. This confirms whether or not minimum exchange rate are being met. The natural ventilation losses through a window can be calculated using the equation:

$$n_F = Q_{L,F}/(V_R \cdot c_L \cdot \rho_L \cdot (\vartheta_H - \vartheta_A) \cdot t)$$

where:
- n_F Air exchange rate, through window [h^{-1}]
- $Q_{L,F}$ Heat loss through window [kWh]
- V_R Volume of considered space [m³]
- c_L Specific heat-capacity of air [kWh/(kgK)]
- ρ_L Density of air [kg/m³]
- ϑ_H Mean zone temperature [°C]
- ϑ_A Outside air temperature [°C]

T Time[h]

The calculation of the air exchange rate introduced by a mechanical system follows

$$n_{LA} = t_B/t \cdot \dot{V}/V_R$$

where:

n_{LA} Air exchange rate, mechanical ventilation [h^{-1}]
t_B Operating time of system [h]
t Considered time period [h]
$\dot{V}$ Air flux of system [m³/h]
V_R Volume of room [m³]

Data acquisition system

As illustrated in Figure 2.2.3 the diverse sensors usually have to be installed during construction or during the retrofit phase of the building. Standard wiring, where each sensor cable is directly connected to the data logger, can be employed as well as more efficient but also more expensive bus-technology based set-ups. If the building controls already use bus-technology then the extra wiring to the data acquisition software can easily be installed later with minimal hard wiring.

The dataloggers are normally configured such, that recordings in ten minute intervals are averaged up to one hour values and are then stored. Different softwares as depicted in Figure 2.2.4 allow configuration of the measurement set-up and support evaluation.

2.2.1.3 Example: School in Stuttgart

Detailed monitoring has been performed in the EROS project [2.2.1] [2.2.2]. The project is extensively documented in the Energy Concept Advisor.

2.2.3.4 Cost

Costs split up into the

1. Development of a monitoring concept phase

2. Installation phase

3. Acquisition and maintenance phase

4. Evaluation phase

To obtain rough cost, estimates average costs for one sensor of 500 € can be assumed. And a large monitoring project would require at least 100 sensors. If the building already has a field bus for controls the cost will reduce.

2.2.1.5 References

[2.2.1] Kienzlen, Volker, et ali: Modellhafte Sanierung einer Schule in Stuttgart Plieningen. gi- Gesundheitsingenieur-Haustechnik-Bauphysik-Umwelttechnik 121 (2000) Heft 1.

[2.2.2] Kienzlen, Volker, et ali: Modellhafte Sanierung einer Schule (MOSES). Abschlußbericht. 1999, Stuttgart, Germany.

[2.2.3] Palmiter, L.; Wheeling, T.: Suncode – A Program User's Manual. Eco-tope Group (1981).

[2.2.4] Imedas: under http://www.hoki.ibp.fhg.de

Figure 2.2.2: Weather stations should be mounted in an unobstructed position on the building or fairly close to it. The outside temperature and solar radiation need to be recorded.

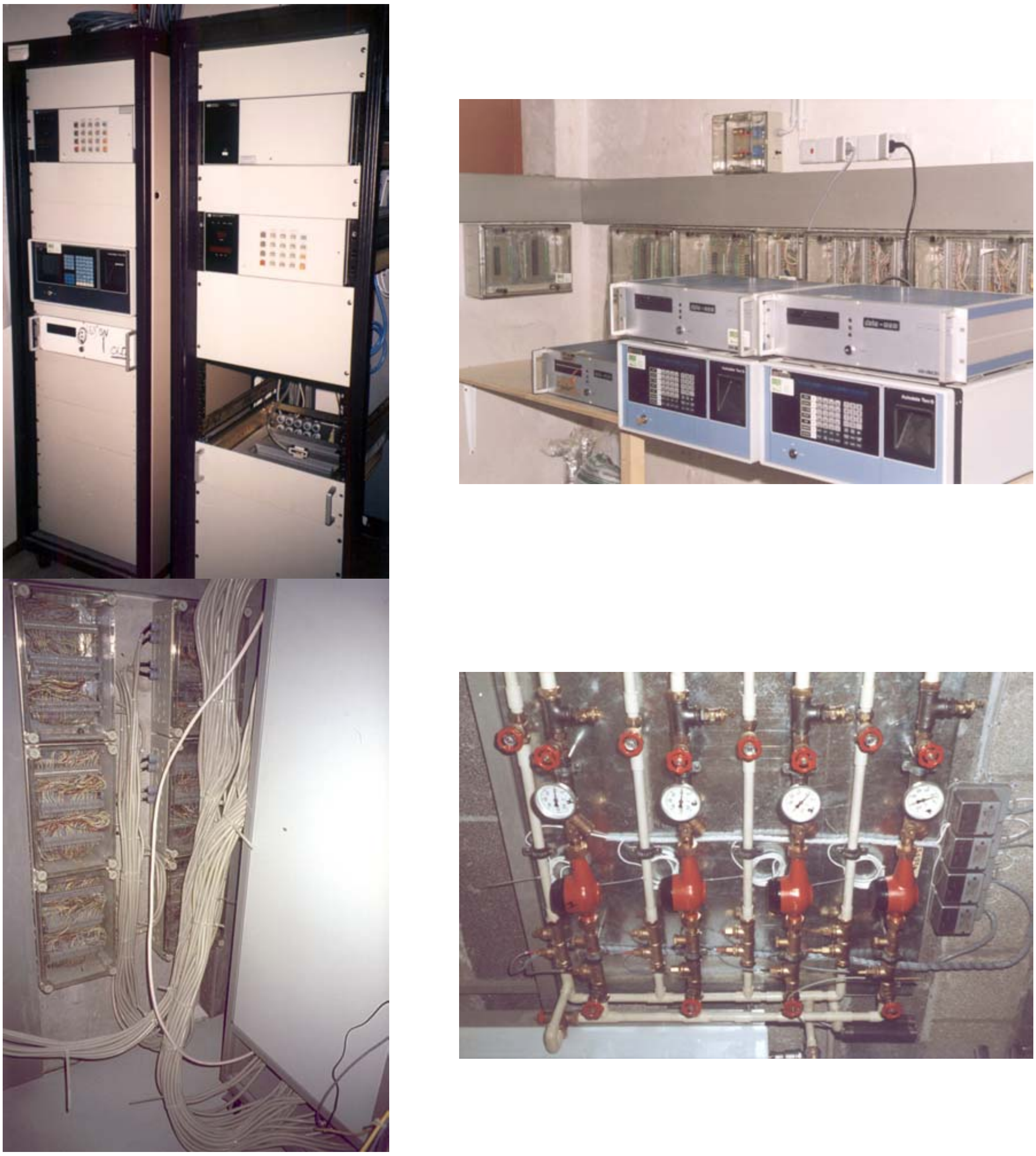

Figure 2.2.3: *Upper pictures showing data acquisition system. Lower left picture required wiring. Lower right picture the measurement of the heatfluxes in an heat distribution system.*

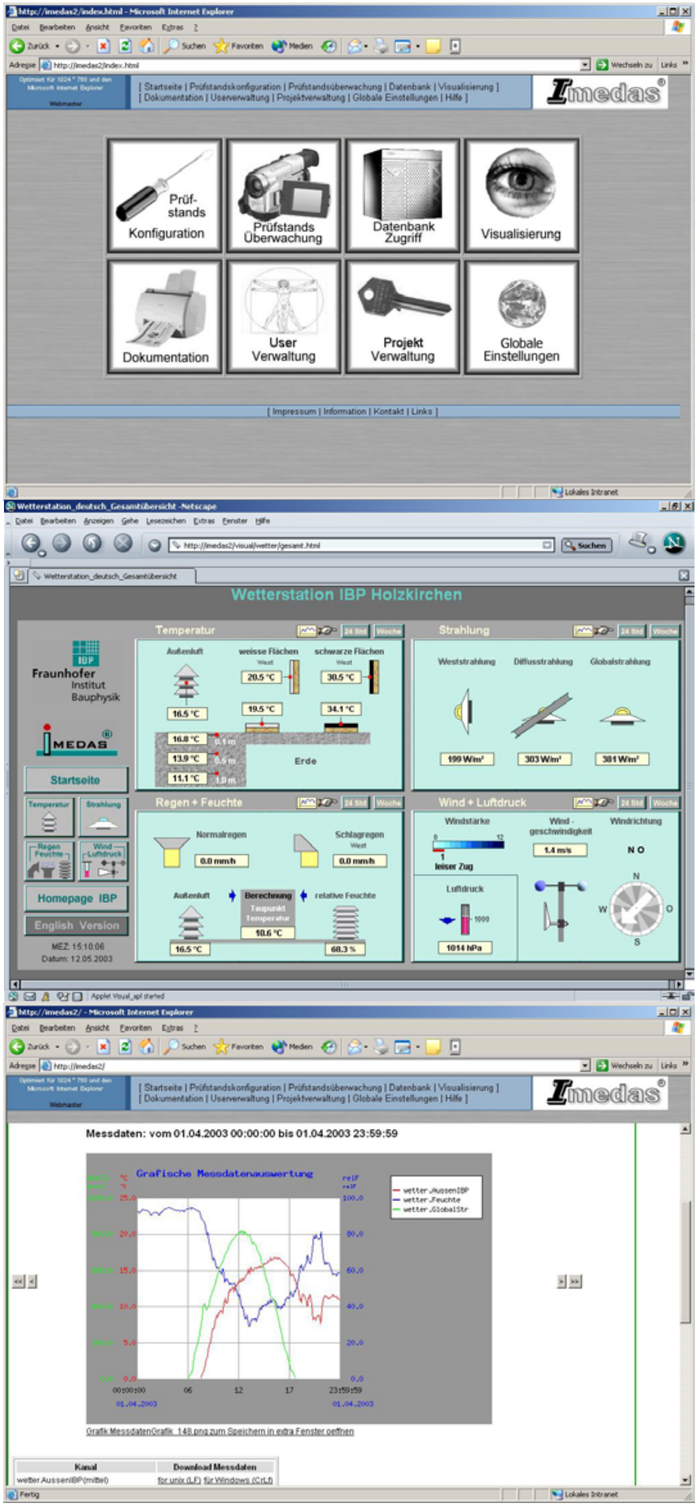

Figure 2.2.4: *Data acquisition software Imedas[4].*

2.2.2 Single Buildings: HVAC Systems (by Fritz Schmidt)

As mentioned before we have four possibilities to influence primary energy consumption

1. Influence the user awareness concerning energy consumption.

2. Adapt system operation to the actual user requirements.

3. Provide an HVAC system which supplies the required heating and cooling energy with a minimum primary energy effort.

4. Reduce the transmission losses of the envelope.

This section deals with system operation and the possibilities to save energy by adapting system operation to the user requirements.

Frequently the measures to be taken are not very expensive compared to the energy costs which can be saved. However to choose them correctly requires considerable knowledge about both system and system behaviour. Therefore performance contracting is a reasonable option to get access to the experts needed for the adaptation of the system operation.
(Note: such adaptations are necessary after building retrofit measures too. They may reduce actual primary energy consumption between 10% and 30% helping to reach the energy targets of the retrofit.)
Some basic requirements have to be fulfilled to apply performance contracting. They include:

1. basic consensus among those dealing with specific aspects concerning energy use of the buildings considered,

2. transparent and up to date measured data of energy consumption,

3. unified and reliable system for evaluation of measures taken to save energy (base line),

4. partners who are able to define measures which have to be undertaken to save energy in a specific building and who are able to implement these measures effectively and in a user friendly way.

2.2.2.1 Experiences from the REUSE Project

University buildings normally use very sophisticated HVAC systems. These systems have to be adapted to the actual user needs quite frequently. If this is not done on a regular basis energy consumption becomes quite heavy. The adaptation of the systems can be financed through contracting.

This chapter describes experiences gained during the REUSE Project (**R**ational Use of **E**nergy at the **U**niversity of **S**tuttgart Building **E**nvironment THERMIE BU 343/94 DE) which was underway at the University of Stuttgart between 1994 and 1998.

The goal of this project was to demonstrate how energy saving potentials can be activated in large heterogeneous real estates. This was done in three steps:

1. Development of an overall concept,

2. installation of an energy management centre, and by

3. optimising selected buildings.

The measures were developed and realised in the campus Pfaffenwald at the University of Stuttgart. The campus Pfaffenwald can be characterised as follows:

- Real estate's inventory: approximately 80 verydifferent buildings with students homes, co-workers homes, institutional buildings, cafeteria, lecture halls, laboratories as well as research institutes.

- Annual consumption amounts to approximately: 62 GWh electricity, 100 GWh heating and 28 GWh cooling.

- Energy supply: The basic power supply is from the university owned combined heat and power plant (CHP). The remaining demand is covered by the local energy supplier (primarily at night).

Numerous daily life difficulties had to be overcome before the project became a success and we were able to obtain worthwhile results. The consequences went far beyond the original goal to save energy worth about 3 to 4 Million Deutsche Marks and finally resulted in a new way of thinking about energy use at the campus. The renovation of the HVAC system of two buildings of the university of Stuttgart provides an impressive example.

Building 1 Electrotechnical Institute 1 (ETI 1)

The building was build in 1984. It includes several institutes and lecture halls seating from 50 to 500 students. The institutes extend up to the 4th floor, while the main lecture halls are located at the ground floor. The institutes include offices, shops and laboratories. The offices (heating only) are mainly on the south side of the building. Rooms which need ventilation and/or air-conditioning are located mainly on the north side. The floor area totals 14500m^2. Both utilisation and energy consumption remained relatively stable over the years.

Building 2 Engineering Science Centre (IWZ)

This is a building composed of four individual sections with a total floor area of more than 30000 m^2. Test facilities and maintenance rooms are located in the basement. The upper floors of the 5 storey building mainly comprise lecture rooms, study rooms and offices. The rooms in the north and west parts of the building as well as the interior zones are cooled with conditioned fresh air as long as no air-conditioning is required. Cooling and electricity demands of the building fluctuate heavily due to scientific tests performed at irregular intervals, thus power consumption was rising continuously in the years before retrofit.

Measures taken

- All energy-relevant heating and air-conditioning functions were connected to a new DDC control system. A higher-ranking energy management system monitors all systems and optimises energy consumption.

- All main ventilation and partial air-conditioning systems were fitted with frequency-modulation fan speed control. This has significantly reduced fan power consumption.

- Thanks to frequency-modulation speed control, ventilation and air-conditioning can be adapted to building occupation trends. For example when the building is largely empty, the ventilation airflow is reduced.

- Substantial energy savings were achieved by resetting the control valves to prevent simultaneous heating and cooling in the partial air-conditioning systems, as often occurs with older installations. Furthermore, efficient sealing of heating system valves is essential in summer for preventing undesirable temperature rises.

- The ventilation and air-conditioning system supply air temperature and heating system intake temperature are adapted to room air temperatures. This prevents discomfort due to excessive room cooling or heating.

- Room heating is optimally reduced at night, with automatic calculation of optimum start-up time the following day.

- Some of the ventilation and air-conditioning systems (in the auditoriums) were fitted with CO_2 sensors in order to adjust fresh air supplies to room occupancy.

<u>Resulting energy savings</u>

The described project concentrates only on the technical systems. No retrofit of the building envelope was undertaken.

- Energy costs before retrofit: 650.000.- Euro/annum
- Energy costs after retrofit: 450.000.- Euro/annum
- Energy savings after retrofit: 200.000.- Euro/annum

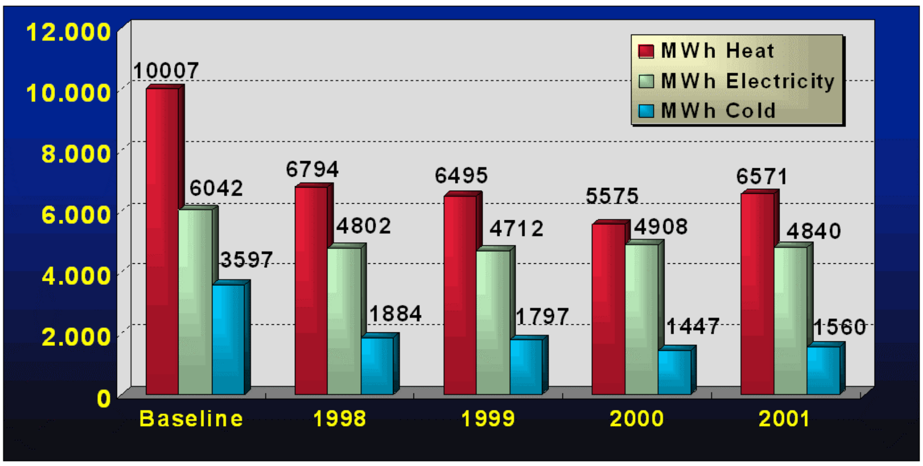

Figure 2.2.5: IWZ & ETI 1 : Energy used before and after retrofit.

Costs

- Systems retrofit: 1.256.000.- €
- System operation for 8 years (energy management and financing): 168.000.- €/a
- Additional savings for the state of Baden Württemberg 32.000.- €/a

Lessons learned

Heating and air-conditioning system control must always take account of current room air temperatures. The simple criterion of outside air temperature normally used (e.g. for controlling heating system feed temperatures) is inadequate for ensuring optimum comfort on the one hand and optimum energy savings on the other. For maximum savings of heating and cooling energy, optimum control valve settings are crucial. There is little point in the computer closing a control valve if leakage flow continues unchecked.

Verification of energy savings

The importance of reliable energy accounting cannot be overemphasised. This demands detailed investigations prior to project execution, since subsequent contractual modifications are always problematic. Attention must be paid in particular to the following points :

Were existing meter readings over the last few years reliable, and are they still reliable (dependability of reference data) ?

- If not, new meters must be installed. The old meters should be retained in parallel, however, so that deviations between the two can be used for backdating reference corrections.

- Did energy consumption change in recent years? Power consumption usually rises slowly (often due to installation of office equipment such as copiers, PCs, coffee machines, etc.). This base load will continue to rise in future, thus tending to reduce energy savings accordingly.

- To be able to verify energy (or power) savings at a later date, a possibility to switch the energy management system over to the former operating mode is very useful.

- If this is not possible, energy or power savings must be verified straight after commissioning and fixed for the entire duration of the contract. Since there is usually a relatively long installation and optimisation phase before energy savings accounting begins, it is often too late for correct verification of energy savings in this state.

Type of contract

Variable term contracts are preferably. With a variable term contract, inaccuracies in energy metering or reference consumptions and fluctuations in tariffs are less significant. Although they affect the term of contract, they only slightly influence cost-effectiveness for one of the two contractual parties. Since both parties are interested in maximum savings and shortest possible term of contract, agreement is quickly reached on any necessary modifications to the contract with regard to changes in reference consumption figures.

Furthermore, the question of tariff change effects does not even arise.

Accounting intervals

Contracts should be based on annual accounting with monthly installments. This system has proved better than monthly accounting, which is subject to considerable variations in energy savings due to different meter reading dates, different weather conditions, etc. These variations can be extreme from month to month, but are far less over a whole year period.

Another advantage of annual accounting is that such variations do not have to be explained to the customer, who often knows little about energy technology.

Comprehensive orientation of all project partners

Prior to contract finalisation, all project partners must be comprehensively informed about all aspects of performance contracting and project execution. This will clear up any conflicting interests and prevent unrealistic expectations. Project partners in this connection can also include persons and institutions not directly concerned with contract finalisation. Performance contracting can only be successful if it is in the interests of all concerned.

2.2.2.2 Strategies for energy analysis

From the experiences of these and other performance contracting projects we concluded that

- Adaptation of system operation to user requirements should proceed any other retrofit measures. Only after such adaptations we are sure to be able to select energy efficient retrofit measures.

- Commissioning of systems before and after retrofit seems mandatory to determine a sound baseline for further decisions.

- Energy management after retrofit should be initiated. This will make energy savings sustainable.

- Training of operators is required. Operators could be internal or external personnel.

- Best results can be achieved by combining retrofit and performance contracting.

Contracting could include :

- Installation of energy management

- Optimisation of system according user requirements

- Commissioning of system

- Guarantee of predicted savings with unchanged comfort conditions

- Control of energy usage and continuous adaptation

- Maintenance of optimised system

- Control of comfort conditions

Retrofit should include all measures which are too expensive to be included in performance contracting but which are required for other reasons. For those who base their energy audit on the tools provided within the energy concept adviser we recommend

- Step 1: Model building, HVAC system and usage.

- Step 2: State limitations of model eg. no kitchen, no swimming hall, etc.

- Step 3: Perform calculation.

- Step 4: compare calculated **Energy Requirement** and measured **Energy Consumption.** For differences greater 10% adjust usage and/or operation, recommend detailed audit. For differences less than 10% use model to evaluate possible retrofit measures.

2.2.3 Remote surveillance systems: KULU (by Jorma Pietiläinen)

2.2.3.1 Small (and simple) can be beautiful also in energy management

Effective utilisation of existing meters by consumers is not possible without supporting tools. Practice has shown that monitoring activities cannot 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 company, and organisation - even in households - 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, monitoring and management 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 is a prerequisite for further improvements.

One example of a 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 companies, buildings and other consumers like households 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 municipalities, public swimming halls and other sports facilities, small housing companies etc.

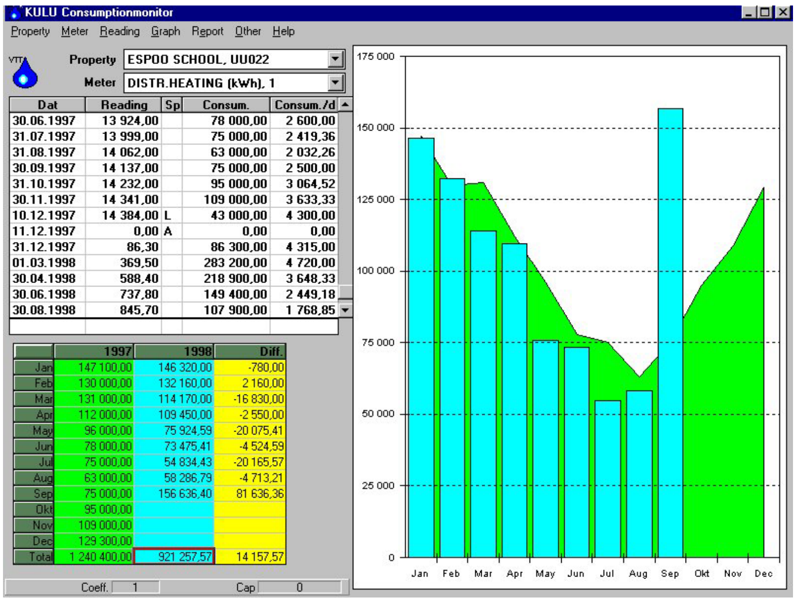

Figure 2.2.6: Screenshot from the KULU user Interface, showing the monthly heating energy consumption of a school building.

In the 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 above 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.) to numeric and graphical summaries. Amongst 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.

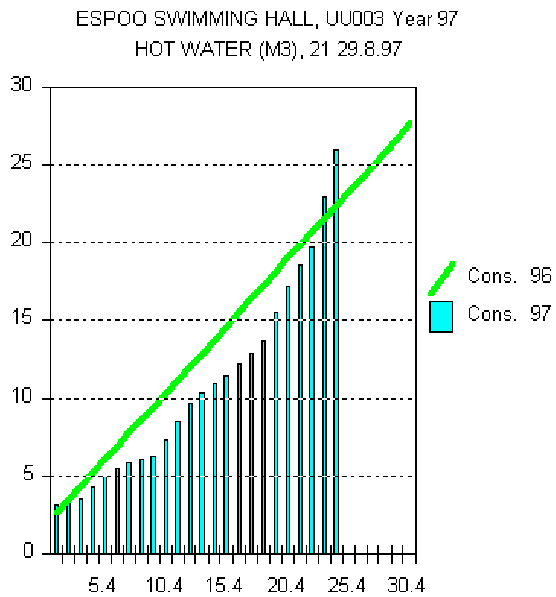

Figure 2.2.7: Comparison of accumulated daily hotwater consumption for two consecutive years for a swimming hall.

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 Figure 2.2.7) give a warning when something extraordinary happens. The accumulated sum for the previous year (or month in the case of daily graph) provides a yardstick for the consumption for the current year. Instead of using the previous year’s figures it is also possible to use values derived from energy calculations, audits or whatever parameters can be most easily used as a yardstick. It is essential that the **actual energy consumption is recorded regularly** and it is **compareded against some "target"** or **"yardstick"**.

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 software. In addition to English many other languages like Swedish, German, Italian, Czech, Estonian are already supported and new language versions can be produced with a minor amount of work. In summary, Kulu provides the basic tools for energy control and management. It is particularly suitable for energy end users but also for small companies/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 of course 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 it offers a good base for data collection and collaborative development projects both on a national and an international level.

Figure 2.2.8: Pocketsized handheld computer and bar code scanner used for meter reading.

Figure 2.2.9: Application of handheld computer and bar code scanner.

2.2.3.2 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. 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 the previous one. 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 hours of a boiler, ventilation system etc. can be collected at the same time. This information can help explain variations in consumption.

Utilising these kinds of devices in big property maintenance companies data from thousands of meters can be collected in a day or two. Using a docking station meter readings can be transferred into the database of Kulu in a fraction of a second. So called 'alarm' reports can be produced immediately after this phase 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. In this way, the Department of Defence in Finland controls monthly energy use in thousands of its buildings. Similarly the energy consumption of hundreds of (civilian) educational buildings are managed in the property management unit of Helsinki University.

2.2.3.3 New information and communication technologies offer a lot of new possibilities

The fast developing 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 generation applications for energy control and management as well. As very first examples of internet based services some utilities have been enabling city residents (consumers) to submit their energy or water meter readings over the internet. Typically also some consumer information on saving techniques, new energy efficient products and services etc, are disseminated via web sites established by utilities, consumer organisations etc.

Also at VTT, the internet has been used for the development of a new type of monitoring and targeting software tools and services. **WebKulu** 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. will be developed soon in collaboration with big property management companies, big cities and state organisations.

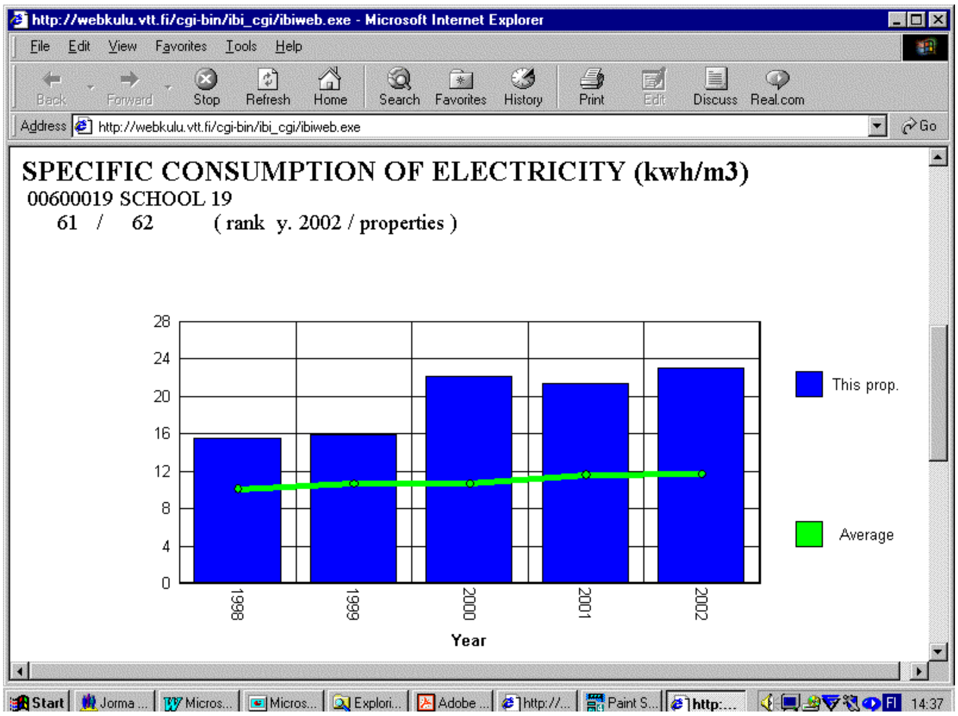

Figure 2.2.10: Example of benchmarking output of the webinterface of Webkulu.

By utilising WebKulu energy saving actions and services can be implemented in a new way. For example service men or other users in school buildings from different locations (and countries) can update their own data whenever they want. The data is immediately available for analysing, comparisons etc. for everybody having access to the system. For example new type building energy certification and labelling schemes can be developed in this way. Even building owners, tenants etc. themselves can easily update – e.g. monthly meter readings or consumption figures and simultaneously they can get feedback not only on their own energy consumption but from other similar cases as well. Utilising WebKulu both national and international energy benchmarking services can be developed but it can be used for many other kinds of energy efficiency purposes as well. For example, the real impacts of new energy saving technologies can be provided and best practice disseminated. Tools and services for performance based contracting and third party financing can also be developed.

Besides manual updating of meter readings via the browser WebKulu includes solutions for automatic data collection. By utilising LonWorks compatible modules, eg those manufactured by the Finnish high-tech company Lonix, meter readings can be collected automatically by WebKulu via ip- or phone network. In this way an energy control system based on automated meter reading (AMR) can be implemented not only in new construction but in existing buildings as well. Consumption data from thousands of meters can be updated monthly, daily or - if needed - even hourly. Comprehensive analysis can be carried out and alarm, summary, etc, reports and graphs can generated automatically and sent with emails or accessed over the internet. As mentioned earlier, soon they will also be available to mobile phones. Via a standard web browser, the latest consumption figures, benchmarking reports, etc, are always available whenever needed – in meetings, by service companies, etc, even at night-time or from abroad.

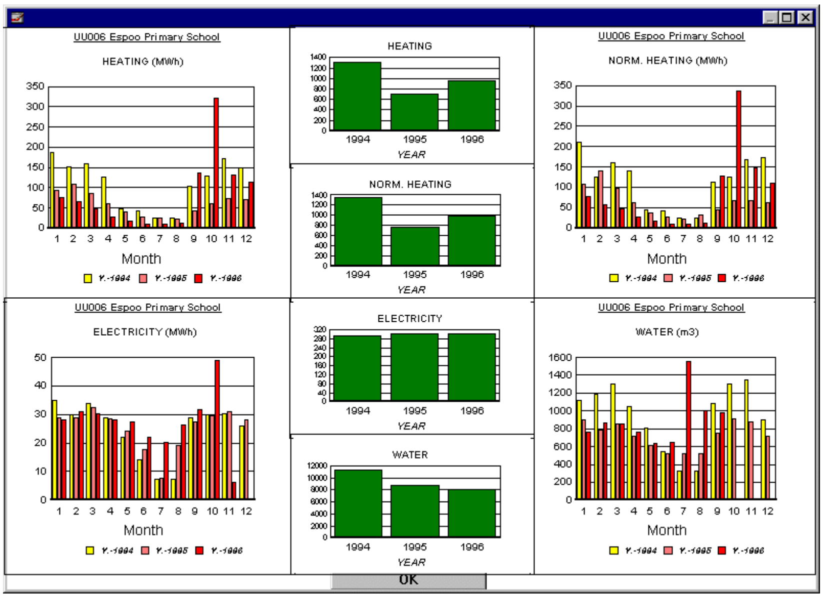

Figure 2.2.11: *Summary of heating, electricity and water consumption.*

The system will be developed further in collaboration with Lonix Oy taking into account the latest development of mobile phones, the internet, portable terminals, etc. Big building owners like cities, state organisations and companies will test the solutions in practice. The development work will be co-ordinated with the COBA project (Connected Open Building Automation, which is presented in more detail on the following web site http://www.lonix.fi/en/coba.htm).

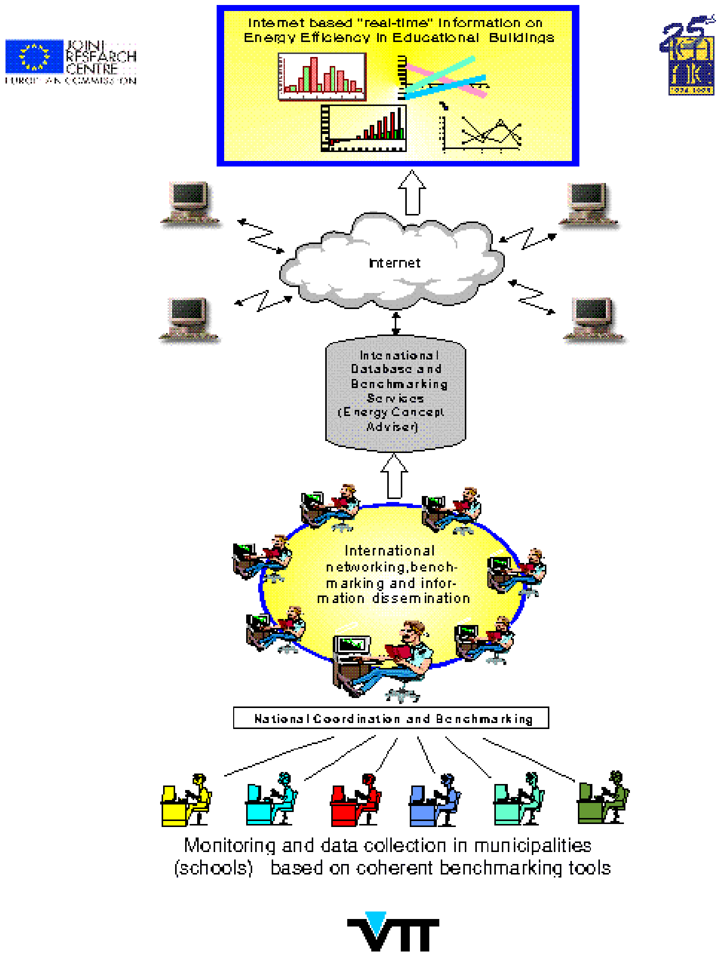

Figure 2.2.12: Coherent data collection for international benchmarking and analysis.

2.2.3.4 Benchmarking KULU in Annex 36

As a first step, the web based monitoring tools mentioned above, could be tested in educational buildings in Annex 36 countries. With the help of the tools (mainly monthly) data on energy and water consumption (real meter readings) could be collected and updated by schools regularly into a central web based database as depicted in Figure 2.2.12. Based on this data, analysis and reporting services could be developed and made available on the same web server. Besides general information on building characteristics, occupancy, etc, basic reports could consist of monthly consumption data from the last 2-3 years (when available) as well as longer term development based on yearly consumption figures. A preliminary example – used for Finnish schools, swimming halls, etc, can be seen in Annex 2. 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, as well as information on typical emissions of greenhouse gases.

2.2.3.5 References

For further information please contact

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VTT Building and Transport, http://www.vtt.fi/rte/indexe.html

2.2.4 Remote surveillance systems: SEKS (by Jan de Boer)

2.2.4.1 Procedure / Monitoring approach purpose

The regular recording and evaluation of energy consumptions is the fundamental to the identification of excessively high energy consumptions. For cities like the city of Stuttgart which have to maintain hundreds of buildings, manual recording and evaluation is tedious and time consuming. Automatic recording may reduce labour costs signifantly and automated evaluation procedures identification of abnormal energetic behaviour in large group of buildings. The city of Stuttgart has therefore installed its *Stuttgart City Energy Monitoring System* [2.2.5], which has now been operating for over 10 years.

2.2.4.2 Description

The technical concepts developed are identical for different building types. As illustrated in picture 2.2.13 :

- An “intelligent” substation is installed within the building.
- Depending on the quantity of data to be recorded. Special interface modules are installed, which digitize the sensor quantities and provide them via an internal bus.
- A computer saves the data and prepares them for transmission
- Using a standard modem the data are transmitted to a central computer.

Depending on the building size and its technical equipment the local configuration of the monitoring system might vary. In bigger buildings it might be meaningful to process detailed data of for instance the heating system. In smaller buildings it has shown to be sufficient to only record the main consumptions, i.e. heating energy, electricity and water.

2.2.4.3 Examples

In a school building connected to the *Stuttgart City Energy Monitoring System* indicated that there was heating energy consumption during summer vacation. The system was still running the hot water supply when it was not needed. The heater was turned off resulting in energy savings amounting to an estimated 6000 kWh. Another example is shown in Figure 2.2.14. The annual electrical energy consumption was reduced by an estimated 7,2 % after connection to the system. As shown in Figure 2.2.15 the EROS project [2.2.6] was also connected to the *Stuttgart City Energy Monitoring System.*

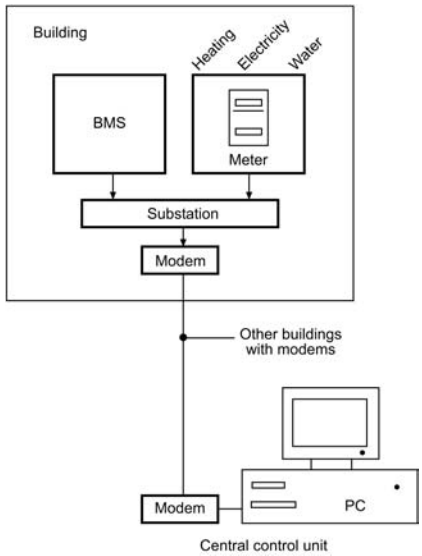

Figure 2.2.13: Technical concept of the SEKS - Stuttgart City Energy Monitoring System.

2.2.4.4 Cost

The cost for a substation including installation of the transmission modules amounts to 4000 € (cost basis: 1992). Annual maintenance costs add up to 600 € for one building. These costsare comparable to the saving in labour costs. Energy savings due to the system add up to a couple of 10 000 € a year for an individual building. In addition, the psychological effect of installing the system, seems to generate savings of some percent points just by itself.

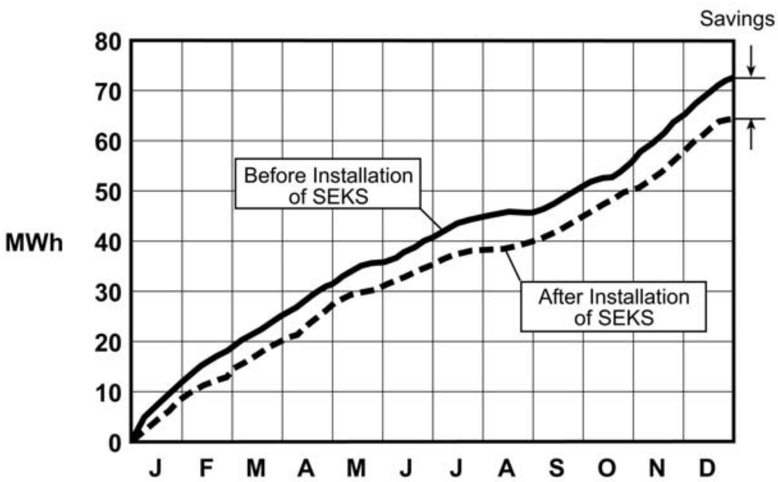

Figure 2.2.14: Exemple of electrical energy consumption of a school before and after installation of Stuttgart City Energy Monitoring System.

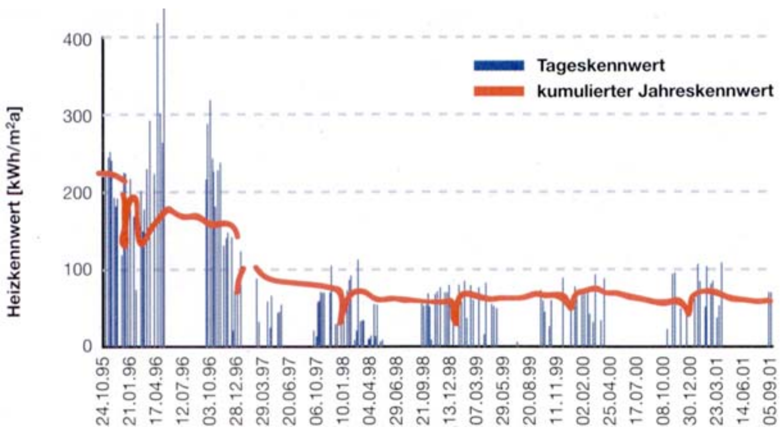

Figure 2.2.15: Example of specific heating energy consumption of the EROS project [2.2.6] monitored by the Stuttgart City Energy Monitoring System.

2.2.4.5 References

[2.2.5] Idler,R; et. al.: Das Stuttgarter Energie-Kontroll-System, Regelmäßige Energieverbrauchsauswertung als Mittel zur Energieeinsparung, Wärmetechnik, 3, 1992.

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2.2.5 Remote surveillance systems: Visual Energy Center (VEC) (by Fritz Schmidt)

There are two basic reasons why the performance of a building is unsatisfactory: poor design and improper operation. Both the envelope as well as the HVAC systems may be poorly designed, while improper operation is only due to inadequate opeation of the HVAC system. According to this we can identify three ways to reduce energy costs:

1. Improve the envelope to meet modern standards. Measures to reduce demands for heating, cooling and lighting can be considered. Experiences show that such measures should be accompanied by the adaptation of the HVAC system to the utilisation of the renovated building envelope (see 3)

2. Improve the HVAC system to meet modern standards. The adequacy of a HVAC system to meet the needs of a specific building is expressd through the efficiency number. For educational buildings efficiency numbers of less than 1.3 are desirable.

3. Adapt the operation of HVAC systems to the actual needs due to the utilisation of the building. This includes 3 substeps

   3.1 Determine the energy demand resulting from utilisation (by analysis for new buildings and by audits for existing buildings)

   3.2 Choose a suitable HVAC system and adapt it to the needs (commissioning)

   3.3 Monitor the system behaviour and adapt it to changing utilisation (energy management).

The Visual Energy Center (VEC) is a tool which supports both building energy analysis and system management during all phases of the building lifecycle. Single buildings as well as communities might be considered.

Building energy analysis and system management are the basis of modern energy management. To support energy management during all phases of the building lifecycle most effectively it is necessary to support :

- Energetic analyses of the building (determine energy demand under theoretical utilisation)

- Detailed modelling of utilisation (determine energy demand under real utilisation)

- Collection of data from counters and sensors in the building to measure the actual energy consumption and to analyse building and systems conditions.

- Modelling of system behaviour (determine primary energy need)

- Comparisons of both measured and simulated data (allow energy management including FDD) .

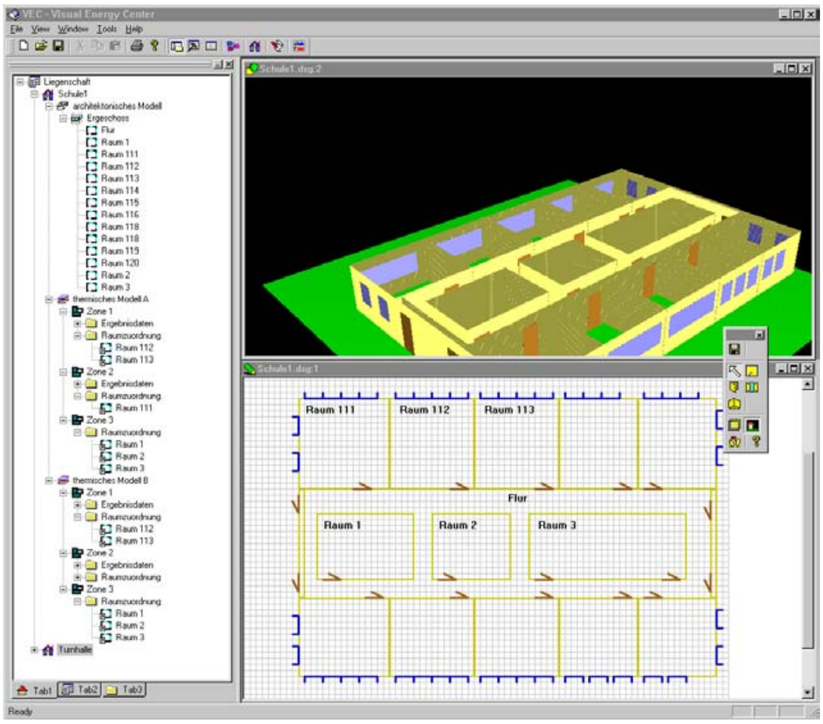


Figure 2.2.16: Visualisation of a school building using the ZoneCad Viewer of VEC.

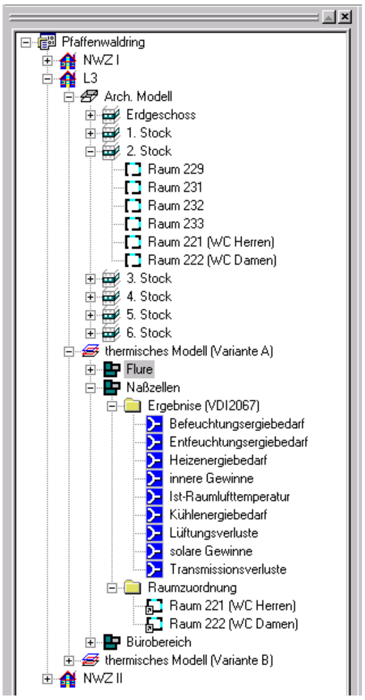


Figure 2.2.17: Data structure used in VEC for architectural model (room based) and engineering model (zone based).

<u>Building Description</u>

At the heart of the VEC is a data model which allows a detailed description of the building, including its technical description and the sensors which take data on the building behaviour. The data model is derived from the more general IFC model developed as an industry standard through the International Aliance for Interoperability (IAI). It can be considered as an aspectmodel 'building services'. Data to describe a building might be provided from IFC files or via the user interface using either tabular or graphical input.

<u>Energy Consumption Data</u>

Data related to energy consumption in the building may be collected from the real building (data measured through sensors) or from simulations (virtual building)

Various interfaces are available for data collection. They include

- Interfaces for requesting and presenting reports on the Internet or Intranet.
- MS-Office Export (Word, Excel, Access, ...)
- Building data exchange via XML, IFC, DWG,...

- Programming interface (COM) for individual expansion and adaptation
- TRNSYS, EnergyPlus, ...
- EDM systems

Several field buses and protocols are supported:

- OPC
- Profibus
- LON
- EIB
- Mbus
- Various PC measuring cards as well as popular data loggers
- New protocols and interfaces are added continuously and upon customers request.

VEC allows the user to compare measured and calculated data. Thus one can control energy consumption and develop a broad spectrum of applications including control and optimisation of systems operation and fault detection and diagnosis.

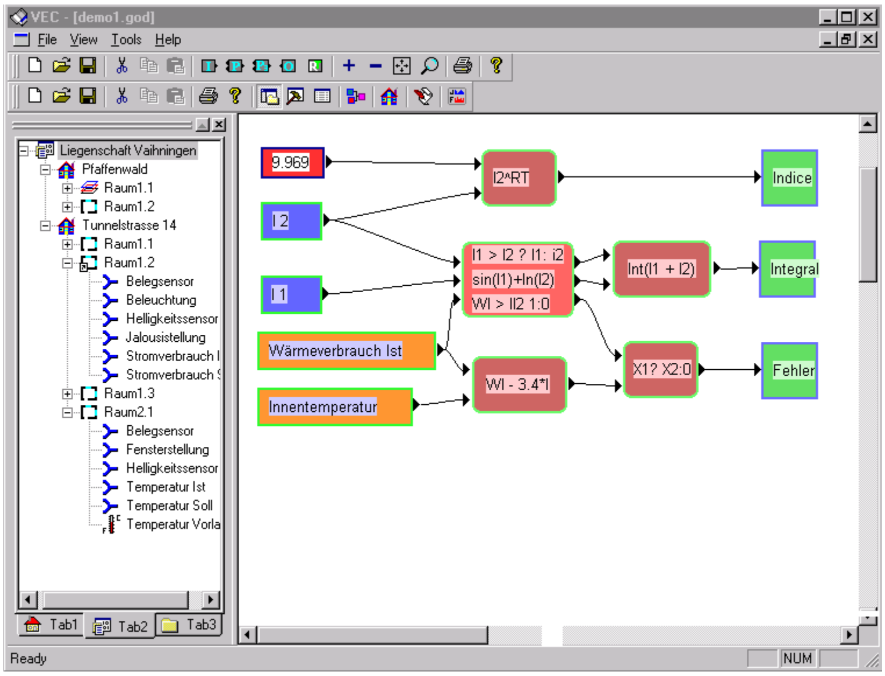


Figure 2.2.18: Data Analyser of VEC: graphical interface for dataanalysis.

<u>Simulation</u>

The building simulation methods of VEC include :

- DIN 4701 for yearly calculations
- DIN En 832 (EnEV) for monthly calculations
- VDI 2067 for hourly calculations
- And offers interfaces to research tools like TRNSYS or EnergyPlus

Thus all phases of the life cycle of a building can be treated adequately. In addition various tasks concerning energy management in buildings can be supported through the VEC. These include thermal analyses, system planning, commissioning, auditing, operation and optimisation. Furthermore it becomes easy to investigate alternative energetic solutions during planning, design, operation and renovation.

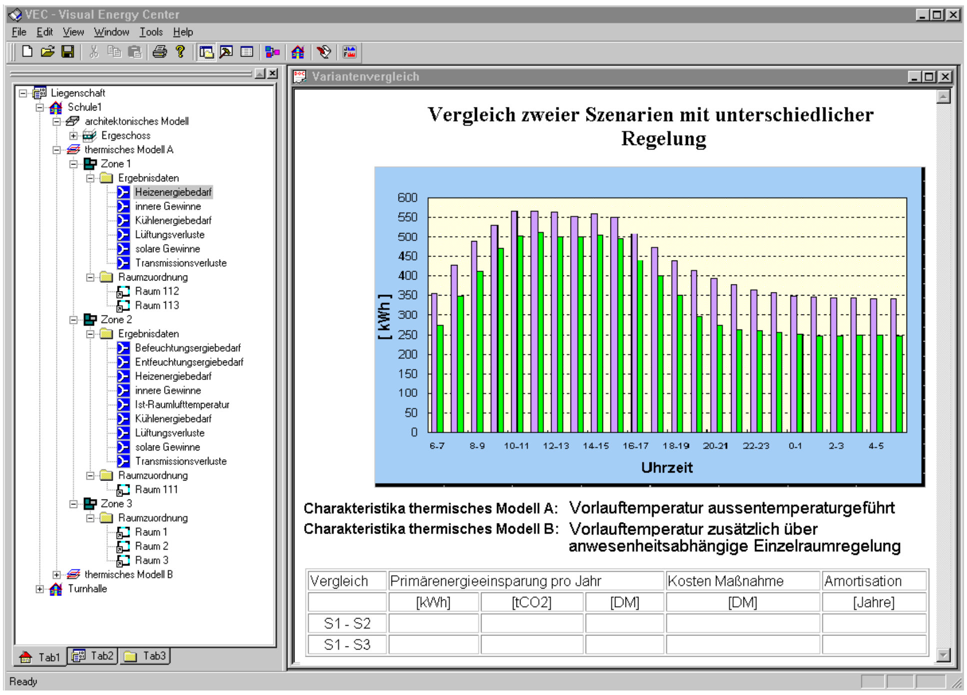


Figure 2.2.19: *Comparison of measured and calculated data: demand and energy delivery.*

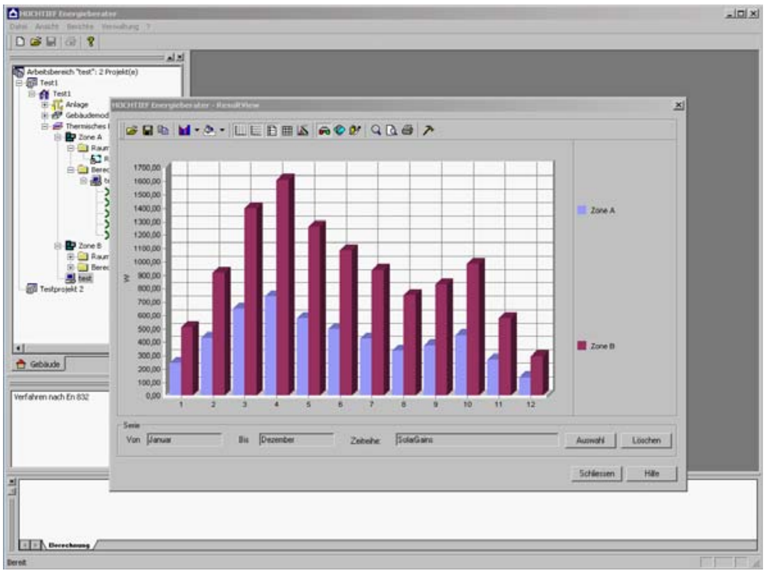


Figure 2.2.20 : *Comparison of calculation results for different zones.*

Analysis and Reporting

In addition to standard Excel reports (energy report, energy certificate, analysis result) one can also prepare individual reports using the Report Editor.

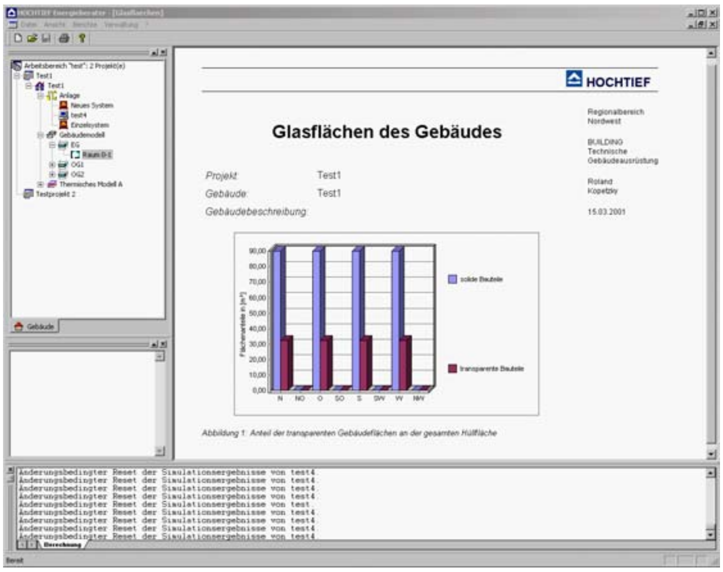


Figure 2.2.21: The VEC can generate reports tailored to the needs of each customer.

VEC Structure

The VEC is a component based small software. Components can be put together according to the particular needs of a customer. Special versions are available for both consulting and administration / management, each at different levels ranging from private homes to communities. An overview on the VEC - concept is given on the next page. A detailed description of the versions available can be found at the VEC homepage http://www.ennovatis.de

Software and Hardware Requirements

Windows 9x/NT/2000

Pentium II-PC, with at least 64MB RAM

Usage in Annex 36 and Availability

Parts of the VEC (En832) were adapted for use in the ECA. Also efficiency numbers for heating systems in schools were calculated using VEC technologies. Finally the evaluation of the ECA calculation programms was primarily performed using more sophisticated methods available in VEC.

References

English and German language versions of VEC are available

The commercial version of VEC is available from

ennovatis GmbH http://www.ennovatis.de

e-mail info@ennovatis.de

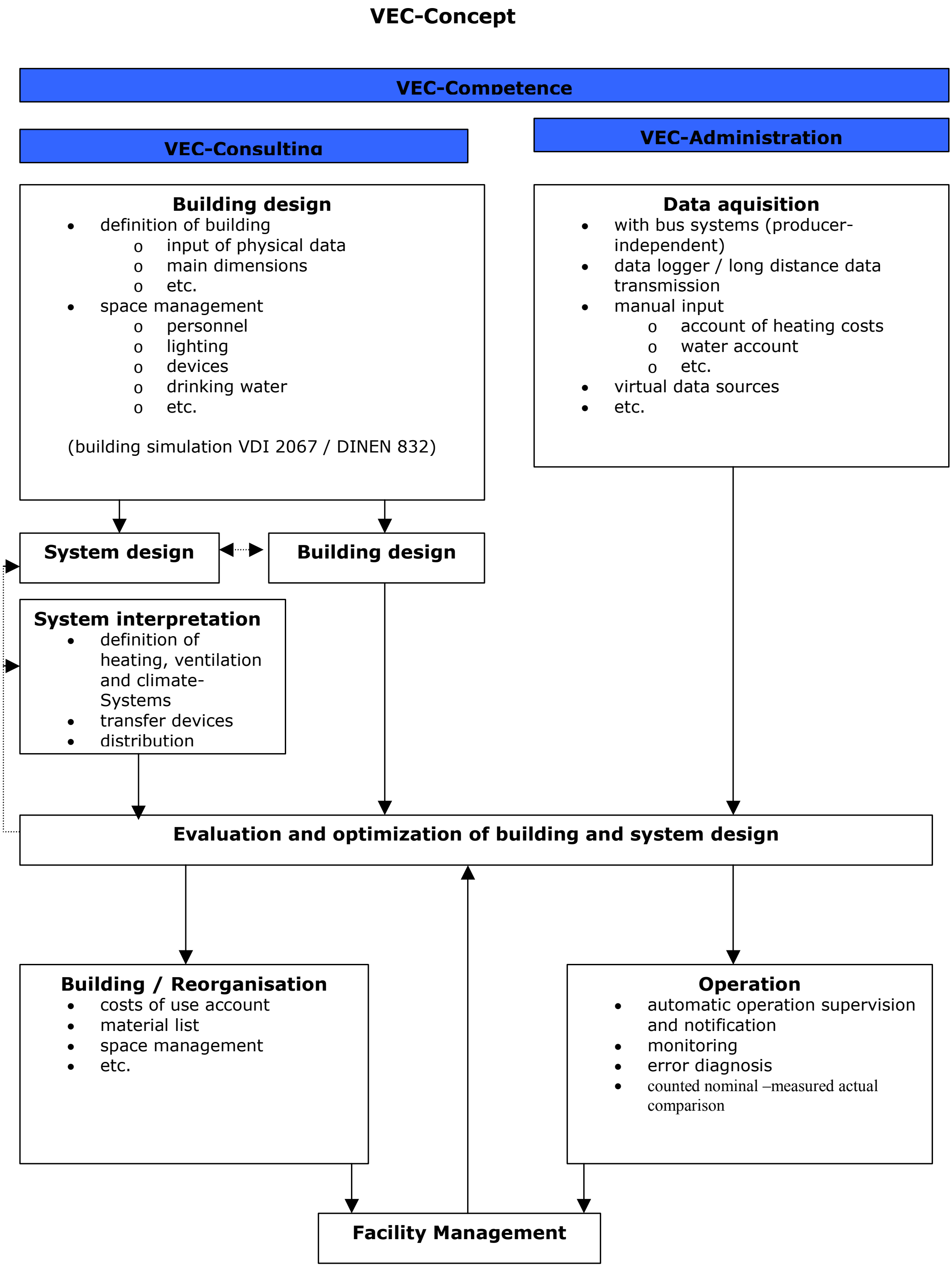


Figure 2.2.22: Basic structure of VEC a modern tool for evaluating, optimising and controling energy use of buildings.

3. Component analysis using Thermography (by Timo Kauppinen)

3.1 Procedure / Monitoring approach

The energy efficiency of the buildings is defined at all three stages in the life of a building: design, implementation and use, operation and maintenance. In the longer term, the use and operational factors are decisive, providing the previous stages have been properly executed.

In surveying the condition and energy efficiency of buildings various methods can be used. We can compare the consumption data of the target building with other, similar types of buildings by benchmarking. Energy auditing helps to localise and determine the energy saving potential. The condition of the building, structures, indoor air quality and building services can be found out by means of a condition survey.
When we assess energy saving measures based on benchmarking and energy auditing, we must determine the thermal performance of the constructions, and different devices and measurements are needed. The thermal perfomance of the building and structures cannot always be evaluated reliably only based on calculations, because implemented structures diverge from the design. In addition, in many renovation cases the drawings, documents and structural information are not available. Furthermore, the functioning of the heating and ventilation systems have an effect on the thermal performance of the building enevelope.

The most generally and also most effective auxiliary method for monitoring the thermal performance of the building enevelope is the infrared camera (the thermal imager). Thermography has been used as an aid in building research and industrial maintenance since the late 1960's. The use of thermography became general after the energy crisis in the mid 1970`s. The fast development of infrared cameras and image processing technology has launched a new push for thermography after the end of the 1980`s.

In Europe, building applications of thermography has been researched first in Sweden, where the first commercial infrared camera was developed in the 1960's. Later, from the 1980's on, there has also been research in various countries concerning the possibilities of using so called active or dynamic thermography in building materials technology. One of the goals was to try to measure the moisture levels of building materials using thermography. In the last few years there has been a push to increase the usability of thermal scanning in the present applications and also to find new ones. The goal is to lift thermal scanning - possibly with the help of other supporting methods - from the present qualitative level to a more quantitative level. This means that in addition to the quality monitoring based on the surface temperature differences and the changes in surface temperature distribution there should be classification of the thermal performance of the structure and the characteristics (moisture, etc.) of the material compared to other materials.

3.2 Description

<u>The basics of the method</u>

Every surface emits radiation, the intensity of which is equal to the surface temperature and the capacity to emit and absorb radiation.

Thermal scanning always requires the surface of the object to have variations in temperature or in the properties of the material. A device that measures the infrared (IR) radiation of an object is called an infrared camera (thermal scanner, thermal imager) if it produces a thermogram that corresponds to the temperature distribution of the object. There are also other measuring devices that are based on measuring IR radiation, such as the temperature profile scanner and the infrared thermometer, which is very commonly used. The IR thermometer is used to measure the temperature of a point, which can be read directly from the display of the device. Compared to an infrared camera the advantage of the IR thermometer is low price and small size. The drawbacks are lack of precision in locating the target point, often restricted measurement distance, possible temperature drift and false measurements caused by environmental factors (the basics of temperature radiation must be known). The method does not give a quick and reliable overall view of the object.

Infrared imaging systems do not "see" or measure temperature. These systems view radiated energy actually emitted from the first 0,01 mm of the surface of an object. Actually, the radiation received by the system is the sum of three components: 1. Energy emitted from the surface (a function of temperature), 2. Energy reflected from the surface (a function of a background source) and 3. Energy transmitted through the object from a source behind the object (in some cases, like plastics) which is lightly attenuated (in some conditions) by the intermediate agent (air in general).

Infrared radiation is electromagnetic radiation, which has a longer wave length than visible light. Thermography uses two ranges of infrared radiation: 3 - 5 µm (so called short wave length range) and 8 - 14 μm (so called long wave length range). In other wavelengths the water vapour and carbon dioxide in the outdoor air effectively absorb IR-radiation.

Infrared cameras have been designed to operate in the range of these infrared windows. Thermographers must have expertise, in both the method and devices and in building physics and construction engineering. Quoting Mr. Herbert Kaplan, Photonics, January 1998: "As infrared camera manufacturers commercialise lower-cost, easy-to-operate, IR focal plane array imagers, smaller companies are re-examining the tempting alternative of the do-it-yourself approach, and larger companies are considering deploying more instruments at 'operating' levels. The trend is popular with camera companies, *but thermography experts warn that untrained eyes can misinterpret infrared data, acting when action is unwarranted or ignoring the early signs of a problem. Such experiences could, in the long run, damage the infrared industry's future* - unless manufacturers also promote proper training".

Thermography of buildings

The purpose of a building is to separate the conditions inside from those outside. Factors such as water, temperature, wind and UV radiation can place a load on the materials which can cause deterioration and damage.

The building envelope is composed of different layers, that have different thermal performance and thermal conductivity. This causes the surface temperatures of the building layers to vary. The surface temperatures are also affected by air flow inside and through the wall and ceiling structures of the building, moisture and insufficient insulation. At points of heat leakage the heat flow through the building envelope increases locally, causing the surface temperature of that point to change. If the heat flow is excessive, there is probably a defect in the building's insulation layer or its cladding.

Faults and defects in the building envelope can cause lower than normal surface temperatures on structures. They can also cause draft and air flow through the structure which can cause moisture damage and increase energy consumption.

Thermography is a good tool for evaluating the thermal performance of buildings and for the condition survey of facades. Heat and mass (mainly moisture) transfer are important factors influencing the long term durability of a structure and building damage. Currently in building physics research the attention has in several countries focused on the performance of building envelopes from the viewpoint of long term durability. When the performance and condition of a structure are evaluated, measurements in a controlled laboratory environment or in the field are necessary in some cases, in addition to the available documents and calculations.

Thermal scanning can be accomplished both from inside and outside the building. There is always a big possibility of mistakes in interpretation when the results of the thermal scanning are analysed. The apparent simplicity of thermal scanning can lead to gross misinterpretations if certain physical facts or basic facts about the method are not understood. The temperatures in the structures are never evenly distributed, and all irregularities found in the surface temperatures do not necessarily mean that there are defects in the insulation or the structure at those spots. In indoor thermal scanning it has to be noted that corners, joints of the ceiling, walls and the floor, breakthroughs, etc. are always at least a little colder than their surroundings. Irregularities within a surface's emissivity factor (especially in outdoor imaging) and the view angle can all make the interpretation of the results more difficult, or lead to false conclusions. By changing the viewangle of the scanner it is often possible to eliminate the effects of reflections. In the same way, shutting off unwanted heat sources (lightbulbs, heating radiators) for the time of the imaging can in some situations be required.

In the Nordic countries outdoor thermography has turned out to be more difficult than indoor thermography, in making the results and the right interpretations more difficult to achieve. Indoors the biggest technical obstacles are curtains, furniture and lack of space. In cold climate conditions imaging from outside the buildings is limited by the ventilation gap, that often exists in houses. Thermal scanning can also be done from the airborne based platform. The energy use of whole population centres and the performance of certain types of roof structures has been researched in Sweden, Middle Europe and North America using thermal scanning from aircrafts or helicopters.

Thermal scanning and its supporting methods or methods used in parallel with it (for example pressure testing and image processing) can be used to examine the thermal performance of a building and the properties of building materials. Advanced image processing technology can for instance be used to compare the thermal behaviour of the object with different loads and in different conditions. In addition, if the interfering factors can be eliminated to a sufficient extent, calculation models could for instance be used to get more information about the structure.

The energy losses in buildings can be roughly divided as follows:

- losses due to heat conductivity of the building envelope
- losses due to air flows
    - controlled: caused by ventilation
    - uncontrolled: from air leakage

Energy is also used in water heating, household equipment, lighting, etc. Part of this energy is recovered as heat. Temperature of the indoor air, temperature radiation, rate of air flow, moisture, clothes worn by the people and their actions all have an effect on thermal comfort. Continuous draft and chilliness can cause health problems. The condensing of the moisture in the air on cold surfaces or structures increases the possibility of moisture damage and could contribute to the growth of mould.

The surface temperature of a structure is lower than normal in places where thermal insulation or its cladding has defects. Thermal bridges and air leaks also cause the surface temperature to decrease.

Evaluation of thermal performance is usually needed:

- for evaluating the need for renovation for different reasons
- when defects have been found in the building, in the structures or the indoor climate
- in quality control of new building

In building technology thermography can be used for numerous different applications, when monitoring the condition and performance of buildings, building parts or structures. Some example uses are:

- locating defective insulation
- locating air leaks

- checking windows and heat leakage
- detecting moisture damage
- locating objects inside structures, ie. pipes, ventilation ducts and anchors
- examining the performance of heating systems, ie. effectiveness, insulation defects, blockages in pipes, distribution of heat and malfunctions in the control units
- preventive maintenance
- condition of electrical devices

The applications presented above are only a few of the many applications for thermography. Thermal scanning of a building or its part can be done in several ways, depending on the structures and the purpose of the scanning. The more precise and advanced methods are used, the greater are the costs. For this reason the actions taken must be appropriate to the objectives and the achievable savings. In general, all the surfaces and structures must be checked.

The interpretation of results

There is lot of information about the indoor surface temperatures of structures, both theoretical and climate-chamber tested and there is heat transfer software available, by which we can simulate the joint temperatures of different structures and even the impact of air leaks. Air leaks decrease surface temperatures very quickly. In spite of these data and information, we actually don`t know how the surface temperatures vary in well constructed, high quality buildings. The crucial problem is: what are the lowest temperatures of different structures and structural elements, which could be considered as "normal" in any weather conditions and we could say that the structure in question is correct and free from as many defects as possible.

The interpretation problem could be divided into three parts:

- the limitations of the method (the thermography practice)

- the performance of the structures in various conditions
- the conclusions based on the results, taking into consideration the two previous factors.

The solutions mentioned so far are however mainly qualitative and their interpretation is based on knowledge about the structures and their thermal characteristics. If the temperature distribution differs from expectations, defects can be assumed to exist. Usually the results of thermal scanning are not processed at the site of measurement. The thermal images are saved on memory cards, recorded on videotape, accompanied with comments, for later analysis and interpretation.

The goal is that in addition to classifying observation, also the nature of the defect should be found. In an ideal case this would mean evaluating a U-value or finding the approximate value of moisture. In theory this would be possible in dynamic conditions, when a structure with different thermal characteristics cools down or warms up slower or faster than its surroundings.

The thermal scanning method can be divided in to two parts, namely quantitative and qualitative. Presently thermography is mainly used in the qualitative sense, ie. for locating insulation defects or searching for objects inside structures without trying to evaluate the absolute magnitude or impact of the defect. The quantitative methods would give better information about the object, but they require more time and expenses. For instance, a straight comparison of insulation defects on the basis of thermal images can be quite misleading, if the emissivities of the object surfaces are different or the objects were in different thermal conditions at the time of measurement.

Thermography could also be divided into passive and active methods. The passive method means imaging the object in natural conditions. The active or dynamic method requires an external heat source, which is used to affect the object for examining the desired property. An external heat source generates heat flow on the surface of the object under inspection. Thermal imaging of buildings is mainly counted as one of the passive maintenance applications. Thermal scanning of a building is usually applied to completed buildings, but it is useful also for portraying the details in buildings under construction. In principle the method could even be used already in the production stage, for example for quality control of building part producing industry.

In all applications a clear line cannot be drawn between active and passive methods. In maintenance also active methods can be used. For example, in Italy a method based on thermal scanning has been developed in building research that was originally used for mapping the direct and indirect (chemical reactions caused by moisture) damage caused by moisture in old buildings with artistic value. Because the restoration costs in these buildings are very high, it is essential to first examine the moisture damage. This can be accomplished by warming up the wall structure under inspection from the back side. The measured temperature distribution depends on the moisture levels, since the heat capacity of water is higher than that of dry material.

Moisture damage in buildings, especially in flat roofs, has been researched also using methods categorised as passive, that is, in natural conditions. The roofs have been scanned at night time and the moist areas have been visible as warmer than the surrounding material. This is again due to water having a higher heat capacity than dry material. Thermal scanning of flat roofs is for instance in the United States a typical consulting business. To locate air leaks and to separate them from thermal bridges air-tightness tests are used in the Nordic countries and also elsewhere in the world.

There is an ISO standard about thermal imaging of buildings, on which also the national standards are based. In practical situations the conditions described by the standard are difficult to achieve. The standard does not explain anything about interpretation.

3.3 Costs

The prices of the devices have come down in the last 5 years. Nevertheless investment costs are still quite high, including infrared camera, image processing software and supporting meters (air flow meter, relative humidity meter, contact temperature meter). The prices of real thermal imaging systems vary between 20,000 € - 60,000 € or more, depending on the model and accessories. There are also second hand markets for used devices.

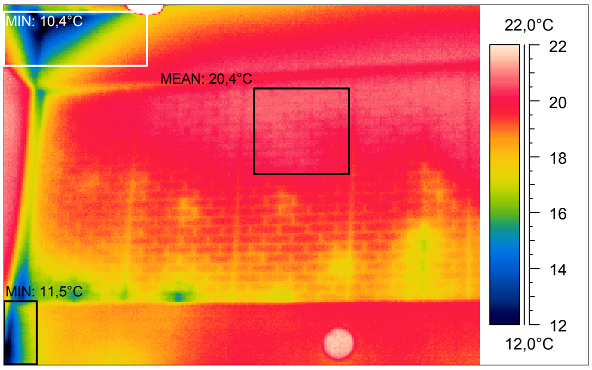
The prices of infrared services varies within a wide range, depending on the task and country. The costs are depending on the task, time consumed and the time for analysing results and for reporting. The customer should beforehand thoroughly judge the problem needs and the purpose for thermography. For simple tasks, prices may start at around 400 US-$ and go up for more detailed investigation to 1500 US-$ or more.

3.4 Examples

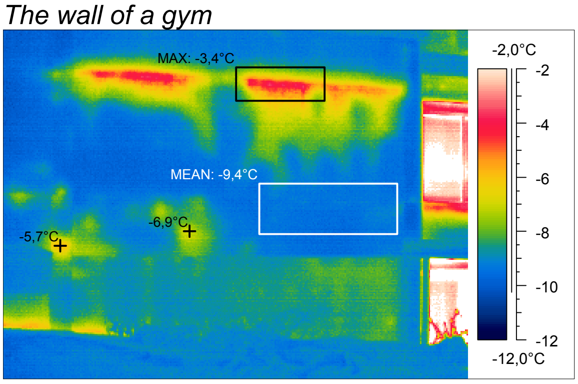
The conventional, passive use of thermography:

<u>A Gym (Finland)</u>

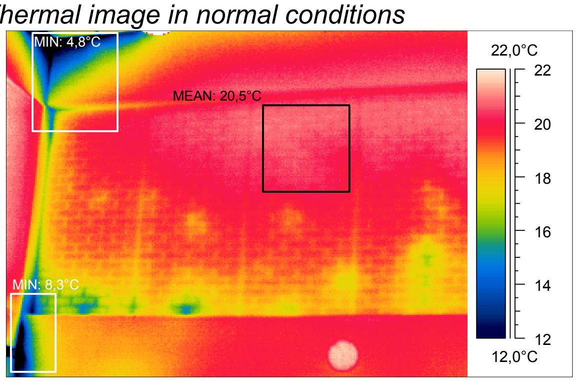
The wall of a gym



Thermal image in normal conditions



Thermal image of the wall of the gym - outside - heat leaks from the joints of the wall - see the indoor pictures

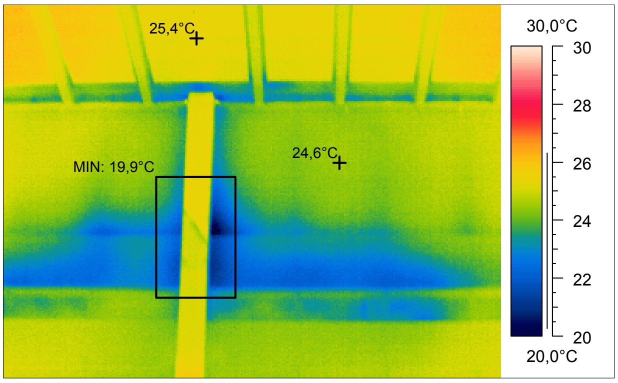


Thermal image of the wall under negative pressure drop - the joints of the ceiling and external wall have cooled compared with the normal conditions

Figure 3.1: *Example of use of thermography in analysing a wall.*

<u>A Swimming hall (Finland)</u>

The wall of the swimming hall

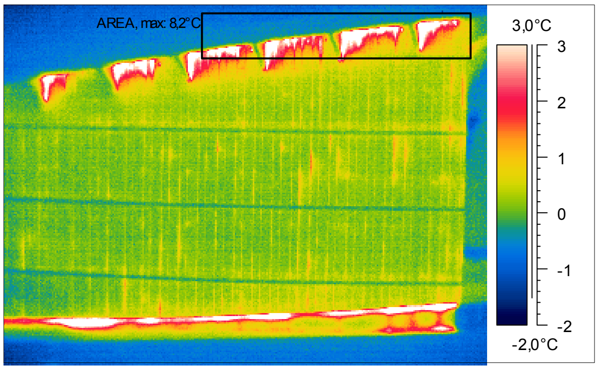


Thermal image of the wall, air and heat leaks

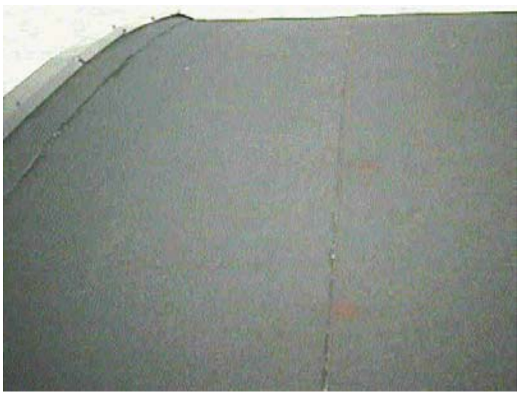
Figure 3.2: *Example use of thermography for analysing a wall in a swimming hall.*

<u>A Recreation centre - sports hall (Finland)</u>

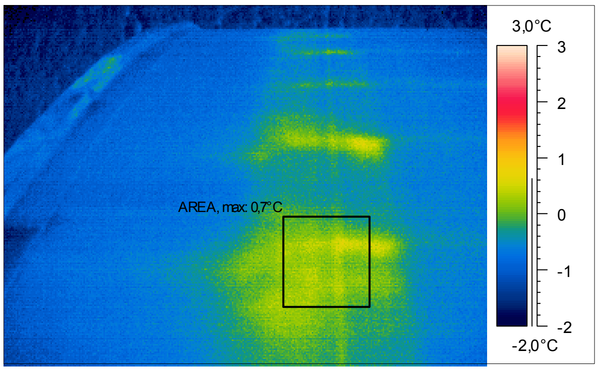
A tower part on the roof (Sports hall)



Heat leaks from the eaves and from the junction of the tower part and the roof



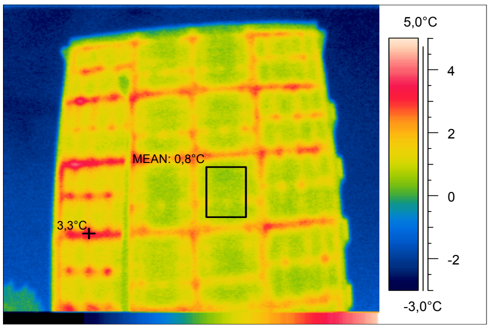
The roof of the sport hall



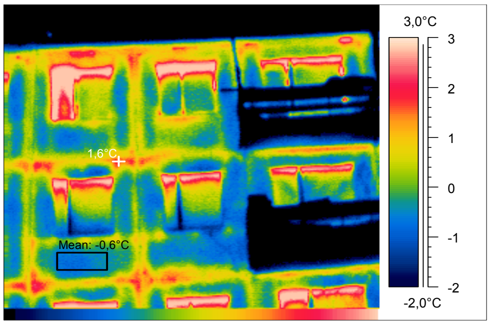
Insulation defects, adjacent to the roof truss (vapour barrier defects, too)

Figure 3.3: *Example use of thermography for analysing roofs.*

Multi-storey panel houses (Estonia)



Heat leaks from the seams, anchoring ties are clearly seen, insulation defects



5b. Heat leaks from the seams, insulation defects

Figure 3.4: Example use of thermography for analysing a multi-storey building.

3.5 References

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4. Airtightness and airtightness testing (by John Palmer)

4.1 Procedure

A supply of fresh air for the occupants of a school is vital for health and comfort and this will normally be provided by controlled ventilation by occupants using windows or a mechanical system. However, in all buildings a certain amount of unwanted and uncontrolled air will pass through gaps and cracks in the building fabric. This unwanted ingress of air into a school can cause occupant discomfort and also add substantially to the energy use of the building. Additionally, it can compromise the performance of any purpose designed ventilation systems. The degree to which the building and its components resist this unwanted air leakage is referred to as the 'airtightness' of the building. There are two main areas that contribute to the leakage, the building fabric and the elements, such as windows and doors that penetrate the envelope.

There are standards that define how much air should leak through the envelope of the building. These standards can apply either to the individual components or to the whole building (Ref. 1 AIVC TN 47). Whilst most countries have standards for component leakage performance, currently, there is no agreed standard for the leakage rate for a whole building that applies cross all countries, either in terms of pressure difference or leakage rates. For example, in the UK the standard for non-domestic buildings (including schools) requires a maximum leakage rate of 10m3/h of external air per m2 of envelope area, at an applied pressure difference of 50 Pa. In Italy the same leakage rate is to be achieved for a pressure difference of 98Pa. However, it is the whole building leakage rate that is the most relevant indicator of airtightness as this measurement takes into account the individual contribution of windows and doors and any gaps that may be associated with their installation at the time of construction.

4.2 Description

The airtightness testing of the building requires air pressure to be applied across the fabric of the building. The rate at which air passes through the fabric then indicates the airtightness of the building. The normal procedure is to produce the required air pressure with a fan, or number of fans, and measure the airflow at a number of pressures up to (and possibly above) the required standard test pressure.

The normal procedure for obtaining an airtghtness test is to engage a specialist testing contractor. The equipment required is specialised and skilled operators are required to carry out the test. This is particularly the case if high air leakage rates are discovered and remedial measures are to be implemented.

The testing contractor will require some information prior to commencing the tests. The information required will relate to the building form, fabric and services and may require the supply of a number of drawings. Key information is that which relates to the calculation of the overall building envelope area and the internal volume of the building. They may also need to have information about existing ventilation services, ductwork and major penetrations to the envelope. As the pressurisation fans need to be installed in a doorway information relating to access to suitable doorways will be needed. This may require a site survey to fully guage access issues.

The test involves assembling the fans into the selected opening (typically a doorway) and ensuring all internal doors are open. All external doors, windows and trickle ventilators should be closed and mechanical ventilation ducts and grills should be covered with air impermeable material. Other opening such as smoke extract vents should be closed but nor sealed.

The test then proceeds by applying increasing pressure with the fan and noting the airflow at that pressure. This will normally be done in steps up to the maximum test pressure. It should be noted that the pressures applied are small and do not form any risk to the building. In fact the pressures are so small that the wind can over-ride their effect and invalidate the test. It is therefore a requirement that test take place of wind speeds of less than 3m/s. the following procedure is as advised in CIBSE TM23.

1. With the fan turned off and temporarily sealed off with plastic sheeting or a purpose-made cover, measure the pressure difference at zero airflow rate.

2. Uncover and start the fan, increasing the speed slowly until a pressure difference of 55 to 60 Pa is obtained. Sometimes this might not be achievable owing to either the

size or the leakiness of the building; no test is possible if the maximum pressure difference obtainable is less than 25 Pa.

3. Check that no temporarily sealed openings have started to leak; reseal if necessary.

4. When the readings have stabilised, with the fan speed constant, take averaged values of pressure difference and airflow rate.

5. Reduce the fan speed and take further sets of readings over at least five (ideally ten) approximately equally spaced values of pressure difference, with none lower than 10 Pa.

6. Check and rectify the failure of sealing of building openings during the test, usually indicated by anomalous data.

A test may last for only one or two hours depending on the nature of the building and ease of access and pre-preparation of the building for the test. However, for some buildings with difficult access and when there is insufficient pre-preparation a test may take a full day. In addition to the basic test it is also possible to carry out a leakage audit to determine where leakage is occurring. The normal methods of determining leakage paths are:

- smoke tubes - for small leaks into a depressurised building
- thermal imaging to show cold air entering a warm and depressurised building
- whole building smoke test to observe air flow out of a pressurised building.

The air leakage of the building may be expressed in to ways. These are defined below.

<u>Air permeability</u>

The air permeability is the air leakage rate at a pressure difference of 50 Pa divided by the building envelope area (m^2), including the floor, walls and roof. Units are m^3 h-1 per m^2 of envelope area. This is referred to in European Standard prEN 13829.

Air Leakage Index

The air leakage index, is the air leakage rate at a pressure difference of 50 Pa, divided by the building envelope area (m^2) including the walls and the roof but excluding the floor.

Figure 4.1: Photograph of fan system being used to test a building of 2000m² floor area.(Courtesy of BRE Watford UK).

4.4 Cost

The cost of a test depends on a number of factors. Most importantly is the size of the building as that determines the size of the fan(s) needed to produce the pressure. Large buildings may require multiple small fans or a large single fan – as seen in the photograph above. This will influence the cost of the test as will the distance for the contractor to travel to the building. Typically in the UK, costs for a test vary between 2000-5000 Euro.

4.5 References

[4.1] Ventilation and building airtightness: an international comparison of standards, codes of practice and regulations. AIVC Technical Note 43 INIVE

[4.2] Testing Buildings for Air Leakage Technical Memoranda TM23 CIBSE London 2000

[4.3] The Building Regulations 2000 Conservation of fuel and power. Part L2. ODPM UK 2002.

[4.4] Airtightness Testing (TN19/01) BSRIA UK 2001

5. Lighting Analysis Procedures (by R. Cantin, G. Guarracino, C. Laurentin)

5.1 Procedure

A lighting analysis procedure aims to evaluate on site, lighting environment quality in educational buildings for refurbishment. This evaluation consists of criterion measurements and comparison with the capability of the lighting environment to satisfy needs.

To reduce the installed power of electric lighting, whilst providing sufficient illuminance, it would be necessary to revise the lighting system with equipment having the best energy efficiency. The lighting equipment should also be adapted to occupant needs and room function and to the amount of daylight.

According to the room function, the technological choices are guided by the following priorities: illuminances - absence of glare, colour and lighting direction, colour rendering - lighting uniformity.

For an efficient refurbishment, a lighting analysis procedure can be identified with the three main steps: recording existing the situation, measurements, and analysis.

Steps	Description
1. Recording existing situation	Site characteristics
	Daylight description
	Electric lighting description
	Lighting control system description
	Furniture description
2. Measurements, monitoring	Visual comfort
	Daylight availability
	Installed power
	Management controls
3. Analysis	Visual comfort
	Energy consumption

Table 5.1: Lighting analysis procedure.

5.2 Description

5.2.1 Recording the existing situation

Site characteristics

For a good monitoring procedure, it is important to note the characteristics of the site. Pictures are useful to be aware of the space, of the lighting environment and of the lighting system. It is necessary also to collect general information such as:

- Whereabouts of the person in charge of the measurements
- Day and time of the measurements
- Address of the building monitored
- Date of construction
- Longitude, latitude, altitude, orientation.

Daylight description

The first consideration in daylight is the dimensions of the windows with respect to the space to be lit. But the most useful parameter is the exact glazing area, which needs to be adjusted by the transmittance of the glazing. When performing on-site monitoring, it is useful to have access to architectural drawings when they are available. Measurements can then be easily written onto the drawings. On site, it is useful to take down the size and position of the furniture and possibly any interventions by the occupants to avoid problems linked to the lighting.

A ratio of the glazed area to the floor area, typically in the range from 5% to 30%, gives a rapid idea of the general brightness of the space over the year, and also the sensitivity of the space to outdoor climatic conditions. Furthermore, it is useful to note the following elements:

- Glazing type: single, double or triple
- Hue: clear, green, bronze, etc.

- Shading device: venetian blind, shutter, curtain, etc.
- Position of shading device : inside, outside, in the double glazing.
- Operational state of the shading devices
- Cleanliness of the system
- Basic description of the outside view.

Electric lighting description

This part of the procedure consists of a description of luminaire positions and the characteristics of the lamps and luminaires.

Lamps	Ballasts	Luminaires
- Fluorescent compact or not, incandescent, traditional or low voltage - Unitary power, diameter, length - Correlated colour temperature and colour rendering index - Flicker (yes or no)	- magnetic or electronic	- recessed, ceiling-mounted, wall, desk light. - Light output : direct, indirect, mixed - Number of lamps per luminaire - Size of the luminaire

Table 5.2: References and type of lighting equipment

Lighting control system description

Concerning a possible lighting control system in a school building, it is interesting to know if the occupants can switch off/on the electric lighting or if the lighting control is common to several rooms, or if the building is equiped with an automatic lighting control system. In this case, it is useful to know: the references, the type (time clock programming, occupancy sensor, daylight responsive lighting control system), possibility of manual control and type of variation with daylight.

Furniture description

This part consists of a description of ceiling, wall and blackboard type, flexibility of walls, presence of screen computers or if there is not, probability to install them, uses needing the luminaires turned off, possibility to operate a complete retrofit.

5.2.2 Measurements, monitoring

It is necessary to collect occupant opinions, to choose measuring devices and measure illuminances, luminances, and to collect installed powers. Lots of pictures can be taken with and without artificial light under sunny and overcast sky. The date, the time, the location and the author of the shot are recorded. All plans and sections must include a graphic scale and the north point must be indicated on the plans.

Visual comfort

The objectives of a survey are to collect subjective information on how the occupants perceive their lighting environment and working conditions. Furthermore, to have an opinion of visual comfort, it is necessary to measure: illuminances, lighting uniformity, lighting quality, including disability glare, presence of veiling-reflections on computer screens or on the blackboard and presence of shadows.

Daylight availability

Since the intensity of natural light varies, it is necessary to consider the daylight factor i.e. the ratio of the local illuminance to the simultaneous outdoor horizontal illuminance due to an unobstructed sky. The display of daylight factor contours provides a clear interpretation of daylight penetration in the monitored room.

Installed power

To measure the installed power, it is necessary to record the number of luminous point sources and the electric power of each source.

Management control

Observing the uses of each room and the presence of daylight, it is necessary to ask if the electric lighting in the room is switched on when it is not necessary or if the illuminances are above the recommended illuminances. The following disfunction could be recorded. In the corridors, the lighting is switched on in the morning at the beginning of the class and is still switched on during the day when no one used the corridor. In the classrooms, the electric lighting is switched on in the afternoon, even if the amount of daylight is enough.

5.2.3 Analysis

Visual comfort

A lux-meter is used for measuring the illuminances of useful surfaces: workplane, walls, computer screens, black-boards, etc. and then characterising indoor lighting distribution.

A luminance-meter is used for measuring luminance distribution. The objectives of these measurements are to avoid disability glare and transient adaptation problems. It also enables an assessment of whether the ratio of the task surrounding luminance lies between 0.3 and 3, and whether the ratio of the task background luminance to the remote surface luminance lies between 0.1 and 10, as is often recommended to prevent disability glare and transient adaptation problems especially at work stations. Vertical illuminance measurements are performed to assess the homogeneity or non-homogeneity of the luminance distribution in the field of view of an observer. They lead to the rating of the ability of a daylighting system to attenuate glare.

Many studies have shown that when occupants can control their visual environment, this improves visual comfort. For visual comfort evaluation, it is necessary to record if the controls are easy to use, have a good location, if there are specific controls for the general lighting of the room and for the luminaires lighting the blackboard or whiteboard.

Energy consumption

It is considered that if DF>3% for the most efficient zone (daylight zone) and DF>1% for the intermediate zone, then the use of a daylight responsive control system for artificial lighting can be considered (taking into account the energy cost). Furthermore, this daylight factor could be interpreted as a percentage of autonomy i.e. as the capability of a room to satisfy the illuminance level desired due to the amount of daylight available. Consequently, from the daylight factor, it is possible to determine the electric light necessary for the maintenance of the illuminance level in the room.

The retrofit of a building could be made only if the value of the specific power is clearly over the reference value. It should be close to quadruple for an annual occupation time of +/- 1 000 hours.

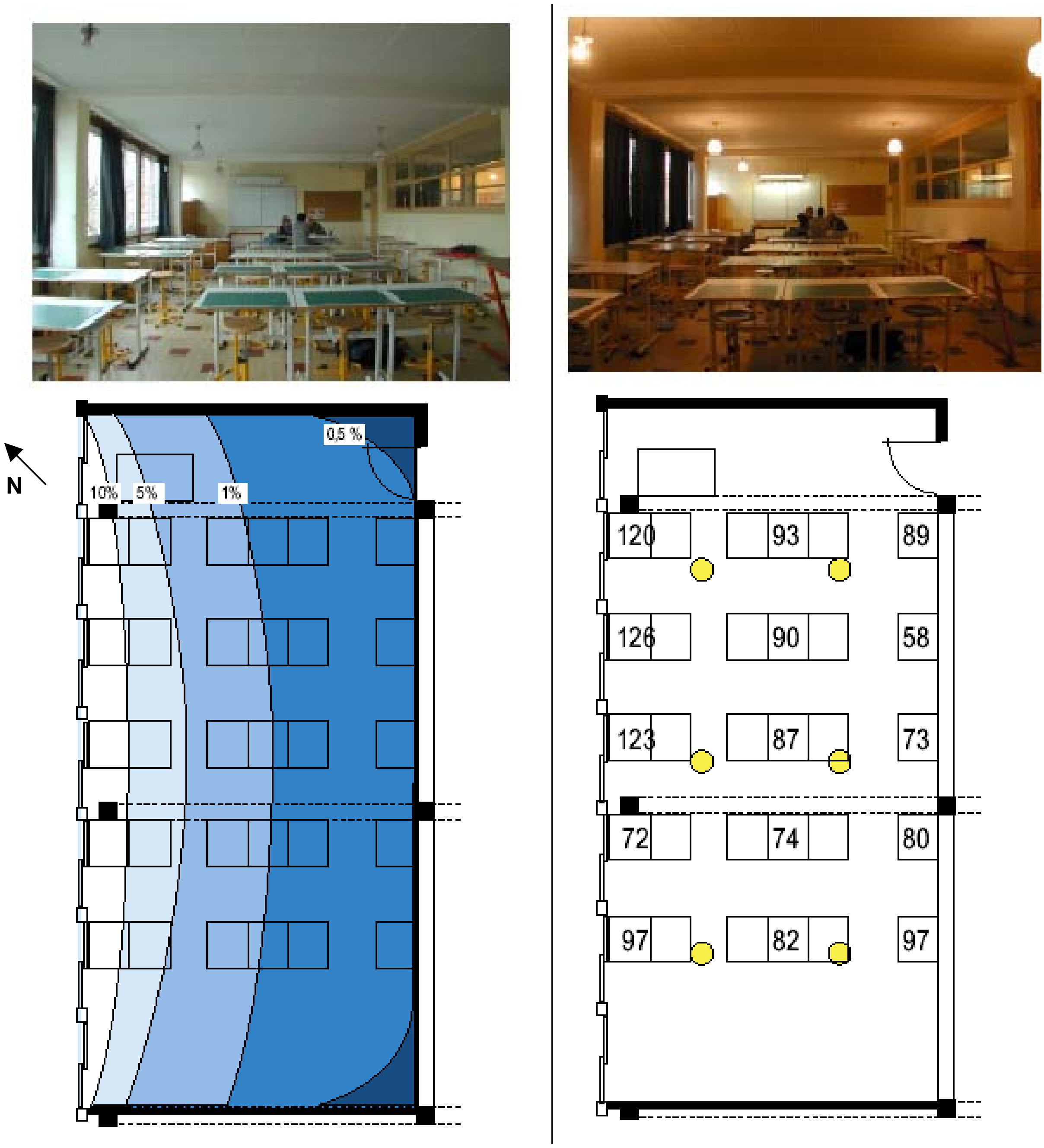
For reference, the existing installation could be compared with an installation of new fluorescent lamps, with high quality equipment. This installation requires 10 to 12 W/m^2. This allows us to know the effect of the retrofit on the electric consumption.

From the analysis, the building could be classified following some criteria as the visual performance (taking into account the illuminances recommended and the daylight factors), the power density, the visual comfort (taking into account the presence of glare) and the pleasantness of the environment.

In an other way, a specific calculation procedure can be used which takes into account the French Thermal Regulation 2000. The energy consumption is the sum of consumption of energy of different zones (offices, educational building, sporting establishment, storage and archives, reception hall and circulation spaces, other premises, etc.). However, the calculation of the lighting power (Watts) and the calculation of operation life of lighting are necessary.

5.3 Example

A classroom in a secondary school (Monge – French New Case study) has been studied with this lighting analysis procedure. Several pictures are taken with and without artificial light. A visit with pictures and monitoring, measurements with lux-meters gives DF isolines which are plotted using logarithmic interpolation. All daylight factors are measured carefully under overcast sky. The classroom is narrow and the indoor daylighting distribution is correct. The Daylight Factor is upper 1% except near the wall of the corridor where artificial lighting could be useful, particularly on dark days. In summer, solar masks created by some trees need artificial lighting. Illuminance values are lower than recommended (500lux). Lighting lamps and luminaires are inefficient. There is no building management system and poor quality of lighting on blackboard, glare on whiteboard using lamps without luminaires. About energy consumption, there are 6 lamps with a total power of 900W and a lighting efficiency of 7,5 lumens/Watt. For the blackboard, there are lamps of 36W. About the quality of daylight and artificial light, before retrofitting, 22% users reported that there was sometimes a problem of poor light at the blackboard and 50% reported problems of reflections or glare from the blackboard. In conclusion, some of the following actions could be done: use high efficiency lamps and ballasts, optimise the number of light fixtures in the room, incorporate controls that ensure peak system performance, successfully integrate electric lighting and daylighting strategies.



Interior picture and Daylight Factor isolines

Daylighting situation

Interior picture and illuminance distribution

Artificial lighting situation

Figure 5.1: Example of analysis.

5.4 Conclusion

This paper describes the main procedures aimed to evaluate the quality of the lighting environment in educational buildings to be refurbished. Different procedures can be developed but they generally follow three steps: recording the existing situation, measurement and analysis. Although only few pictures are inserted in the final report, there should be no hesitation in taking lots of pictures for the lighting analysis. Using simple measuring equipment, this procedure, in three steps, provides a pragmatic approach to lighting diagnosis. Recording the existing situation, taking measurements and monitoring give elements for reducing the installed electric lighting whilst ensuring sufficient illuminances. Further details regarding the lighting analysis procedures, the results and the equipment will be found in the references.

5.5 References

[5.1] Lighting techniques. Strategies and technologies. IEA ECBCS Annex 36: Retrofitting in Educational Buildings – Energy Concept Adviser for Technical Retrofit Measures.

[5.2] Solar control techniques. Strategies and technologies. IEA ECBCS Annex 36: Retrofitting in Educational Buildings – Energy Concept Adviser for Technical Retrofit Measures.

[5.3] Building bulletin 90, Lighting design for schools, Department for Education and Employment, Architects and Building branch, UK (www.teachernet.gov.uk/schoolbuildings).

[5.4] Daylight performance of buildings. Edited by M. Fontoynont. Published by James and James Science Publishers Ltd, London. 1999.

[5.5] An analytic model for describing the influence of lighting parameters upon visual performance. CIE 19/2.1 & 19/2.2. 1981.

[5.6] Lighting Handbook. Illuminating Engineering Society of North America. Ed. M. Rea, IESNA. 1993.

[5.7] Design guide for daylight responsive lighting control systems. IEA Report of task 21-B : Daylight in Buildings. 2000.

6. Labelling

6.1 Labelling : Energy Saving Acts in Denmark (by Kirsten Engelund Thomson)

The main requirements of the Danish Building Regulations, [6.1.1] [6.1.2], for thermal insulation is that buildings shall be insulated in order to avoid unnecessary energy consumption and to ensure adequate health conditions. One way of complying with the requirements is to calculate *the energy frame*, the energy required for heating and ventilation, where the calculations are based on the standardised method in European Standard EN 832:1998 [6.1.3].

In 1997, a new act “The Act to Promote Energy and Water Savings in Buildings” was passed in Denmark to promote energy and water savings and to increase efficiency in all utilisation of energy and water in buildings.

Energy Labelling is mandatory in residential buildings, public buildings and buildings used for trade and private service. Both new and existing buildings are included. Buildings, which are exempted, are buildings used for commercial production and for energy production and buildings with very low energy consumption.

The act is divided into two parts: one for small buildings (area under 1500 m^2) and another for large buildings. The energy rating for small buildings consists of a standardised rating containing information about the calculated consumption of energy and water and CO_2 emission of the building. The calculation method uses as a basis the same method as mentioned above in the Building Regulation. For large buildings energy rating is not calculated, but based on registration of the actual consumption.

For all buildings an energy plan shall be drawn up that includes proposals for profitable savings for all types of consumption of energy and water of the building. Furthermore, the energy plan shall include an estimate of investments and annual savings involved in the individual proposals and the estimated economy during lifetime of the measures proposed. Finally the plan shall state the user-economic cost-effectiveness of the individual proposals.

A new Act to Promote Energy and Water Savings in Buildings entered into force on 1 January 1997. The act is divided into two parts: one for small buildings (area under 1500 m^2) and another for large buildings. There are special rules for owner-occupied flats.

The Act to Promote Energy and Water Savings in Buildings is intended to contribute to reducing the total environmental impact in Denmark, not least emissions of carbon dioxide (CO_2).

6.1.1 Energy Rating of Small Buildings

The Act stipulates that, in future all buildings of less than 1,500 m^2 and all owner-occupied flats must be energy rated and an energy plan for them must be drawn up *when they are sold*. To be valid, the energy rating and energy plan should not be drawn up more than three years before agreement on sale is entered into.

The idea behind energy rating is to provide buyers with thorough knowledge of energy conditions in the building before they enter an agreement to buy. In addition, energy rating can be used to compare energy and water consumption in several different buildings. As large, individual variations in consumption energy occur, information cannot be based solely on the energy consumption of the seller. For this reason the energy rating takes its point of reference in calculated consumption, on the basis of a set of standard assumptions. Moreover, the energy rating includes a plan for proposals for implementing savings in the building, and the financial advantages to the owner of carrying out these proposals.

Authorised, specially trained energy consultants conduct the energy rating. "Normal use" is declined as a family consisting of the average number of persons who would normally live in a building of that size, with typical consumption patterns of an average family with regard to electricity, heating and water.

The energy consultant assesses the energy condition of the building and labels it A, B or C on the Energy Rating: A is the highest mark. Heating, electricity and water are assessed separately. When heating is being assessed, the marks A, B and C are further divided into five sub-categories from 1 to 5, 1 being the best mark. Thus the scale for heating goes from A1 to C5. The energy consultants note the estimated annual consumption of gas or district heating and total costs of heating on the Energy Rating. Similarly, the Energy Rating contains information concerning estimated consumption of electricity and water and the costs involved.

Energy rating for heating

Total energy consumption of a building (gross) for space heating and domestic hot water is divided into different *heat loss/energy demand* and into different *heat gain* that reduce the demand.

Heat loss/energy demand are 1) Transmission loss through the defined surfaces to the heated floor area of the building, 2) Ventilation loss, 3) Heating of domestic hot water, 4) Loss in heat pipes and domestic hot water pipes and 5) Loss in heat-producing plant.

Heat gain comes from 1) Solar radiation through windows, 2) Heat gain from persons, lighting and appliances (internal heat gain) and 3) Supplement from renewable energy. A distinction is made in the calculations between

- *Net heat demand*, which is the building's actual energy demand for space heating and domestic hot water

- *Gross heat demand*, which in addition to the above also allows for heat loss from domestic hot water tank, heat pipes and domestic hot water pipes as well as gain from renewable plants

- *Gross energy demand*, which in addition to the above allows for the efficiency of the main heating source.

The heat demand is determined for the whole building. Consumption, costs and energy rating etc. must be calculated on the basis of the *main form of energy supply*, for example an oil furnace. Small heat supply plants are often standard plants of the same size, and the heat loss will depend on the condition of the plant, independent of brand. For plants with an annual total net heating demand of less than 40,000 kWh, the following formula is used for calculating gross energy demand (Q_{BEB}):

$$Q_{BEB} = (DT \times TT + Q_{BVB}) / (1 - ST - LT)$$

where :

Q_{BEB} is the gross energy demand of the building in kWh/year (when loss in the heat-producing plant has been included in the calculation)

Q_{BVB} is the building's gross heat demand in kWh/year (when loss in the heat-producing plant has been included in the calculation)

TT is stand-by loss, kW

DT is operation hours (for boilers operating for the whole year, DT = 8,760 hours)

ST is stack loss = flue gas loss, %

LT is cover loss, %.

Energy rating for electricity

The building must be awarded energy rating for electricity and information must be provided about the size of electricity consumption as well as proposals for improvements. Calculated electricity consumption will depend on the energy conditions of the appliances that form part of the sale and on the calculated number of persons in the building and thus on the heated floor space area. Therefore appliances are calculated using the standard consumption of the building that is calculated on the basis of the heated floor area of the building.

Heated area of the building A_e	Flats	Single-family houses
[m^2]	[kWh/year]	[kWh/year]
$A_e < 60$	1600	3300
$60 \le A_e < 140$	300 + 23 * A_e	2650 + 12 * A_e
$A_e \ge 140$	3600	4400

Table 6.1: Standard Consumption for electricity.

Next, electricity consumption is corrected for the appliances present in relation to average consumption. The building is awarded an Energy Rating for electricity – A, B or C. The electricity rating is to signal the energy condition of the electric appliances of the building stock. The rating depends solely on the energy conditions of the electric appliances that are included in the sale of the building and are thus independent of the size of the household and the area of the building.

Energy rating for water

The water consumption should communicate a credible expectation of future consumption under specified circumstances. Calculated water consumption depends on the calculated number of persons in the building (and thus, indirectly, on the heated area of the building) and on the conditions of the water-consuming appliances and installations.

Heated area of the building A_e	Flats	Single-family houses
[m^2]	[m^3/year]	[m^3/year
$A_e < 60$	50	50
$60 \leq A_e < 140$	$1.6 * A_e - 45$	$1.6 * A_e - 45$
$A_e \geq 140$	180	180

Table 6.2: Standard Consumption for water.

Next, the calculation of the water consumption is adjusted for fittings, lavatories, dishwasher and washing machine present in relation to average consumption. The building is awarded an Energy Rating for water – A, B or C. The rating should signal that it is good to have water-saving fittings and efficient washing machines etc. and is exclusively dependent on the conditions of water-consuming appliances and thus independent of the size of the household and the area of the house.

Energy rating for CO_2 emission

The environmental impact of the house converted to CO_2 emission is part of the energy rating. CO_2 emission is calculated on the basis of gross energy consumption and the CO_2 content of the fuel used. A rating from A to C is awarded depending on the size of the CO_2 emission in the same manner as for electricity, water and heating. The environmental impact of energy consumption depends on electricity and heat consumption and on the type of fuel used.

6.1.2 Energy Rating of Large Buildings

Energy rating and an energy plan shall be drawn up *once a year*. Energy rating shall consist of a standardised energy rating based on inspection of the building and the owner's registration of actual energy and water use, and CO_2 emission. The energy plan shall include proposals for profitable saving for all types of energy and water use in the building. Furthermore, the energy plan shall include an estimate of investments and annual savings involved in the individual proposals and the estimated economy during the lifetime for the measures proposed. Finally the plan shall state the user-economic cost-effectiveness of the individual proposals. The energy rating scheme also covers non-domestic buildings.

6.1.3 Energy Savings

The expected energy savings and consequences for environment are in 2005 4 - 6 PJ heating, 3 - 600 GWh electricity, 5 - 10 mill. m^3 water and 0.6 - 0.8 mill. tons of CO_2 per year. Totally the savings amount to 2 - 3% of total heating and electricity consumption in these sectors. This corresponds to 5% of the expected reduction in 2005 in Energy 21 (the Danish Government's Action Plan).

6.1.4 References

[6.1.1] *Building Regulations*. Danish Housing and Building Agency. 1995.

[6.1.2] *Danish Building Regulations for Small Dwellings*. Ministry of Housing and Urban Affairs. 1998.

[6.1.3] *EN 832:1998 - Thermal Performance of Buildings - Calculation of energy use for heating - Residential Buildings.* CEN. Brussels, Belgium

[6.1.4] Aggerholm, S. et al. (1995). *SBI Direction 184: Energy demand in buildings* (In Danish, with an English summary). Danish Building Research Institute. Hørsholm. Denmark.

[6.1.5] Grau, K and Aggerholm, S. (1995). *Building's Heating Demand 95 - PC-programme for calculation of heating demand and energy frame - User's Guide.* (In Danish). Danish Building Research Institute. Hørsholm. Denmark.

[6.1.6] The following Danish legislative documents are available in English from The Danish Energy Agency, Amaliegade 44, DK 1256 Copenhagen K., Denmark or are available at www.ens.dk.

- Act to Promote Energy and Water Savings in Buildings, No. 485 of 12 June 1996.

- Executive Order on Energy Rating etc. in Buildings, No. 1169 of 16 December 1996.

- Executive Order on Fees and Liability Insurance for Energy Rating of Buildings, No. 1170 of 16 December 1996.

6.2 Ecoprofile (by Kari Thunshelle)

Ecoprofile is a method for simplistic environmental assessment of buildings and gives a good picture of the building's resource and environmental profile. Ecoprofile can be used as an internal management and steering tool for the building owner. The tool was developed in Norway. The Ecoprofile of a building is divided into three principal components:

- External environment
- Resources
- Indoor climate

The Ecoprofile method was first developed for office buildings, then for dwellings. A modified version is used for school buildings. An analyses will normaly be carried out by a trained assesor. Ecoprofile is translated into English and has been submitted to ISO/TC59/SC3/WG12 "Sustainable Building" as prenormative documentation for future international standardisation.

6.2.1 Goal

An *Ecoprofile* for a building will:

- give a quick and simple overview of the environmental impacts of the building
- be used as an internal management tool, to show a building's environmental condition
- give market advantages in connection with sale and rental of buildings
- be a basis for carrying out and prioritising environmental improvements
- form part of the documentation of a building's environmental condition

6.2.2 Areas of use for Ecoprofile

An environmental evaluation method such as Ecoprofile can, in principal, be used for three different applications:

1. As an *internal management and steering tool*, where the building owner, through environmental classification, gets a good overview of the building's environmental condition and what needs to be done to improve that condition.

2. To *environmentally classify buildings*. A good environmental classification can lead to a market advantage in connection with the sale or rental of a commercial building.

3. As an *aid in project engineering*, where the goal is to create a building in a way that the requirements for best classification are achieved for each and every parameter.

6.2.3 Classification

The Ecoprofile method is adapted to different kinds of buildings, eg. office buildings and dwellings. The three principal components in the method are given the designations ”External Environment”, ”Resources” and ”Indoor Climate”. Figure 6.2.1 shows the structure for Ecoprofile.

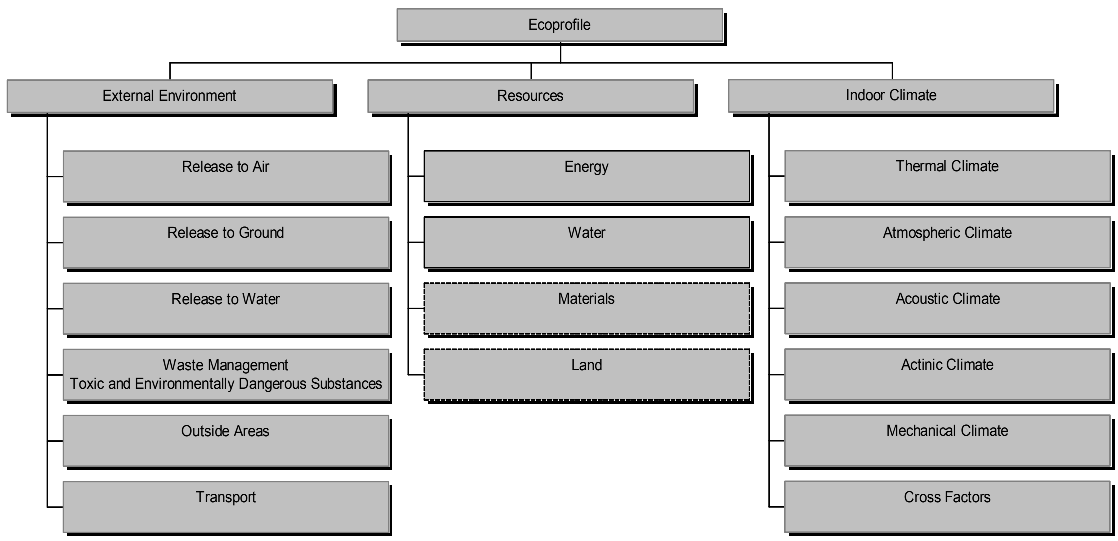


Figure 6.2.1: Structure for the three principal components of Ecoprofile.

The three principal components are divided into sub-areas that have different consequences for the principal components and are therefore weighted. Each sub-area contains a number of parameters, all together there are approximately 80 parameters.

Each of the parameters is individually evaluated and given a grade. A description of the classes is similar to that found in NS 3424 Condition Evaluation of Structures. The grading scale is from 1 to 3 where:

- Class 1 = Lesser environmental impact
- Class 2 = Medium environmental impact
- Class 3 = Greater environmental impact

Eventually a class 0 is going to be included that will represent a sustainable construction, but currently there is no basis for defining such a level.

This classification method is objective and it avoids the need for any measurement equipment, but rather is used as a checklist during a site visit. The results are processed by a computer software to generate the Ecoprofile graphs.

6.2.4 Results: Graphical presentation of Ecoprofile for a Building

A building's Ecoprofile can be visualised in two ways. The tool generates a bar graph, and three rose-diagrams, one for each of the three categories of environmental impact. The principal components can be combined in a bar graph according to large, medium or small environmental impact for external environment, resources and indoor climate, see Figure 0.2.

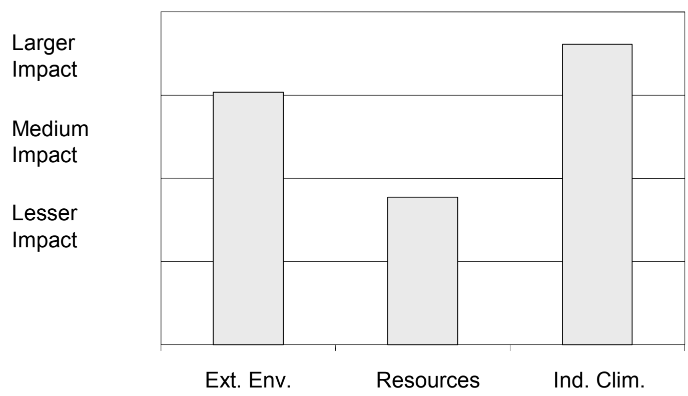


Figure 6.2.2: Graphical presentation of results at principal component level.

Rose diagrams show more detailed survey results, see Figure 6.2.3. High values represent a large environmental impact.

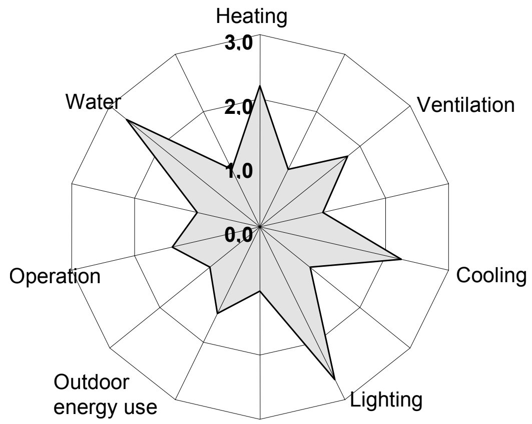


Figure 6.2.3: Graphical presentation of results as a rose-diagram.

Two additional computer programs are used to feed data into the computer software. These are :

- a database of energy consumption norms for different types of building, that show the potential energy savings that can be achieved by a building, and

- a program that is used to evaluate the effect of various parameters on the indoor environment (IAQ, thermal comfort. etc) in a building.

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RESUMÈ

Energy audits are the key procedure to identifying energy saving potentials in buildings to be retrofited. They can underline the necessity to start the retrofit process and can give indications which measures to focus on.
Recorded energy performance values can then serve as reference to which retrofit measures the savings can be related to.
Moreover, audits can be used during commissioning and after completion of the retrofit process to validate the implemented measures and to track building performance over the whole building life cycle.
This document covers a wide band of practical and useful methods, from monitoring the energy behaviour of whole schools or campus sites, down to the behaviour of single systems or just single components.