

Calculation Tools for the Energy Concept Adviser

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Abstract

The Energy Concept Adviser (ECA) is a tool to support decisions to improve energy efficiency of existing educational buildings through the identification of improvements to the building including its technical systems and the calculation of potential energy savings. It suggests systems or design elements to be considered for inclusion in the design.

To achieve this, the ECA provides various sources of information (eg case studies, retrofit measures) and two classes of calculation tools:

A tool called KULU to monitor energy consumption before retrofit (auditing) and after retrofit (control).

A suite of tools to determine primary energy demand which considers heating, cooling, lighting and system behaviour for educational buildings in all member countries of this annex.

The ECA provides a common calculation methodology as requested in the directive 8094/2/02 of the European Parliament and the Council on the energy performance of buildings. The ECA calculation methodology includes all the aspects which determine energy efficiency and not just the quality of the building's insulation. This integrated approach takes account of aspects such as heating and cooling installations, lighting installations, the position and orientation of the building, heat recovery, etc. Therefore, the methods provided in the ECA can be considered to be a first attempt to implement the ideas of the directive 8094/2/02 for the retrofit of schools and other educational buildings. The methods and how they were selected and adapted are described in this report.

Availability

This report is published in electronic form and available on the IEA ECBCS Annex 36 CD

It can also be received in its most actual form from the editor Fritz Schmidt

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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 projects 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, occupancy studies 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 HEVAC 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 Energy 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 throughout 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 overwhelming 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 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 features. There are no “rules of thumb” to enable a quick and easy estimation of the levels of required investment, prior to the detailed analysis of the building structure. Therefore, the development of an energy concept adviser for economical retrofit measures would be useful during the planning and realisation phase, on the one hand to help the investor to find the most energy efficient and economic energy saving measures and also to prevent 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.

Fraunhofer Institute of Buildings Physics in Germany is, on behalf of the Forschungszentrum Juelich, coordinator of 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 Fritz Schmidt, Germany. The chapters are written by individual authors and participants of the Annex 36. Special thanks to Fiona Fanning, Richard Daniels and Jean Lebrun for reviewing the document.

Stuttgart December 6, 2003

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1 Introduction (by Fritz Schmidt IKE)

1.1. Status at the beginning of Annex 36

Before the start of the Annex 36 project a questionnaire was distributed by Pekka Tuomaala, VTT Finland among the participating countries to get an overview of the utilisation of calculation tools for the retrofit of educational buildings. The following questions were included:

1. In general, how commonly are calculation tools being utilised in your country compared with other countries?
2. Please list the five most important and commonly used calculation tools being used in your country.
3. Have you been involved in developing any calculation tools?
4. How often are calculation tools typically used among different end-user groups?
5. What is the typical attitude of clients towards calculation results?
6. Is there any certification system of calculation tools in your country?
7. Are there any noticeable calculation tool development projects going on in your country?
8. Are there any organisations taking responsibility for calculation tools in your country?

Answers were received from nine organisations in eight participating countries (Germany, Sweden, USA, France, UK, Finland, Denmark and Italy). The answers could be summarised as follows.

Question # 1: According to the questionnaire, different calculation tools are most commonly utilised in Sweden, UK and Finland. This may be due to a longer tradition and a positive attitude towards these tools in these countries.

Question # 2: The most important and commonly used calculation tools varied considerably in different organisations and participating countries. Traditionally TRNSYS, DOE-2 and ESP-r are used in many countries, but the number of other - both old and new - tools is extensive.

Question # 3: Most of the participating organisations have been or are involved in the development of calculation tools. Therefore, the majority of participants are aware about realistic applications of calculation methods as research tools.

Question # 4: While engineers use tools weekly and sometimes even daily such tools are very rarely used rarely used by consultants and even less by architects. The frequency of utilising calculation tools is different among the different professions. Based on this questionnaire, it seems that the calculation tools available are not especially suitable for architects.

Question # 5: Attitudes among clients seems to be quite positive towards calculation tools. However to some extent, the attitude depends on clients themselves.

Question # 6, # 7 and # 8: Tools are under development in all participating countries. Also there are organisations which are taking responsibility of such tools. However, nobody seems to try to certify such systems.

To conclude, Pekka Tuomaala stated that the answers to the calculation tools questionnaire received from the different participating countries indicated the importance of calculation methods as valuable tools in building research work. There are several parallel development projects going on, and a large number of different simulation tools are being used. Therefore, the results of this questionnaire confirm the need of better international co-ordination. This conclusion was further confirmed during the course of the Annex 36 project.

A more detailed presentation of the questionnaire and the results can be found in a Subtask A report /1/. Based on these findings we developed a strategy for integrating calculations tools into the energy concept adviser. This strategy is described in the next subchapter.

1.2. The role of Calculation Tools for Retrofitting in Educational Buildings

There is a general procedure on how to proceed in retrofitting a building. The typical steps are described in Fig.1.1:

1. Collection of deficiencies of an existing building.

Usually energy might be included but very rarely energy is the driving force. Therefore it is necessary to provide tools to demonstrate benefits of taking into account energy saving measures during retrofitting. One class of such tools are those which support energy audit procedures. A special report on Energy Auditing Procedures /2/ was produced as one of the outcomes of the work carried out in Subtask C.

2. Determination of Measures

Once it has been decided to take into account energy during retrofit, it should be allowed for an easy selection of possible measures. Simple calculation tools like those available within the Energy Concept Adviser (ECA) produced in the frame of this Annex can be used to evaluate measures in regards to their efficiency in the building.

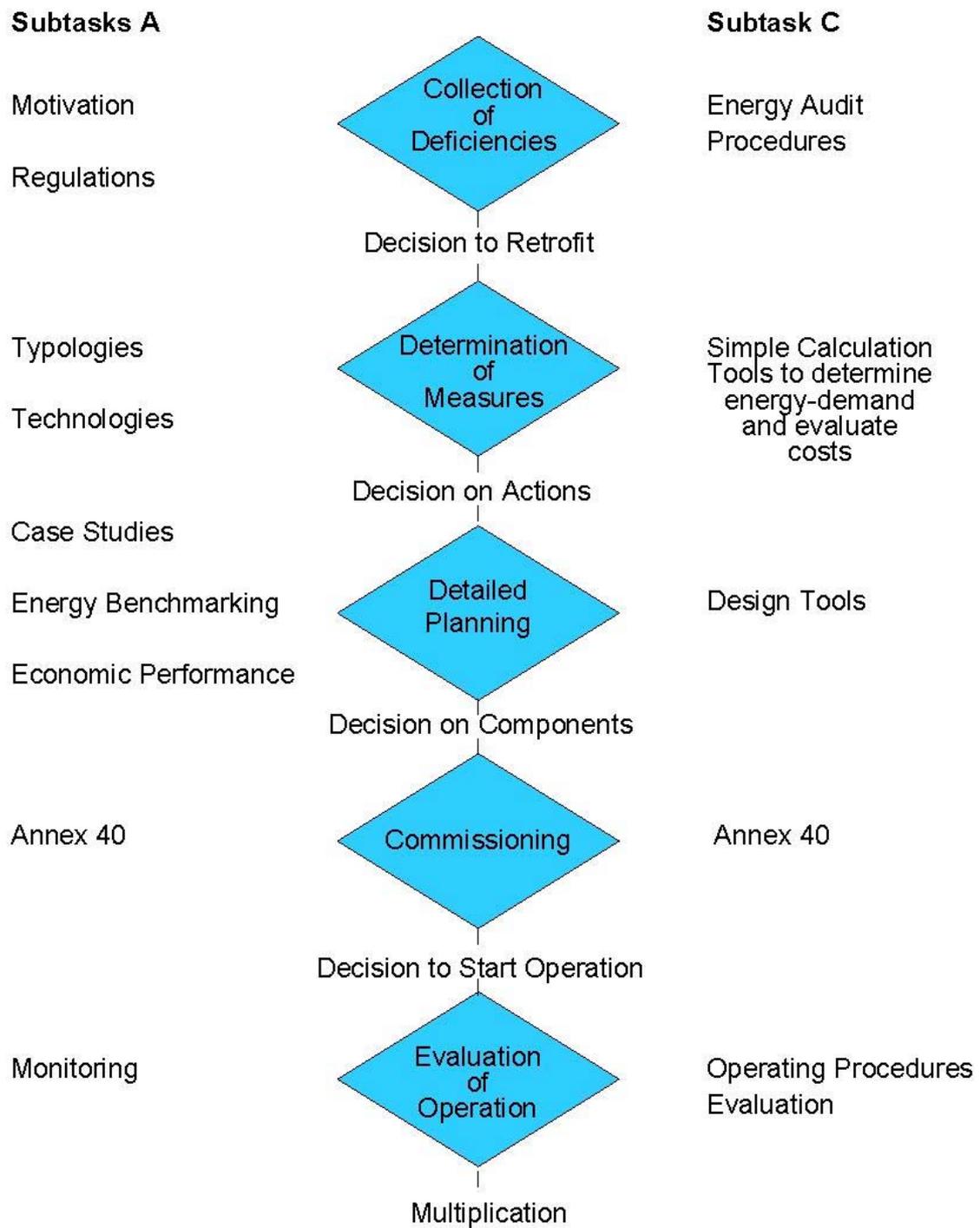


Fig. 1.1: Including Energy Optimisation into General Procedure for Retrofitting of Educational Buildings

3. Detailed Planning

Detailed planning requires Heating, Ventilation and Air-conditioning (HVAC) specialists. Very little support can be given at this stage through the Energy Concept Advisor. However, to those engineers who need special support Information on tool providers might be a first step.

4. Commissioning

Once the planning is finished retrofitting can start. After the retrofit process is finished commissioning takes place. Rules for commissioning will be developed in a separate Annex and can be used for retrofitting in educational building as well.

5. Evaluation of Operation

For energy saving, evaluation of operation is essential for the success of retrofitting. It requires tools which can be used to obtain the perspective of people occupying the building. Such tools typically support the comparison of expected and actual consumption data.

All of these steps can be supported by theoretical considerations (Subtask A) by case studies (Subtask B) and by computational tools (Subtask C). This is also shown in Fig. 1.1 and can be considered as one of the fundamental ideas of the Energy Concept Adviser.

1.3. Contributions of Subtask C to Annex 36

It was possible to draw several conclusions from the analysis presented in the last subchapter and derive various actions to be taken in Subtask C:

1. Subtask C should not try to develop new calculation methods or tools but rather give reasons for the selection of existing tools to be used in the ECA.
2. For the selection of the tools two sets of criteria were applied:
 - It should be simple tools applicable primarily during concept development
 - The tools should be able to evaluate measures proposed in Subtask A and under conditions which are defined only on a crude basis
3. Such tools have to be adapted for the analysis of educational buildings and particularly for schools
4. The adaptation has to be done under the assumption that the buildings are not yet optimised for energy efficiency and still have a high energy consumption which makes retrofit measures necessary.
5. It seems to be undesirable to provide design tools including computational fluid dynamics. However it would be helpful to have a list of recommendations (what to avoid) and a short description of "simple" measures to improve comfort.

6. In Subtask C it is necessary to concentrate on:

- C1 Simple Calculation Tools
- C2 Energy Audit Procedures
- C4 Operating Procedures

7. Connections to other subtasks should be as follows

Obtain from Subtasks A and B

- Energy efficient goals of retrofitting
- Selection of measures (options)
- Guidelines for operation and energy consumption targets

Provide the Energy Concept Adviser with tools and examples of use of such tools

1.4. Conclusions for the structure of the report on calculation tools

The results of the work from Subtask C will be presented in 2 reports. The first one is the report on audit procedures/2/. The second one is the present report on calculation tools which includes tools for both analysis and monitoring.

The work regarding calculation tools will be structured as follow:

Chapter 2 will present the working groups understanding of the role of design models in building design. It will concentrate on energy efficiency of schools and will try to give some correlation between the complexity of the design models and the details of the answers to be achieved.

Chapter 3 will describe the methods selected for the ECA. The criteria for the selection follow those given in the introduction of this chapter.

Each method is connected to real buildings and their utilisation by a certain set of parameters (data model). This is discussed in more detail in chapter 4. The parameters used in the ECA models will be described and the assumptions necessary to derive real values for a real educational building will be given.

Model equations and model parameters together form a simulation model. Chapter 5 will describe some of the work performed to validate the ECA simulation model. Both comparisons with more detailed models and measured data from real educational buildings, will be presented.

Chapter 6 will derive some conclusions from the validation work. It will explain the accuracy to be expected and identify some of the most critical parameters. Also it will attempt to give some hints how to use the simulation model of the ECA most profitable.

The report contains three appendices which describe the Climate areas provided for the ECA, and give user manuals for the ECA building evaluation code/3/ and the ECA monitoring tool KULU/4/

1.5. References

- /1/ Report on State of the Art Overview; Ed. IEA Annex 36 Working Document of Subtask A, T Mróz., H Erhorn, January 2003
- /2/ Energy Audit Procedures, Working Document of Subtask C, Ed. J de Boer, Nov.,2003
- /3/ ECA: <http://www.annex36.de> S Wössner
- /4/ KULU: <http://www.vtt.fi/kulu>

2 Modelling - Basics

A model is an abstraction of a part of the reality. Therefore different models can be used to describe the same reality. Each of these models is valid only in a defined context and all results of simulations based on a model are limited to this context. The limitations usually can be reduced by increasing the complexity of the model.

It is the aim of this chapter to describe the relevant context for modelling in the ECA. Based on this a short description of the models chosen for the ECA is given in the next chapter. Following this there will be a discussion on the limitations connected with the various models chosen for the ECA (see chapter 4)

Energy is used in buildings to meet a number of end-use demands, the most significant of which are space and water heating, lighting, catering, air conditioning and refrigeration, and equipment including, domestic appliances, computers, lifts and office equipment. The following figure illustrates the average breakdown of energy consumption by end uses in EU tertiary buildings /1/.

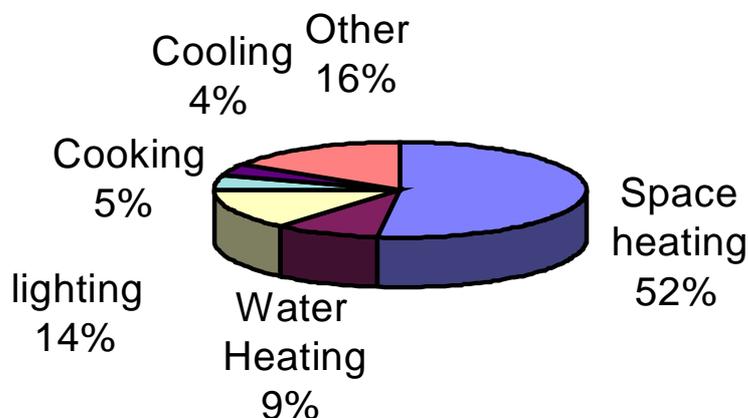


Fig. 2.1: Energy consumption by end use in the tertiary sector including also educational buildings

However there are substantial variations across countries depending on the climate and economical, cultural, historical conditions etc. In Finland, ventilation accounts for over half of the heating energy consumed in a school building. Ventilation, is defined here as both mechanical ventilation and leakage ventilation. If the external walls and roof leak a lot – for example, if the windows are in poor shape – ventilation may account for as much as 70 % of heating energy consumption. The thermal conductivity of the external walls and the roof accounts for approximately 40 % of heating energy consumption and the use of warm water for between 5 and 10 %.

Lighting has been observed to account for between 45 and 55 % of the electricity consumption in Finnish school buildings. Appropriate use of lighting has a major effect on the electricity consumption of a school. Kitchens account for 10 to 15 % of the energy used. The proportion of electricity used for electrical appliances (eg computers and equipment) depends upon the number of appliances installed and their efficiency. Fig. 2.2 presents a breakdown of the electricity use of a new school building that houses a great deal of electrical equipment installed.

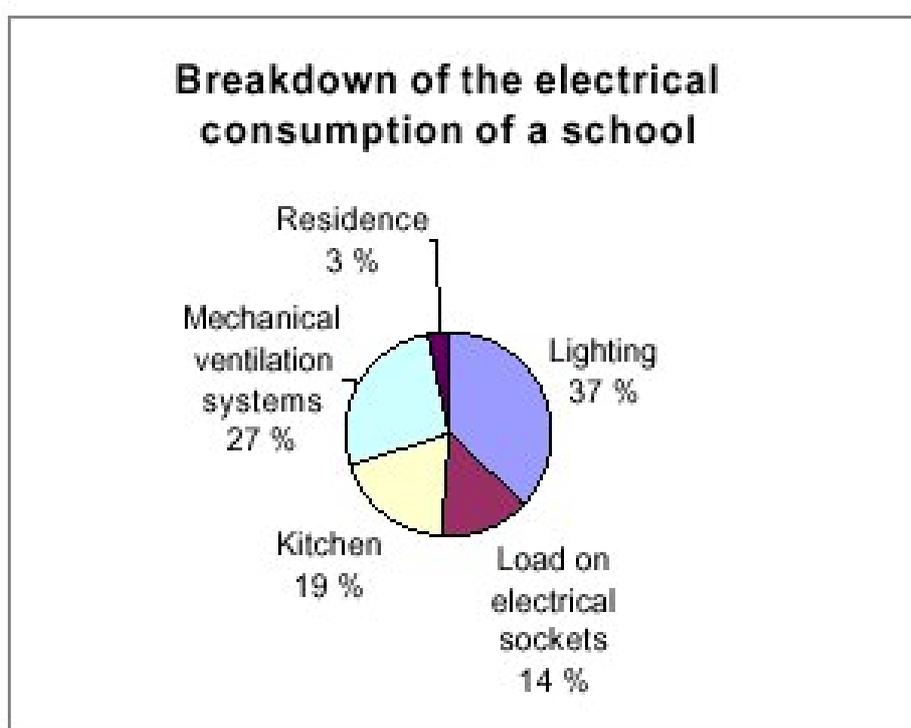


Fig. 2.2: Breakdown of the electrical consumption of a school.

Source: Energiaa säästävät sähkötekniiset ratkaisut. Opas julkisia rakennuksia varten. (Energy-saving Electrotechnical Solutions: A Guide For Public Buildings.) Motiva.

Annex 36 took an integrated approach to view the energy system of educational buildings. This is similar to the approach taken in the MOTIVA project /1/ to describe the energy system of a school. There the energy system of a school refers to the chain comprised of the functions that track the amount and costs of the energy used by the school as well as the functions through which the school attempts to reduce them. Methodical efforts lead to results: the first tangible results are that new measures are taken, events are held and energy issues are incorporated into teaching. An energy system yields real benefits as a consequence of these actions. The manner in which a school manages its energy use – that is, its energy system – was described in the MOTIVA project in this manner:

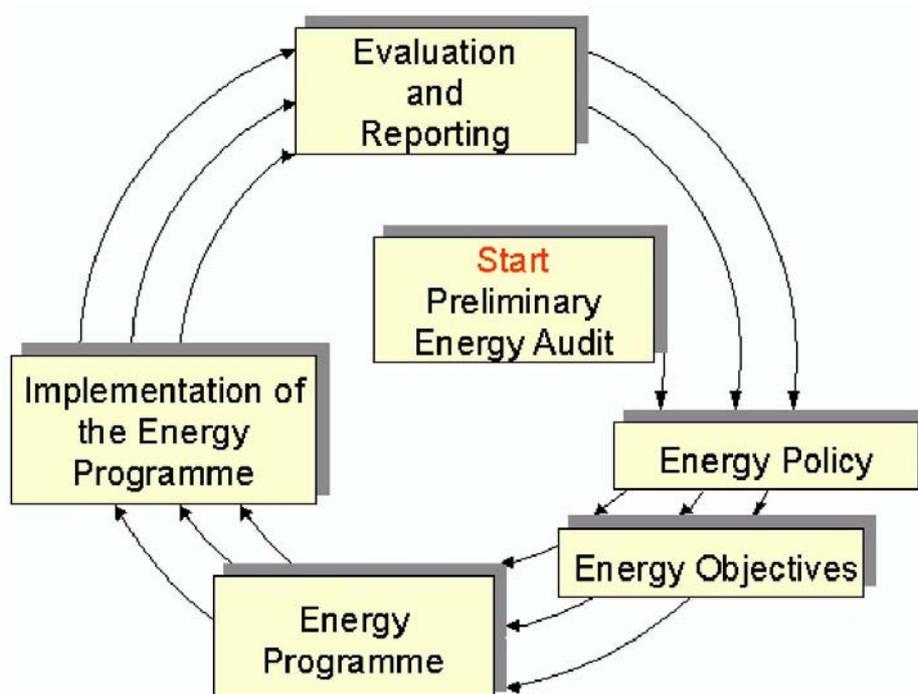


Fig. 2.3: Management of energy use at schools (from MOTIVA)

Constant learning and development of systems is the most important element in the energy system of a school. The system is set up step by step, and each school will implement this in its own way. Active teachers who are interested in their environment will find new ways of including their work on the energy system into their teaching. Positive achievements inspire people to tell others about them, and this in turn fuels the rise of new ideas. The environmental and energy system is usually launched as a separate project, but in time it becomes an integral part of the school's operations which is as intended.

It is recommended that the tracking of energy use begins with a preliminary audit. This will allow the user to arrive at a rough estimation of the potential savings. The Audit Report /2/ produced in Subtask C describes some principal methods. The third part of the MOTIVA guidebook /1/ presents an example of how to conduct an energy audit as part of the student's work.

A school's "energy policy" is a short but important declaration of the objectives the school has set in its drive to be as energy-efficient as possible. The school's government is responsible for both drafting and signing its energy policy. The ECA is intended to support decision makers in this task. The content of the energy policy is reviewed annually. After an energy policy (either officially signed or a preliminary policy) has been achieved and an energy audit has been performed, the energy conservation targets can be specified.

A school's energy programme is a plan that comprises the tasks that must be carried out to achieve targets, the people responsible for these tasks and a schedule. This plan has to be implemented. Once the implementation is finished a continuous control is necessary to make the achievements sustainable.

References

- /1/ MOTIVA: SAVE End Users' Energy Guidebook for Schools,
ISBN 952-5304-06-X,ISSN 1456-4483, Copyright Motiva, Helsinki, 1999
- /2/ J. de Boer, Ed Energy Audit Procedures, Working Document of Subtask C,
Nov.,2003

2.1. Role of Models (by F. Schmidt, IKE and J. Pietilainen, VTT)

Energy is needed to provide comfort. Comfort in regards to temperature requires heating or cooling. Comfort concerning air requires ventilation and control of humidity. Comfort concerning lighting requires a combination of daylighting and artificial lighting.

Comfort has to be specified through requirements. Requirements have to be defined for both times with and without usage of the building (operation times without usage include nights, weekends or holidays). Comfort has to be provided during usage times only. Thus requirements during other times are less stringent. However to reach certain conditions time and additional effort is required.

Measures to provide comfort conditions include

- Construction of a building which fulfils comfort requirements as far as possible
- Installation of technical equipment which improves conditions in a building where necessary
- Operation of technical equipment with a minimum of effort which means the highest possible efficiency.

The effort necessary to fulfil energy demand through technical equipment can be reduced by

- Adaptation of system size to energy demand of building
- Co-ordination of user need and system operation
- Operation of all systems at optimal points

For existing buildings it is possible to use the following strategy to determine comfort conditions in the building

- Determine the possible energy demand through energy balance
- Select systems to provide the energy required and determine the primary energy need
- Select operation conditions to reduce energy consumption
- Choose measures to reduce energy consumption
- Evaluate costs and determine payback times
- Control energy consumption and
- Determine further measures to improve energy efficiency

Thus energy management is a continuous process as already indicated in Fig. 2.3. Information technology can support this process in different ways.

- An analysis of the energy efficiency of the building can reveal measures to reduce the energy demand of the building. To start modelling therefore a thermal model of the building has to be selected.
- The co-ordination of the user behaviour, the system operation and the energy demand will reveal measures to reduce energy consumption. Thus the thermal model of the building has to be supplemented by a user model and a model which describes system behaviour.
- To be able to select possible measures to be used on the building it is necessary to be able to evaluate the possible measures. Very often economic criteria are of the greatest importance. Economic Calculation procedures are therefore discussed in the context of the ECA modelling too.
- To make the energy savings sustainable, continuous control of the energy consumption and management of the energy system are necessary. Tools to collect and to evaluate consumption and other energy relevant data are therefore of great importance too.

All the tools used have to be simple ones to support the decision makers and those that support energy saving at schools effectively. More complex tools are desirable or even necessary only if we consider buildings with high energy consumption as might be found in universities or if it necessary to support specialists in solving problems which require more detailed results.

Whatever happens the results produced through the ECA tools must be easy to understand. Thus we will concentrate on integral values (eg energy consumption per year) and comparisons on a more or less qualitative basis (eg measure A will reduce energy consumption by a% and have a medium payback time).

For the ECA the most important element is the simulation of the thermal behaviour of the building. This area will be elaborated to extend the understanding of the role of modelling.

Numerous models, codes and simulation technologies exist to do this task. The majority differ in

- Time resolution
- Details of building description and
- Physical effects that are taken into account

Corresponding to the different model complexity results in different detail are achieved. A model is considered to be correct (consistent with the modelling goals) if the anticipated results can be achieved with certain accuracy. (Additionally it is considered to be efficient if this can be done with a minimum of computer resources). Consequently, if the simulations are restricted to well defined applications and clearly stated results it is possible to optimise the models to obtain satisfactory results (considering for example uncertainties in boundary conditions and information on actual operation) with most simple models. The following

table gives an overview of assumptions for models to predict building behaviour and the possible details of the result.

Tab. 2.1: Correlation between modelling detail and results to be achievable

Time interval	Building description	System description	Detail of result
year	Whole building zone	Effort number	Energy demand whole building
month	Whole building many zones	Effort number	Energy demand each zone Estimate of energy consumption
hour	Whole building many zones	Diagram model	Energy consumption
minutes	Selected rooms	Detailed model of selected systems	Detailed behaviour of system
seconds	Selected rooms	Detailed model of selected systems	Emulation of control system

2.2. Energy demand (by Fritz Schmidt IKE)

Energy demand is usually calculated through energy balances. A well known presentation of such balances is the one given in EN832 (reference!). According to this standard three external sources of energy are distinguished:

- Energy input for heating (Q)
- Solar gains (Q_s)
- Electricity for lighting and technical equipment

And two sources of internal gains (Q_g)

- People (Q_i)
- Heat recovery

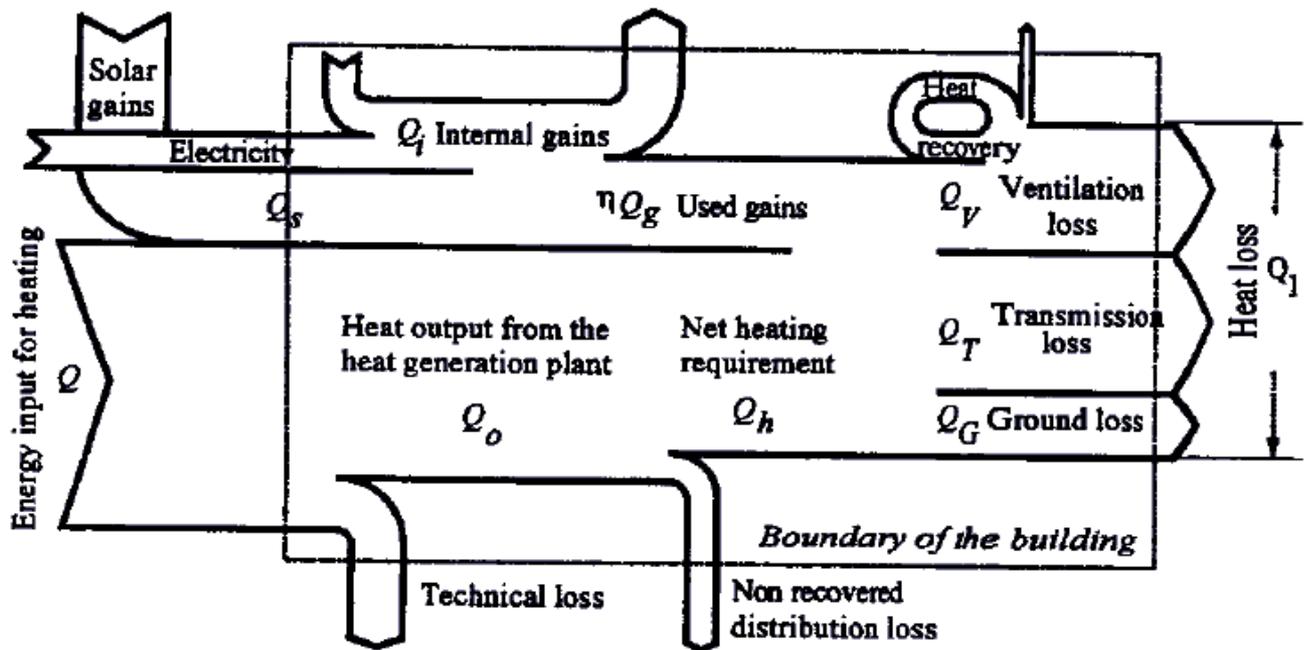


Fig. 2.4: Energy balance associated with a building according to EN832

Energy is lost through:

- Ventilation Q_v
- Transmission Q_T
- and to the ground Q_G

In addition energy is lost during heat generation and heat distribution and gained through heat recovery. All of these processes are dependent from both the system used and its operation. Usually this is expressed through the energy efficiency number associated with each technical system. This will be elaborated in the subchapter on energy consumption. For the determination of the energy demand however it is necessary to assume ideal operation conditions.

The heat loss Q_l has to be accounted for through usable internal gains, heat recovery and heating energy provided by the heating system. The heating energy provided by the heating system is therefore called heating demand.

Finally solar and internal gains can only be used as long as outside temperature is low enough to make the losses larger than these gains

To adjust temperatures in a room to the comfort conditions demanded from the user it is necessary to provide

- Adjustments to heating energy for the winter season
- Adjustments to the cooling energy for summer time temperatures
- Latent energy to the humidity of air in a room

The different physical phenomena considered in standard applications are shown in Fig. 2.5.

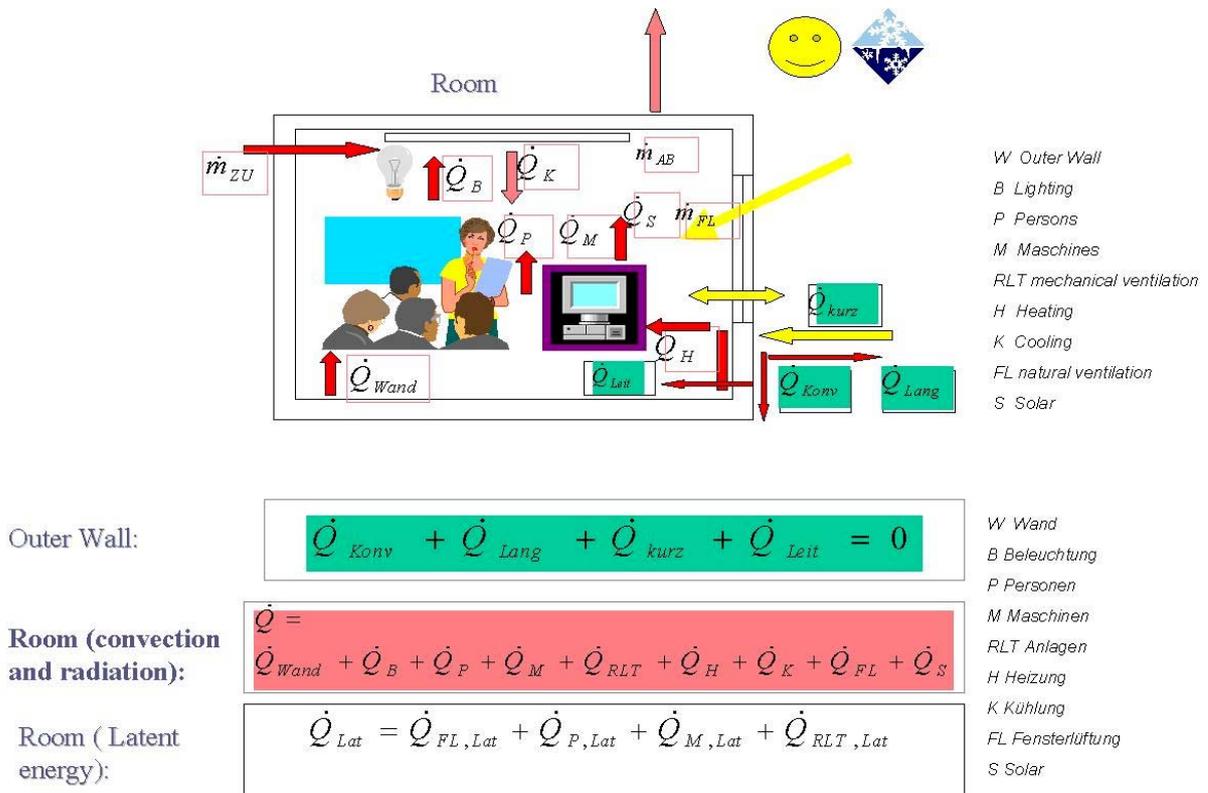


Fig. 2.5: Energy balances in room or zone - detailed description

The dot means that we consider loads (energy/time). We distinguish three balances

Energy balance in the room

$$\dot{Q} = \dot{Q}_{Wand} + \dot{Q}_B + \dot{Q}_P + \dot{Q}_M + \dot{Q}_{RLT} + \dot{Q}_H + \dot{Q}_K + \dot{Q}_{FL} + \dot{Q}_S$$

where

\dot{Q}_{Wand} storage from the walls

\dot{Q}_B lighting

\dot{Q}_P persons

\dot{Q}_M equipment

\dot{Q}_{RLT} mechanical ventilation

\dot{Q}_H heating demand

\dot{Q}_K cooling

\dot{Q}_{FL} *natural ventilation*

\dot{Q}_S *solar*

\dot{Q} *energy change in room.*

$\dot{Q} = 0$ means room conditions (room temperature) remain constant

Energy balance on the outer wall of the room

$$\dot{Q}_{Konv} + \dot{Q}_{Lang} + \dot{Q}_{kurz} + \dot{Q}_{Leit} = 0$$

where

\dot{Q}_{Konv} *Convection*

\dot{Q}_{Lang} *long wave solar radiation*

\dot{Q}_{kurz} *short wave solar radiation*

\dot{Q}_{Leit} *Conduction*

and energy balance for latent energy in the room

$$\dot{Q}_{Lat} = \dot{Q}_{FL,Lat} + \dot{Q}_{P,Lat} + \dot{Q}_{M,Lat} + \dot{Q}_{RLT,Lat}$$

with

\dot{Q}_{Lat} *Latent energy total*

$\dot{Q}_{FL,Lat}$ *Latent energy contribution due to natural ventilation*

$\dot{Q}_{P,Lat}$ *Latent energy contribution due to personas*

$\dot{Q}_{M,Lat}$ *Latent energy contribution due to equipment*

$\dot{Q}_{RLT,Lat}$ *Latent energy contribution due to mechanical ventilation*

Again each of these phenomena has a different time-constant and can be modelled in different ways reflecting different aspects of behaviour and giving results of different detail. Please note again simple models are adequate if average results are required. A more complex model does not necessarily mean an improvement of these results but it is necessary to obtain more detailed analysis.

2.2.1 Heating

How to describe comfort during wintertime conditions

A room is felt to be comfortable if the room temperature remains during the utilisation period at a requested value (with only small deviations) and the temperature distribution in the room is quite uniform. Due to the local distribution of heat loads an almost uniform distribution of temperature can only be reached by using elaborated design and control technologies, which are not subject of this report.

Energy is necessary to reach this conditions. This energy is called heating energy.

Use of simulation to determine the heating demand for winter conditions

To determine the heating demand for winter conditions by simulation it is necessary to solve the energy balance equation for the building. Usually this is done by setting the comfort conditions and determine \dot{Q}_H (heating demand) in a way that \dot{Q} becomes 0.

Numerous models and codes exist to do this. The methods implemented in the ECA will be described in chapter 3 .

2.2.2 Cooling

How to describe comfort under summertime conditions

There is a linear correlation between room temperatures felt to be comfortable and outdoor temperatures[1]. Values applicable for Germany are given in column 1 and 2 of Table 2.2.

Tab. 2.2: Correlations between average monthly temperature, allowable room temperature and unusable heat load for residential buildings and schools

Maximum Average Monthly Temperature [°C]	Maximum Allowable Room temperature [°C]	Normalised Maximum unusable heat load ³ [Kh]	
		Residential building	Schools
< 16,5	25	8000 ¹	11000 ²
< 18,0	26	11000 ¹	14000 ²
< 19,5	27	14000 ¹	17000 ²
< 21,0	28	17000 ²	20000 ²
< 22,5	29	20000 ²	23000 ²

1) Determined through simulations [1] 2) Extrapolated assuming a linear correlation 3) Normalised to average monthly heat loss coefficient

A room is felt to be comfortable if the room temperature exceeds the maximum allowable room set point temperature only in less than 10% of the time the room is used./1/

Various methods are available to determine room temperatures during the utilisation of a room.

Each method should take into account that:

- people like to open the windows in summer time to decrease temperatures (air change rate may increase by a factor of 4)
- walls are able to store heat, which results in a delayed reaction concerning heat balances
- actual utilisation of the room (working days, holidays, weekends)

To take these effects into account, detailed hourly information is required which can be gained either from measurements or simulations. In the frame of a project like Annex 36 the only way to collect meaningful hourly data is to use simulation.

Use of simulation to determine the cooling needs for summer conditions

Simulations of building behaviour during summertime can be used to

- prove that the conditions for comfort are met under the assumed building behaviour
- investigate modifications to the building parameters to meet comfort conditions
- estimate the energy necessary to generate sufficient cooling to meet the comfort conditions.

To derive such information two strategies were proposed for this project:

- the performance of hourly balance calculations which allow direct determination of the times when the room temperature exceeds the maximum allowable set point room temperature.
- the performance of monthly balance calculations. This however requires an estimation of the hourly conditions for each month and to derive averaged correlation parameters which map the hourly results to monthly calculations.

Hourly calculations

Hourly calculations allow flexible modelling of user behaviour, internal loads and solar loads which all influence the thermal building behaviour under summertime conditions. If hourly calculation methods and data to generate simulations for a specific building are available, then these should be used.

Monthly calculations

Two alternate monthly methods were investigated. These were:

- the method according to DIN 4108-6 (monthly calculations) developed in SANIREV /2/
- the method according to TETD/TA developed in TOBUS/3/.

The SANIREV method relies primarily on results available from ISO/DIN 13790 calculations.

The TOBUS method requires a typical day to be defined for each climate region that required to be considered

For the ECA we decided to apply the SANIREV approach which will be discussed in more detail in the chapter X.

References

- /1/ Deutscher, Elsberger, Rouvel: Vereinfachte Berechnungsverfahren für den sommerlichen Wärmeschutz. Endbericht zum AP 1.1 des SANIREV Vorhaben, Feb. 1999. (German only)
- /2/ Kolmetz, S.: Thermische Bewertung von Gebäuden unter sommerlichen Randbedingungen - Ein vereinfachtes Verfahren zur Ermittlung von Raumtemperaturen in Gebäuden im Sommer und deren Häufigkeit. Diss. Uni. Gesamthochschule Kassel, 1996. (German only)
- /3/ NATIONAL OBSERVATORY OF ATHENS (NOA) and DANISH BUILDING RESEARCH INSTITUTE (SBI): TOBUS A decision-making tool for selecting office building upgrading solutions Contract No JOR3-CT98-0235 FINAL TECHNICAL REPORT Reference Number 00-040 25/08/2000

2.2.3 Lighting

Many problems in lighting design, both artificial as well as daylighting, can now be treated and solved with simulation software. Depending on the complexity of the problem, the stage of the building design process, the desired accuracy, as well as the quality of the output information, the application of more sophisticated tools is often the only way to proceed. Although these tools normally ask for detailed modelling, require a thorough knowledge of the programs, demand high computational power, and the modelling processes have simplified over the last few years, they still can be rather time-consuming.

Complex simulations are often not appropriate to outline basic daylighting strategies in early design stages and to solve simple, frequently occurring problems (eg the sunshine duration at considered spots or a general decision about the type of rooflights to select), because it takes too much time to use them, ie, they are not cost-efficient.

The development of simple design tools has been, and still is, motivated by a number of reasons:

- Historically, due to the need to approach daylighting problems (without the support of computer technology being available), a number of simple tools, often closely tailored to practioner's needs has evolved. These tools deliver fast and generally sufficiently accurate results; as the majority have been well-tested and validated.
- Simple design tools like tables, nomograms etc. are often the outcome of a "knowledge compression" from complex parametric studies. The required data are, for example, obtained from model studies under artificial skies or numerous computer program runs. The interdependence of design parameters can then be studied quickly for example by defining for atria design and certain paths of boundary conditions in a nomogram, and then finally giving the daylight factors in the adjacent offices. These tools are based on extensive experience. The parametric variations do not need to be performed again by the user of the tools.
- With computers being available at almost every workplace, a number of simple computer tools were developed and are still in use. Simple programs or simple parametric inputs to

more sophisticated tools deliver fast solutions for specific problems while keeping modelling efforts and computation time limited. These are especially suited for performing simple variations of parameters (eg varying the window size and placement). The implementation of equations in spreadsheets and their "display" in diagrams with programs like MS-EXCEL, is fast and convenient to use.

With hundreds of design tools existing in the field of daylighting, a survey has been performed in the frame of IEA Annex 29 (TASK 21 /ECBCS). This survey did not and could not attempt to cover all available and developed tools. Rather the survey was a collection of various types of tools and of the different fields of application. Tools based on analytical solutions, tables, nomograms, diagrams, so-called protractors, simple computer tools, typological studies, and also the method of using scale models are described. The tools provide support at the various stages of the design process helping to judge the impact of the design on natural lighting conditions: building site and building layout planning (ie sunshine duration at considered spots, shadow and reflection analysis), typological support for the selection of a daylighting strategy, determination of the type and size of daylight openings and the corresponding daylight factors for different daylighted rooms, as well as energy efficient and thermal aspects of lighting design.

The survey results were based on responses from a questionnaire distributed to the participants of IEA SHC TASK 21 /ECBCS Annex 29. In total 18 tools are presented and discussed in the survey, including several newly developed tools.

Details of this survey were published as an IBP report (J. de Boer, H. Erhorn Survey Simple Design Tools, IEA solar heating and cooling programme Task 21, Annex 29 Daylight in Buildings May 1999, T21/C4-10/GER/98-05).

2.2.4 Climate data

Climate data are taken from Test Reference Years (TRY). A TRY is a collection of weather data for a given location and for one year. Usually TRYs are given as hourly sets of simultaneous weather data. For the purpose of the ECA we had to use monthly mean values or sums. Such data are normally published by the national meteorological services.

The main purpose of a TRY is to assess the influence of solar radiation in solar energy systems or in building climatology. They are used as input data for computer simulations of the all-year performance of solar energy systems and of the heating and cooling loads of buildings.

TRY's have been generated for a number of locations all over the world. Various names have been given to such data collections, eg Example Year in the UK, Standard Weather Data in Japan or Typical Meteorological Year (TMY) in the USA. In the ECA data (monthly mean temperatures and average monthly solar radiation) are available for the following locations:

Tab. 2.3: Locations for which TRY's are available in the ECA

Country	Location	Remarks
Denmark	Reference	
Germany	Reference	
	Bremen	
Finland	Reference zone 1	Generated by IKE with VTT support
Italy	B (Palermo)	
	C (Napoli)	
	D (Roma)	
	E (Milano)	
	F (Cuneo)	
U K	Edinburgh (Turnhouse 1976-1995)	
	London (Heathrow 1976-1995)	
USA	Phoenix AZ	Hot Dry
	Mobile AL	Hot Humid
	San Francisco CA	Temp Mixed
	Memphis TN	Temp Humid
	Salt Lake City	Cool Dry
	Milwaukee WI	Cold Humid
	Indianapolis IN	Cool Humid
Norway	Oslo (reference)	
France	Lyon (H1)	
Poland	Poznan PUT	
Greece	Reference	

The following figures show the average temperatures corresponding to the different locations and the average horizontal radiation.

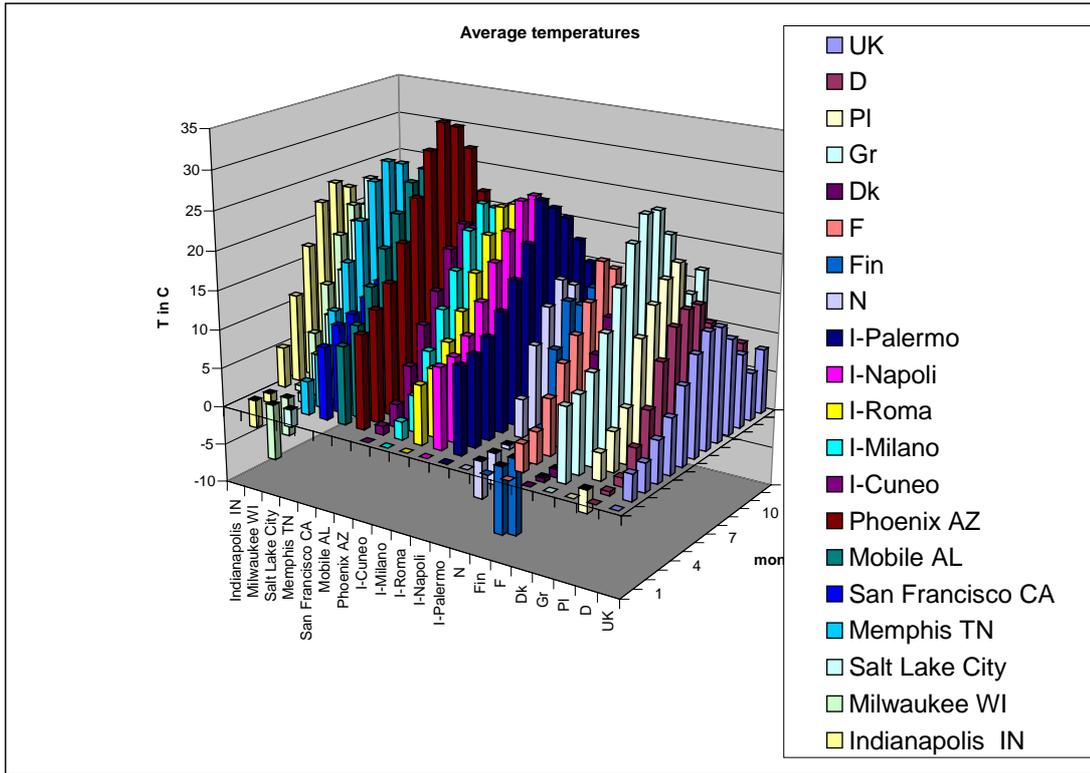


Fig. 2.6: Average monthly temperatures for locations available in the ECA

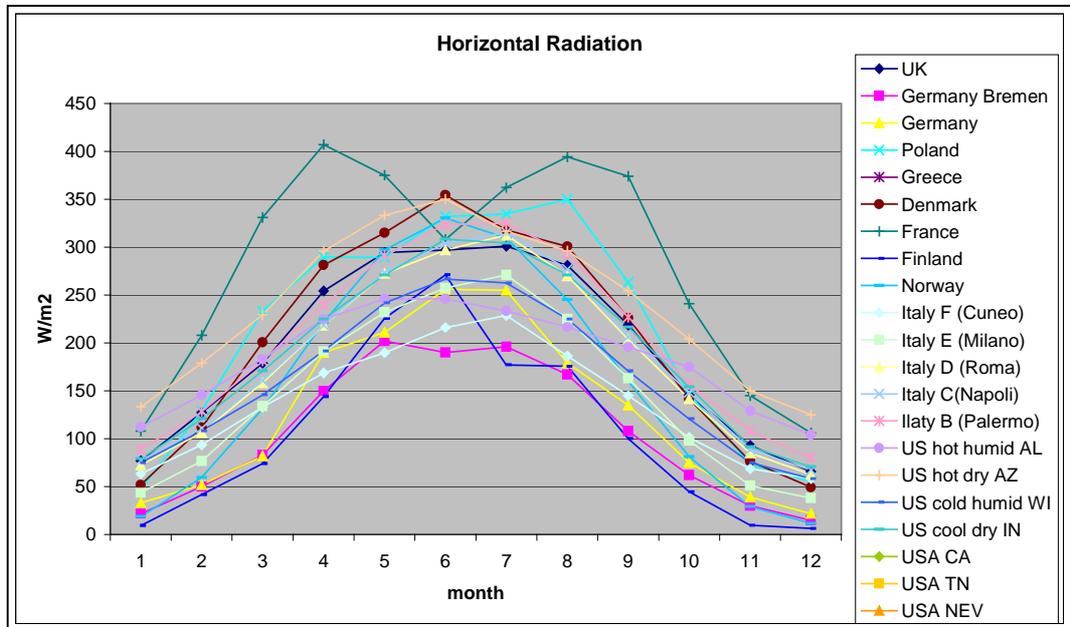


Fig. 2.7: Average horizontal radiation for locations available in the ECA

2.2.5 References

H. Lund, Test Reference Years for the European Countries, published under EC contract, EUR 9765 (1985)

2.3. Energy Consumption (by Fritz Schmidt IKE)

2.3.1 Profiles for Usage

School buildings have different methods of being used. Most important there are classrooms but also there are unheated areas like staircases and floors, halls offices and sometimes dwellings integrated. In the following we concentrate on classrooms and make some additional remarks on unheated areas.

Internal loads

Most important internal heat sources are people and lighting.

In Germany most people are either in the classrooms between 7:30 and 12:30 in the morning. Special classes are usually taught in the afternoon from about 14:00 to 17:15. Some schools are used during evening hours as well. Nobody is present during the night, weekends or holidays.

The heat load per person is about 125 W. In Germany there are typically 24 people in a classroom of 60 m² during teaching time . This results in an internal load of 50 W/m² which is quite high compared to internal loads in houses. Also, it is necessary to add the contribution from lighting which amounts to between 10 and 15 W/m².

Ventilation

In Germany most schools use natural ventilation. It is normal to expect air change rates of 4 to 5 l/h. Mechanical ventilation is required primarily for larger rooms. This should provide about 30 m³/h/people of fresh air.

References

H.Erhorn, K.Gertis, Mindestwärmeschutz oder/und Mindestluftwechsel, Gesundheits-Ingenieur 107, Heft1, 1986(German only)

DIN 1946-2, (VDI-Lüftungsregeln) 1991(German only)

DIN 4701.2, Regeln für die Berechnung der Heizlast von Gebäuden - Teil 2, 1995(German only)

2.3.2 HVAC Systems

The new edition of Germany's VDI guideline 2067 and DIN 4701 Part 10 follow the development of a requirement for a building with its envisaged use and the loads which arise from this and the climate, through benefit transfer (heat, cooling, conditioned air) and distribution to the heating and cooling generation system. Since none of these system areas - benefit transfer, distribution and generation – can be achieved perfectly, an additional energy input is necessary in each case. 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.

Heating systems are evaluated by comparing benefit and expenditure as it is done in other technical systems. The benefit of a heating system is the ability to maintain comfortable thermal conditions in the rooms for its occupants. The requirements of the occupants to

their thermal environment are independent from the heating system. Mostly they specify their demands with nominal temperatures for the air in the room 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 outside air flow, which is necessary because of hygienic and building physical reasons to room air temperature. The delivery of the benefit by the heating system is called "benefits delivery". Planning for good benefits delivery consists of suitable selection, sizing and location of the room heating systems.

It is possible to determine the heat load which is defined as the energy which must be transferred to a room in order to supply exactly the existing demand. The time dependent integral of the heating loads ie the ideal minimal energy demand Q_0 , is an energy efficiency value which can be used to compare the different system to satisfy the demands (benefit delivery, heat distribution, heat generation). Figure 2.6 shows the direction of the demand development in a building. Starting from the building itself, its planned usage and the Climate influences for the first level are benefits delivery, for the second level it is heat distribution and the third level it is the heat generation system. Since each of these subsections – benefit delivery, distribution and generation – cannot be implemented in an ideal way, an additional energy demand is caused. If this additional energy demand is brought into relation with the ideal minimised energy demand Q_0 , (which is typical for a building, its HVAC system and its use under optimal operation conditions), an efficiency number e_i can be defined. This efficiency number will be used as an energetic evaluation value for the individual subsections. Therefore the ideal minimal energy demand Q_0 multiplied with the expenditure value e_i of the individual subsections gives the yearly energy demand. It is needed by the heat generation system. It is planned to provide the expenditure values for every sub-system of heating system. DIN EN 13790, DIN EN 832, DIN 4108-6 or VDI 2067-10 and -11 contain the description for calculating the building-specific and reference load requirements of heated and air-conditioned buildings. Part 12 contains the description for calculating load requirement for heated drinking water.

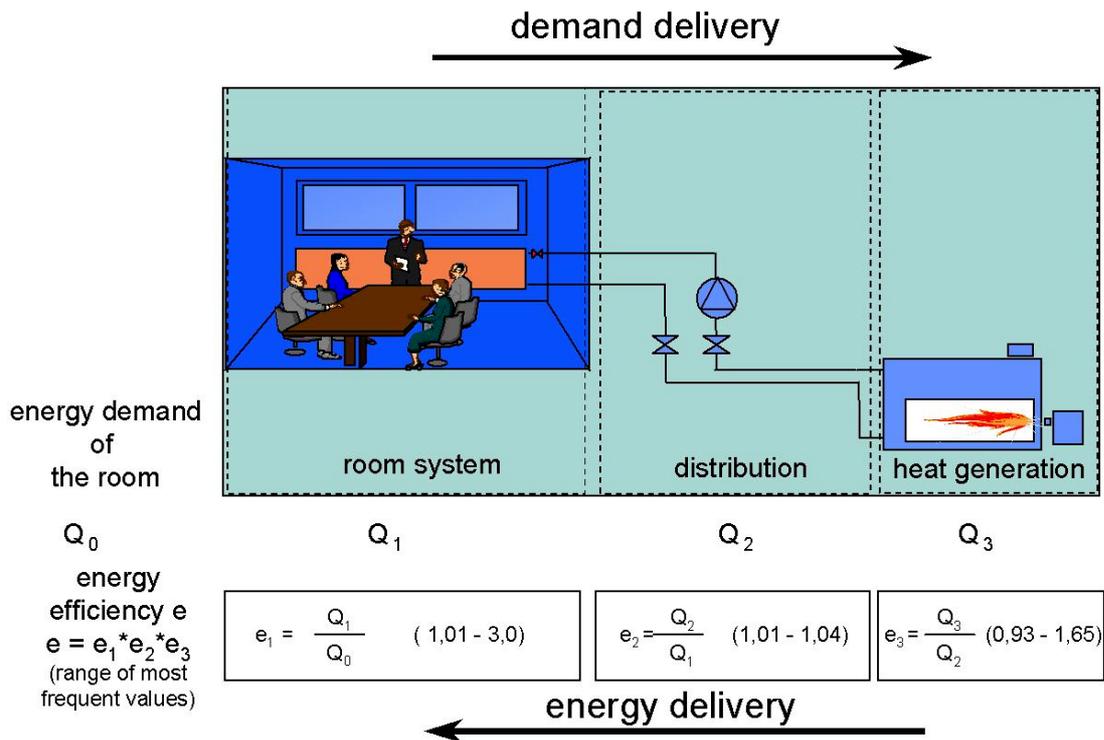


Fig. 2.8: Demand and energy delivery

DIN 4701-10 and VDI 2067 parts 20 – 27 describe the energy Q_1 of the respective installation systems for benefit transfer. The energy efficiency number for benefit transfer incorporates the system technology effort for heating, cooling, water supply or ventilation, including control. Depending on the system technology, the Q_1 values are determined separately for heating, cooling, current etc. The benefit transfer boundary in the area of distribution is always the surface of a system technology that delivers a particular “benefit” (eg radiators, heat exchangers, air-heaters, -coolers etc.).

DIN 4701-10 or VDI 2067-30 also contain the data for calculating the energy Q_2 for distribution. In this case a distinction is made between the energy effort for heat loss in the supply system and for hydraulic resistance in the distribution system.

DIN 4701-10 or VDI 2067-40 ff. studies the energy Q_3 in building-specific load generation or supply (meaning in this case the energy transformation process of solid, liquid or gaseous fuels or electrical current into heating or cooling).

This approach is also the base for the following classification. In some cases (eg 2.1.1 – 2.1.3) heat transfer, distribution and heat generation take place in one system. They usually have a combined efficiency number. Anyhow they are rationed under “Transfer system” because the particular “benefit” will be delivered at the surface of the system technology.

We would like to stress at this point that efficiency numbers as described in this chapter only are valid for an optimal operation. If a system is not operating at its optimal set point the effort to deliver a certain benefit will increase. Such increases were found especially in systems which were operated for several years without major adaptation to the actual user demand.

2.3.3 Uncertainties in calculating consumption

To predict consumption is much more difficult than predicting demand. Reasons for uncertainties are:

- The meteorological conditions which are not known in advance.
- Possible changes in usage due to additional lectures, changes in vacation times or changes in user behaviour.
- Possible changes in system operation due to system faults or uncontrolled operation.

To account for uncertainties in meteorological conditions the concept of degree days was developed. This concept allows adjusting predicted and actual consumptions to the actual weather conditions

To account for uncertainties in user behaviour and system operation is much more difficult. If greater differences in predicted and actual consumption occur only a more detailed audit can clarify the reasons.

This also has to be kept in mind if one wants to compare results predicted through the ECA and measured on a concrete building.

The situation could be improved considerably with the help of detailed measurements and dynamic simulation codes. An example for this was given by Kraft at a conference held in Dec. 2002. We quote one of his examples to increase the confidence in detailed modelling. Such models however are not applicable during the decision phase which is covered primarily by the ECA.

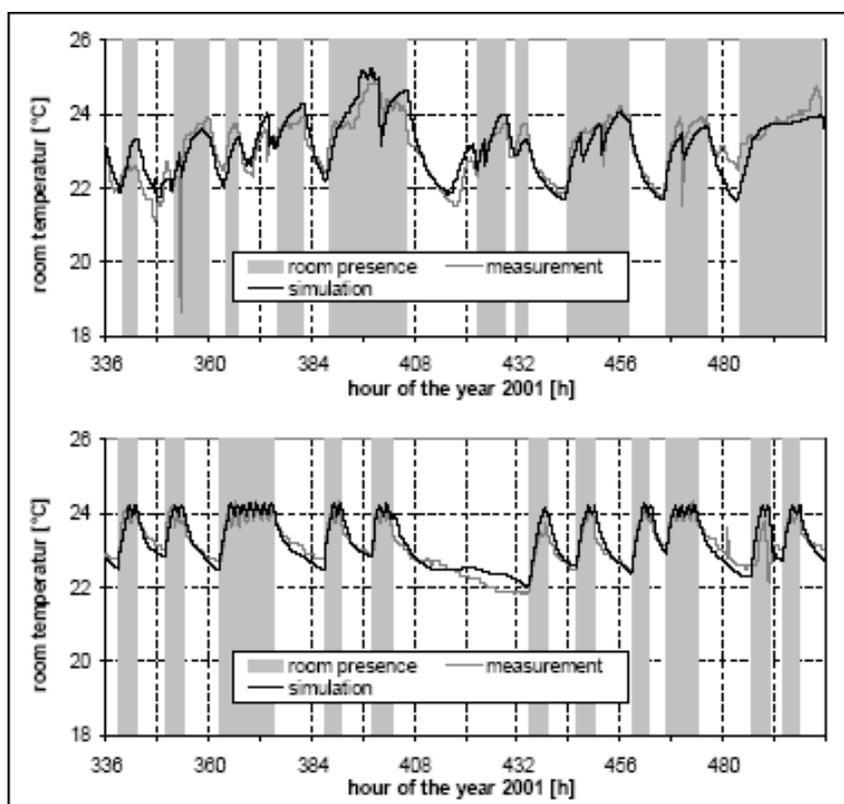


Fig. 2.9: Example of Measured and simulated air temperature during a winter week as described by Kraft

2.3.4 References

DIN 4701: Regeln für die Berechnung des Wärmebedarfs von Gebäuden, Beuth-Verlag, 1947-1983

VDI 2067 Blatt 11: Wirtschaftlichkeit gebäudetechnischer Anlagen- Energiebedarf beheizter und klimatisierter Gebäude, Entwurf, VDI-Verlag, Düsseldorf, Juni 1998

VDI 2067 Blatt 20: Wirtschaftlichkeit gebäudetechnischer Anlagen- Energieaufwand der Nutzenübergabe bei Warmwasserheizungen, VDI-Verlag, Düsseldorf, 2000

Armin Kraft, Manfred Kleemann Energy saving potentials in “smart homes” –a dynamic system simulation, SSB'2002 Liege Dez. 2002

2.4. Economic Calculation Procedures (by T. M. Mroz, PUT)

The choice of the retrofitting scenario of educational building depends on the actual preferences of a decision maker eg building owner, administrator or building manager. Very often the economic criteria are of the greatest importance. Depending on the calculation method there are several approaches to derivation of the economic criteria. The evaluation of the questionnaire on economic calculation procedures was performed within the preparation phase of IEA Annex 36: Retrofitting in Educational Buildings [1], showed that the two methods most commonly used in project participating countries are:

- Net Present Value (NPV), and
- Simple Payback Time (SPBT).

Therefore it has been decided that both these methods will be included in the Energy Concept Advisor calculation platform as the calculation procedures for derivation of the economic performance of different retrofitting scenarios of educational buildings.

2.4.1 Net Present Value

Net Present Value calculations are based on the estimation of the overall discounted cash flow of the project of retrofitting related to the time period of the analysis [2]:

$$NPV = \sum_{i=1}^t \frac{CF_i}{(1+R)^i} - I_0 \quad (1)$$

where:

NPV - Net Present Value, Euro,

CF_i - Cash flow of the project caused by retrofitting, Euro,

t - time period in number of the years of the analysis,

R - the effective rate of discount,

I_0 - the total cost of the retrofitting scenario, Euro.

A project is profitable when the calculated NPV value is a positive quantity. The annual cash flow of the project in the “i” year of analysis can be calculated as the cost of the energy saved due to the process of retrofitting:

$$CF_i = \left[\sum_{j=1}^n \Delta E_{i,j} \cdot P_{i,j} - C_{FIX} - C_{VAR} \right] - [T_{INC}]_i \quad (2)$$

where:

$\Delta E_{i,j}$ - the decrease of the “j” energy annual consumption, kWh/a,

$P_{i,j}$ - the price of the “j” energy unit in the calculation year “i”, Euro/kWh;

C_{FIX} - the additional annual fixed cost of building exploitation due to the retrofitting

process, Euro/a,

C_{VAR} - the additional annual variable cost of building exploitation due to the retrofitting process, Euro/a,

T_{INC} - the annual income tax, Euro/a,

The decrease of the “j” energy consumption is derived from the annual energy consumption balance before and after retrofitting process:

$$\Delta E_{i,j} = E_{0,j} - E_{i,j} \quad (3)$$

where:

$\Delta E_{i,j}$ - annual “j” energy savings after retrofitting process, kWh/a,

$E_{i,j}$ - annual “j” energy consumption in the “i” year after retrofitting, kWh/a,

$E_{0,j}$ - annual “j” energy consumption before retrofitting, kWh/a.

Concerning the space heating demands of an educational building annual energy savings can be calculated using the formula based on degree-day approach:

$$\Delta E_{SH} = SD \cdot (\dot{Q}_{SH} - \dot{Q}_{SH,0}) \cdot \frac{24}{t_i - t_e} \quad (4)$$

where:

ΔE_{SH} - annual space heating energy savings after retrofitting process, kWh/a,

SD - the number of degree-days of heating season, °C.d,

t_i - the internal calculated temperature, °C,

$t_{e,obl}$ - the external calculated temperature, °C.

\dot{Q}_{SH} - the heating capacity demand of an educational building for space heating after retrofitting, W,

$\dot{Q}_{SH,0}$ - the heating capacity demand of an educational building for space heating before retrofitting, W.

The equation (4) is valid for building itself without analyzing the efficiency (effort figures) of the heating system operating in building. Taking into account the simultaneous impact of building itself and its heating system on energy performance the annual energy savings can be described by the equation:

$$\Delta E_{SH} = SD \cdot (e_1 \cdot e_2 \cdot e_3 \cdot \dot{Q}_{SH} - e_{1,0} \cdot e_{2,0} \cdot e_{3,0} \cdot \dot{Q}_{SH,0}) \cdot \frac{24}{t_i - t_e} \quad (4)$$

where:

e_i - effort figure of heating system of educational building after retrofitting,

$e_{i,0}$ - effort figure of heating system of educational building before retrofitting.

Concerning the mechanical ventilation systems the reduction of the heat consumption can be achieved by the introduction of heat recovery devices to air handling units. The energy in that case savings can be derived as follows:

$$\Delta E_H = DH_N \cdot \frac{\dot{Q}_H}{(t_N - t_e)} \cdot \eta_{t, sr} \quad (5)$$

where:

ΔE_H - annual energy savings joined with the introduction of heat recovery device, kWh/a

DH_N - the number of degree-hours of air heater operation – eg (4), °C.h/a,

\dot{Q}_H - the capacity of air heater, kW,

t_N - the air supply temperature, °C,

t_e - the calculated external temperature, °C,

$\eta_{t, sr}$ - annual average heat recovery efficiency.

The equation (5) is valid if the temperature of supply air is approximately equal to the exhaust air temperature ($t_N \cong t_{ex}$).

The number of degree-hours of air heater operation can be calculated according to the formula:

$$DH_H = Z_H \cdot T \cdot (t_N - t_{e, sr}) \quad (6)$$

where:

Z_H - annual number of days of air heater operation, d,

$t_{e, m}$ - annual average external air temperature, °C,

T - daily number of hours of ventilation system operation, h/d.

2.4.2 Simple Payback Time

Simple payback time is defined as the ratio of total investment cost and the cost of annual energy savings caused by the retrofitting process. It can be calculated according to the equation (4):

$$SPBT = \frac{I_0}{\sum_{j=1}^n \Delta E_j \cdot P_j} \quad (7)$$

where:

$SPBT$ - simple payback time of the retrofitting scenario, a,

I_0 - the total cost of retrofitting scenario, €

ΔE_j - annual “j” primary energy savings after retrofitting process, kWh/a,

P_j - the price of the “j” energy unit in the year of retrofitting project termination, €/kWh;

The lower the payback time of the retrofitting strategy the more preferable it to the decision maker. It has been proposed in the recommendation part of the Energy Concept Advisor, that all retrofitting strategies can be ranked according to the simple payback time using the following rules:

- Short payback time – SPBT = 2 to 5 years,
- Medium payback time – SPBT= 6-10 years,
- Long payback time – SPBT= 11-20 years.

2.4.3 Sample calculation

In order to demonstrate the calculation, NPV and SPBT values have been performed for an example building – a Secondary School in Swarzedz, Poland (Polish Case Study – PL1). The description of the school building is given in the table 2.4.

Tab. 2.4: The description of the school building of Secondary School in Swarzedz, Poland

Building typology	Central corridor school
Building heated volume [m ³]	5120
Surface of building external envelope [m ²]:	1700
• External walls:	840
• Windows:	215
• Attic:	445
U values of building external envelope [W/m ² K]:	
• External walls:	1,51
• Windows:	2,60
• Attic:	1,16
Average U _B [W/m ² K]	1,38
Average U _L (natural ventilation 1,0 h ⁻¹) [W/m ² K]	0,88
Heat demand of the building for space heating [kW]	138,3

The following retrofitting scenarios have been taken into consideration:

- Alternative A - thermal insulation of external walls – 10 cm of Styrofoam with mineral finishing, $U_{exW} = 0,38 \text{ W/m}^2\text{K}$,
- Alternative B - thermal insulation of attic – 16 cm of mineral wool, $U_{Att} = 0,23 \text{ W/m}^2\text{K}$,
- Alternative C - Window exchange for double glazed low emission windows – $U_{WIN} = 1,1 \text{ W/m}^2\text{K}$,
- Alternative D – simultaneous actions A + B + C.

The economic factors describing retrofiting alternatives are given in the table 2.5.

Tab. 2.5: Economic factors of retrofiting alternatives

Investment cost I_0 [Euro]:	
Alternative A:	12600
Alternative B:	4400
Alternative C:	26000
Alternative D:	43000
Heat price P_H [Euro/kWh]: (total cost based on district heating in Poznan, Poland)	0,032
Rate of discount R : (polish market 2002)	0,05
Number of years of NPV analysis t [a]:	10
The annual income tax rate [%]:	19

The simplified calculations have been performed using the equations (1) to (4) for NPV derivation and (4) and (7) for $SPBT$ derivation. The results are listed in the table 2.6.

Tab. 2.6: The results economic calculation for different countries

Economic factor	Alternative A	Alternative B	Alternative C	Alternative D
Annual energy savings for space heating - ΔE_{SH} [kWh/a]	68300	29250	23100	120600
Annual cost savings [Euro/a]	2.200,-	940,-	740,-	3.860,-
SPBT [a]	5,7	4,7	34,9	11,1
Annual cost savings [Euro/a]	2.200,-	940,-	740,-	3.860,-
Annual fixed cost C_{FIX} (10% of investment cost) [Euro/a]	220,-	100,-	70,-	400,-
Annual variable cost C_{VAR} [Euro/a]	0,-	0,-	0,-	0,-
Annual Cash flow of the project CF_i [Euro/a]	1.600,-	685,-	540,-	2.815,-
NPV₁₀ [Euro]	- 245,-	890,-	- 21.800	- 21.250,-

According to the table 2.6 the best retrofitting alternative is the thermal insulation of the attic. That alternative is characterised by the shortest payback time (less than 5 years) and is the only one retrofitting scenario that has a positive net present value. The worst scenario refers to the window exchange – payback time over 34 years.

2.4.4 Conclusions

Considering the experience of different countries participating in IEA Annex 36 project the *NPV* and *SPBT* seem to be the most applicable methods of evaluation of the economic performance of retrofitting projects.

The *NPV* calculation is more suitable for ranking the retrofitting alternatives according to their financial efficiency – for financial institutions of decision makers, while *SPBT* method gives the fast recommendation on the choice of retrofitting scenario.

Economic performance of retrofitting projects is highly dependent on national economic factors.

The national economic factors: rate of discount, primary energy cost, investment cost coefficients, may vary significantly, so the same retrofitting project may have significantly different rates of profit and hence NPVs in different countries.

2.4.5 References

- [1] Mróz T.: Evaluation of questionnaire action on economic calculations; Subtask A Report on State of the Art Overview; Ed. Mróz T., Erhorn H., IEA Annex 36 Working Document, January 2003,
- [2] Kreith F., West R.E.: Handbook of Energy Efficiency, CRC Press Inc. 2000, pp. 101-125.

2.5. Control and Management (by Jorma Pietilainen, VTT)

Energy control has always had an important - though not always conscious - role in the whole lifecycle of building. It can be stated, that one of the main objectives of a building is to offer good circumstances and services for the occupant activities by controlling the energy flows between the building and the outer world. In 1970's the so-called energy crises brought out importance of building energy consumption. World wide concern for global climate change and the greenhouse gas phenomena today strongly underline the need for better energy efficiency in buildings. The adoption of the Kyoto Protocol and the ongoing international efforts to address climate change will have many impacts in the building sector, which in Europe for instance is responsible for about 40 % of total energy consumption. In the future, control and management of building energy consumption will be one of the key issues also in educational buildings.

2.5.1 Control via systematic approach

Control of energy should be linked to the entire lifecycle of a building. In each phase from building design through construction and operation processes to the final demolition and possible recycling (or reuse) energy efficiency issues should be taken into account. In order to improve the quality control in energy saving actions and in construction in general systematic methods and practices must be utilised.

2.5.2 Commissioning

Building commissioning is, especially in the USA, rapidly becoming an important new field. More and more architectural and engineering companies are including commissioning services as a core business component. Commissioning is defined in ASHRAE Guideline 1-1996 as the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent. The guideline states that "commissioning begins with planning and includes design, construction, start up, acceptance and training, and can be applied throughout the life of the building." For the most part, building commissioning is at the moment a term associated with new construction projects as a process of ensuring that new buildings and their systems perform as designed. In addition to this also definitions for existing-building commissioning known also as retrocommissioning as well as continuous commissioning exist.

In the Practical Guide for Commissioning Existing Buildings (Tudi Haasl, Portland Energy Conservation, Terry Sharp, Oak Ridge National Laboratory) **retrocommissioning** is defined as an event in the life of a building that applies a systematic investigation process for improving and optimising a building's operations and maintenance. Many of its components are similar to those for new-construction commissioning. Retrocommissioning, however, occurs after construction, as an independent process, and its focus is usually on energy-using equipment such as mechanical equipment, lighting, and related controls. It may or may not emphasise bringing the building back to its original intended design. Retrocommissioning ensures system functionality. It is an inclusive and systematic process intended not only to optimise how equipment and systems operate, but also to optimise how

the systems **function together**. Although retrocommissioning may result in recommendations to investigate further capital improvements, operation and maintenance (O&M) tune-up activities and diagnostic testing are primarily used to optimise the building systems.

The **continuous commissioning** process involves many of the same planning elements and investigation procedures as retrocommissioning. Its objectives are essentially the same. And like retrocommissioning, it is a systematic way of identifying and correcting building system problems and optimising system performance in existing buildings. Continuous commissioning, however, more rigorously addresses the issue of persistence. A key goal is to ensure that building systems remain optimised continuously. To achieve this, continuous commissioning requires benchmarking pre-and post-energy use via metering equipment that is permanently installed. Data are then continuously gathered and compared against the post-commissioning benchmarks to ensure that the building systems function optimally throughout their lives /3/.

Commissioning and its methods will also be focused on in a separate annex, IEA Annex 40 "Commissioning of Building HVAC Systems for Improved Energy Performance". In the Annex 40 website (<http://ddd.cstb.fr/annex40/annexe40.htm>) it is stated:

"The primary goal of building commissioning, from an energy perspective, is to verify and optimise the performance of energy systems within a building. The objective of annex 40 is to develop, validate and document tools for commissioning buildings and building services that will help facilitate the achievement of this goal. These tools will include guidelines on commissioning procedures and recommendations for improving commissioning processes, as well as prototype software that could be implemented in stand-alone tools and/or embedded in building energy management systems (BEMS)."

In retrofitting, project building commissioning procedures can be used to control and verify that the building and its overall systems meet energy and environmental performance targets as intended by owners (investors) as well as by designers. Lots of publications (guides, models etc.) about commissioning are available over the internet, including models and examples which can be followed also when systematic control strategies for educational buildings are developed. Also commissioning will be discussed in more detail in a separate chapter of this report.

2.5.3 Measurement and Verification (M&V)

The energy efficiency opportunities and their inherent benefits prompted the U.S. Department of Energy in early 1994 to begin working with industry to develop a consensus approach to measuring and verifying efficiency investments in order to overcome existing barriers to efficiency. **The International Performance Measurement and Verification Protocol (IPMVP)** was first published in 1996. It provides an overview of current best practice techniques available for verifying results of energy efficiency, water efficiency, and renewable energy projects. It may also be used by facility operators to assess and improve facility performance. Energy conservation measures (ECMs) covered include fuel saving measures, water efficiency measures, load shifting and energy reductions through

installation or retrofit of equipment, and/or modification of operating procedures. IPMVP 2000 has been published in two volumes:

- Volume I, Concepts and Options for Determining Energy and Water Savings
- Volume II, Concepts and Practices for Improved Indoor Environmental Quality
- Volume III for renewable energy projects is under preparation

The IPMVP version of 1997 has been translated into Bulgarian, Chinese, Czech, Japanese, Korean, Polish, Portuguese, Romanian, Russian, Spanish and Ukrainian. The original and some of the translated versions of the IPMVP are available through the website www.ipmvp.org.

The basic concepts and methodology of IPMVP is based on the simple fact that energy or demand savings can be determined by comparing measured energy use or demand before and after implementation of an energy savings measures. This can be presented and visualised by a simple equation:

Energy Savings = Baseyear Energy Use - Post-Retrofit Energy Use ± Adjustments

The "Adjustments" term in this general equation brings energy use in the two time periods to the same set of conditions. Conditions commonly affecting energy use are weather, occupancy, plant throughput, and equipment operations required by these conditions. Adjustments may be positive or negative.

IPMVP includes four M&V options, which can be applied for different kinds of saving projects (see Tab. 2.7):

IPMVP offers a lot of instructions and examples on how to control and assess the impacts of applied energy saving measures. Utilising it requires some background knowledge however and it is mainly targeted to specialists or professionals in building energy problems. As such it is perhaps too "heavy" for many of the decision makers in educational buildings but useful especially for experts who are needed at least in the more complicated and bigger retrofit projects.

Tab. 2.7: Overview on M & V Options

M & V Options	How Savings Are Calculated	Typical applications
<p>A. Partially Measured Retrofit installation</p> <p>Savings are determined by partial field measurement of the energy use of the system(s) to which an Energy Control Measure (ECM) was applied; separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous.</p> <p>Partial measurement means that some but not all parameter(s) may be stipulated, if the total impact of possible stipulation error(s) is not significant to the resultant savings. Careful review of ECM design and installation will ensure that stipulated values fairly represent the probable actual value. Stipulations should be shown in the M&V Plan along with analysis of the significance of the error they may introduce.</p>	<p>Engineering calculations using short term or continuous post-retrofit measurements and stipulations.</p>	<p>Lighting retrofit where power draw is measured periodically. Operating hours of the lights are assumed to be one half hour per day longer than store open hours.</p>
<p>B. Retrofit installation</p> <p>Savings are determined by field measurement of the energy use of the systems to which the ECM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the post-retrofit period.</p>	<p>Engineering calculations using short term or continuous post-retrofit measurements</p>	<p>Application of controls to vary the load on a constant speed pump using a variable speed drive. Electricity use is measured by a kWh meter installed on the electrical supply to the pump-motor. In the baseyear this meter is in place for a week to verify constant loading. The meter is in place throughout the post-retrofit period to track variations in energy use.</p>
<p>C. Whole Facility</p> <p>Savings are determined by measurement of energy use at the whole facility level. Short-term or continuous measurements are taken throughout the post-retrofit period.</p>	<p>Analysis of whole facility utility meter or sub-meter data using techniques from simple comparison to regression analysis.</p>	<p>Multifaceted energy management program affecting many systems in a building. Energy use is measured by the gas and electric utility meters for a twelve month baseyear period and throughout the post-retrofit period.</p>
<p>D. Calibrated Simulation</p> <p>Savings are determined through simulation of the energy use components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility. This option usually requires considerable skill in calibrated simulation.</p>	<p>Energy use simulation, calibrated with hourly or monthly utility billing data and/or end-use metering.</p>	<p>Multifaceted energy management program affecting many systems in a building but where no baseyear data are available. Post-retrofit period energy use is measured by gas and electric utility meters. Baseyear energy use is determined by simulation using a model calibrated by the post-retrofit period utility data.</p>

2.5.4 Control and monitoring is key for successful retrofitting

As stated in commissioning guides and IPMVP reliable energy consumption data before and after retrofitting is the basis for the assessment of the impacts of saving measures. Without proper knowledge about energy used in buildings and their processes no real management or improvement of current activities is possible. Good results in energy saving depend decisively on the **attitudes and habits of users** on the one hand, and on the **motivation and know-how** of persons responsible for the **operation and maintenance** of buildings, processes, etc. (foremen, service personnel etc.) on the other. Both groups mentioned can be strongly influenced by consumption monitoring and effective feedback.

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

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

The first step in the way of better energy control in buildings is the continuous and regular recording of actual use of energy and water. On the basis of the information received in this way the functions of the building and it’s technical systems can be controlled. Simultaneously also feedback from the influence of users as well as from the quality of operation and maintenance works can be achieved. At intervals also more accurate checking and investigations will be needed in the form of commissioning, energy auditing, retrofit planning, etc.

2.5.5 Existing utility meters – an undervalued source of data

When aiming at improved energy management in the majority part of existing buildings, installation of new sensors, meters, automation systems, etc, is not a realistic option at least in the short term because of high costs. But in fact there is no need for this kind of effort. Existing utility meters already offer a sound basis for the development of monitoring activities. Actually the **information needed for the basic energy management and control is already available** for almost every building. Until now this existing important data source has been almost forgotten or at least undervalued. Compared to invoices, utility meters can be easily used to gather the short term information needed for energy control and management and for energy saving actions. In addition to their wide existence (investments already done) another important benefit is that the accuracy and performance (maintenance) of utility meters is quite well guaranteed and controlled because of the economic interests of both the utility companies and the customers.



Fig. 2.10: Example of existing utility meters

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

2.5.6 Simple tools sufficient for basic control and management

Effective utilisation of existing meters by consumers is not possible without supporting tools. Practice has shown that monitoring activities can not be carried out as manual paper work only. The modern version of pen and paper – the PC – offers a solution to this problem.

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

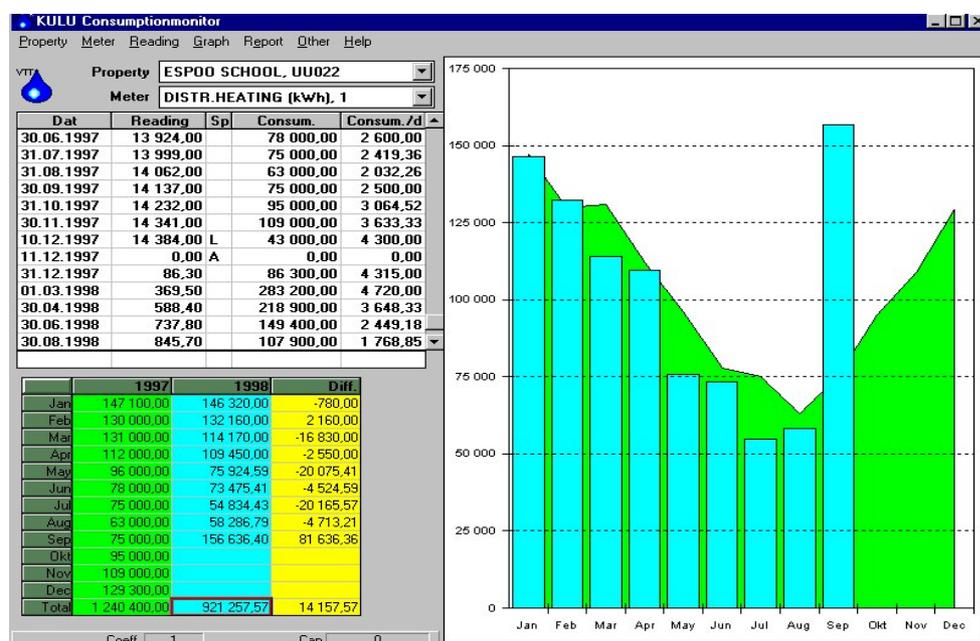


Fig. 2.11: Sample page from KULU

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) into numeric and graphical summaries. Among other things the user can freely choose the time span of monitoring (eg 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.

2.5.7 Building energy management systems (BEMS)

Control especially as part of more comprehensive energy management can be understood and defined as an energy saving technology itself. Besides simple tools like Kulu there are also lot of more dedicated systems and products on the market, which utilise computers and modern ICT in their data acquisition, control and other functions. These technologies are called Building Energy Management Systems but also referred to by various other names like Energy Management (Control) System or Building Management System. In the appendix there is a general description of the technology. In the following a short presentation is made based on the Thermie project Atlas /4/.

2.5.8 History

Thermostats and TRV's were the first control equipment to disseminate in the building sector owing to the first energy crisis. Building management systems developed in the '80s in the residential and services sectors, as simplified applications of systems and technologies already developed in the industrial sector in the '70s to automate production processes and to optimise plant performance.

These technologies were mostly based on the concept of Programmable Logic Controllers (PLCs). Subsequent developments, as well as most residential applications, were later based on "distributed-intelligence microprocessors", whereby "intelligent" peripheral units are capable of managing a variety of tasks and functions while a central unit acts as a supervisor.

Once the trend to industrial automation had expanded sufficiently in industrial countries, these technologies sought new applications and markets in other sectors. As these systems were rather expensive, the richest segments of the services and residential sector were the first target. Hence the first buildings to be equipped with systems and devices were banks, large business offices and prestige buildings, and a few villas and mansions for wealthy people. The most widely used applications at the beginning were for security/safety purposes and later on for air conditioning (heating/cooling) purposes. The concept of "intelligent building" in its current definition was born about 10 years ago.

Due to their cost, the first applications to become popular (and the ones with faster market penetration rates) in the services and residential sector were security and safety devices (alarm systems against burglars and intruders, fire alarm systems and smoke detectors, gas-presence detectors). Other applications, especially those for energy management, have had a much slower diffusion. Besides the cost of the equipment, which remains high even when it is not very sophisticated, installation costs must be supported. These are substantial and when already existing buildings have to be retrofitted they may be very high.

2.5.9 BEMS functions

The term Building Management Systems (BMS) encompasses a wide variety of technologies which includes energy management systems and building controls. Their function is to control, monitor and optimise various functions and services provided in a building, including heating and cooling, ventilation, lighting and often the management of electric appliances.

The basic control technologies have been in existence for some time. Systems available range in complexity, from the extreme case of the timer-controlled water heater or thermostatic radiator valves (TRVs), to the so-called "intelligent houses" which manage everything from the security and safety systems to the air conditioning, lighting and ventilation system, to telematic services and to most appliances of a house according to efficiency criteria.

The use of these technologies allows the optimisation of various services often with large energy savings. There are numerous methods by which building services within buildings can be controlled. Most systems seek to control either by:

- Time ie when a service like heating or lighting for instance is provided and when it should not be provided or

A parameter representative of the service like temperature for space heating or illuminance for lighting. This can also vary with time. As an example typical Controls & BMS methods are described hereafter:

Time Control Methods (for heating):

- Time switches turn on and off the heating (or water heating) system at pre-selected periods (of the day, of the week)
- Optimisers: these control the start up of the heating system in a building at a variable time to ensure that, whatever the conditions, the building reaches the desired temperature when occupancy starts.

Temperature control methods:

- Frost protection generally involves running heating system pumps and boilers when external temperature reaches a set level (0°C) or less in order to protect against freezing.
- Compensated systems: which control flow temperature in the heating circuit relative to external temperature thus allowing a rise in the circuit flow temperature when outside temperatures drop.
- Thermostatic radiator valves: these units sense space temperature in a room and throttle the flow accordingly through the emitter (radiator and convector) to which they are fitted.
- Modulating control: can be applied to most types of heat emitters and is used to restrict the flow depending on the load demand and thus controlling the temperature.
- Proportioning control: involves switching equipment on and off automatically to regulate output.
- Other methods are thermostats, occupancy sensing (described hereafter for lighting control) and user interactive control.

Lighting control systems:

Different control systems exist, either based on time control or a required level of illuminance or use of lighting:

- Zoning: Lights are switched on in zones corresponding to the use and layout of the illuminated areas, in order to avoid lighting a large area if only a small part of it requires light.
- Timed control: to switch on and off automatically in each zone to match a prerequisite schedule for light use.
- Occupancy sensing: In areas which are occupied intermittently, occupancy sensors can be used to indicate whether or not anybody is present and switch the light on or off accordingly. Detection systems are based on ultrasonic movement or infrared sensing.
- Light level control: this consists of switching or dimming artificial lighting to maintain a light level measured by a photocell. It is particularly necessary to give value to ambient daylighting.

Building Management systems:

These technologies consist of both hardware and software.

The hardware is typically represented by one (or more) control and processing units and by a number of other peripheral devices (which control the operation of heating or cooling systems, artificial light-sources or other appliances and which can also be represented by sensors, thermostats, etc.) connected to the control units. The control unit, based on the information supplied by some of the peripherals or based on pre-set instructions, runs the system. The control unit can be as simple as a relay or a timer switching on or off an electric water heater or as sophisticated as a microprocessor operating on «fuzzy logic». Commands can be sent from the central unit to the peripheral units through Ethernet cable, power-lines or telephone lines, or fibre-optic cables. The material "medium" through which commands and messages between the various parts of the system are exchanged, is often called (Field)BUS.

The software is simply the program and the instructions that allow the control unit to manage the operations of the peripheral devices and of the appliances.

The ongoing fast development of information and communication technologies is rapidly changing the technology basis of BEMS too. The development is moving towards more open systems and standards from the proprietary and therefore expensive systems of today. In the future the BEMS technology will evolve from vertical into horizontal where big companies perhaps no longer control the whole chain. Open interfaces at every level of system enable open competition throughout the life cycle of systems. Internet, mobiles and wireless technologies will be widely popular in the control of buildings.

2.5.10 References

CEN TC247/WG3. 1998. Building management products and systems for HVAC applications. Part 2: Equipment Functionality. Brussels: European Committee for Standardisation. 86 p.

Kärki, S. 1998. Control Assessment. 82 p. (Working paper of the EDIFICIO project.)

2.6. New regulations will bring new means (by Jorma Pietilainen, VTT)

Planning of retrofits or new buildings is in all countries influenced by building energy codes, which often tend to replace efficient design strategies because most designers do not care much about optimising energy consumption and also because they often do not have the appropriate design tools and information. Because the current building codes don't motivate to the use of efficient design strategies, there is a trend to develop the energy control of this phase from prescriptive regulations (max. U-values etc.) towards functional energy regulations, where targets for energy efficiency are set in terms of overall energy consumption. This will in the long term promote energy efficient design and also improve the availability of practical design tools, as the compliance with functional energy regulations has to be verified, for example, by simulations.

2.6.1 Integrated performance standards

In order to improve the current practices of energy control the EU passed a directive on the Energy Performance of Buildings on the 4 January 2003. The directive will lead to increased co-ordination of legislation and building codes in European countries. The directive proposes a common methodology for calculating the integrated energy performance of buildings and application of minimum standards on the energy performance to new buildings and to certain existing buildings when they are renovated.

A common methodology for integrated energy performance standards can integrate, in addition to the quality of insulation of the building, heating installations, cooling installations, energy for ventilation, lighting installations, position and orientation of the building, heat recovery, active solar gains and other renewable energy sources. With today's highly insulated new buildings and the trend towards low energy houses, these additional factors can play an increasingly large role. An integrated approach will give more flexibility to designers to meet energy reduction standards in the most cost-effective way. It would also facilitate the comparison of buildings throughout the EU for prospective users and make it easier for designers and constructors to apply standards in other Member States. A common methodology could then form the basis for integrated minimum energy performance standards for different building categories to be adopted by EU countries, reflecting local circumstances, particularly Climate differences.

According to the draft directive new residential buildings and dwellings as well as new buildings in the tertiary sector - like schools - should meet the minimum energy performance standards based on an integrated methodology. Furthermore these standards should also be applied to larger (ie, greater than 1000 m²) existing buildings, when the buildings undergo larger renovations.

2.6.2 Energy certificate for existing buildings

The largest potential for energy saving is in the renovation of existing buildings. One of the main reasons for market imperfections as regards investment in energy efficiency on the rental market is the fact that the owner and tenant of a building, dwelling or office have different interests. As the tenant normally pays the energy bill, the incentive for the owner to invest in energy efficiency is weak. The best way to make these investments more attractive

is to provide clear and reliable information to prospective tenant. Clear information will influence the rent that can be asked and therefore will be an incentive for owners to make investments in the energy efficiency of buildings and houses.

To facilitate the transfer of this information on the energy performance of buildings and apartments, energy certificates for new and existing buildings and dwellings should be available when these are constructed, sold or rented out. This certification, which should not be more than 5 years old, should be based on the same integrated approach as used for the minimum standards for new buildings and should include accompanying advice on how to improve the energy performance of the building.

In the case of public authority buildings and certain privately owned or occupied buildings frequented by the public, energy certificates not more than 5 years old must be prominently and permanently displayed for the public. Public authority buildings and buildings frequented by the general public are able to demonstrate efficient technology and to set examples by incorporating energy efficiency measures into the renovation of such buildings.

Appropriate measures can make the public aware of the energy performance of these buildings and also provide recommendations to improve them. This is best done by means of a certification procedure.

In addition, for public authority buildings and buildings frequented by the general public, in order to inform the public and to promote the proper use of heating, air-conditioning and ventilation systems, certain information should be clearly displayed. The displayed information should include the range of indoor temperatures and, when local climate conditions require it, other relevant climate factors such as relative humidity, that are recommended by the authorities for that specific type of building. This will help to avoid unnecessary use of energy and to safeguard comfortable indoor climate conditions (thermal comfort) in relation to the outside temperature. The current inside temperature and, when appropriate other relevant climate factors, should also be displayed and indicated by means of a reliable device or devices.

Also heating installations like boilers with an effective output of more than 10 kW should be regularly inspected to improve their operating conditions. In the case of boilers more than 15 years old, the entire heating installation should be inspected and advice should be given to the users on alternative solutions which could reduce energy consumption. Similar measures should be taken as regards air conditioning systems, in particular in larger buildings.

The EU Energy Performance of Buildings Directive (see http://europa.eu.int/eur-lex/pri/en/oj/dat/2003/l_001/l_00120030104en00650071.pdf) has brought new types of control strategies into the use also in educational buildings. Not only the professionals but also the general public will receive regularly updated information on the realised energy performance and indoor conditions. This is very important because in numerous retrofitting projects it has been found that 80% of successful energy saving is connected to organisational, social, etc, factors and just 20% is based on technology.

2.7. Remarks on Computer codes (by F. Schmidt, IKE)

Numerous codes exist for yearly and monthly balance calculations. Only a few codes to simulate energy behaviour of buildings with a higher time resolution are available on the market. Most of them originate from the United States.

The Department of Energy (U.S) has collected information on energy performance calculation tools on the web site: http://www.eren.doe.gov/buildings/tools_directory/ . Described here are 272 energy-related software tools for buildings, with an emphasis on using renewable energy and achieving energy efficiency and sustainability in buildings. The tools can be sorted by name, country or platform. Tools from most of the countries participating in Annex 36 are listed there.

A survey of tools by type and country was produced in 2001 in Annex 31.

([ECBCS Annex 31 Tools Inventory.pdf](#))

The basic idea behind this was similar to the one followed in Annex 36:

Improving the environmental performance of buildings and building stocks is best accomplished using tools as decision-making aids. Many countries now have a variety of tools that have been tailored for use by specific users and to fill particular analytical needs. The purpose of the survey of Annex 31 was to provide a quick overview of the tools that are currently available or that are soon to be released. Each tool is described in terms of its functions, audience, users, software application & tech support, data requirements, strengths, availability and contact information.

The Annex 31 survey was designed to complement the United States Department of Energy Tool Directory. Both the Annex 31 site, and the US DOE site, use a similar format for organising and describing tools.

Annex 31 Tools are categorised as follows:

- Energy Modelling software
- Environmental LCA Tools for Buildings and Building Stocks
- Environmental Assessment Frameworks and Rating Systems;
- Environmental Guidelines or Checklists for Design and Management of Buildings
- Environmental Product Declarations, Catalogues, Reference Information, Certifications and Labels

Also of more general interest is CADDET, IEA's international newsletter on energy efficiency. CADDET stands for Centre for Analysis and Dissemination of Demonstrated Energy Technologies. It is an international information network that helps managers, engineers, architects and researchers find out about renewable energy and energy-saving technologies that have worked in other countries. <http://www.caddet.co.uk/>

Energy Performance of Buildings Calculation procedures used in European countries were collected in the frame of the ENPER project which was initiated and is co-ordinated by the

Belgian Building Research Institute (BBRI-WTCB-CSTC) in the frame of the SAVE programme of the European Commission, DG TREN. It involves partners from 15 countries on the topic of energy performance standardisation and regulation. In addition, 6 other European countries are associated on a voluntary basis. More information on the final report of the project can be found under

http://www.enper.org/pub/download/02_126R2_jcv_B1_final_report.pdf

Another area of interest might be the Building Code of Australia (BCA). Of course this is not a tool but rather a labelling scheme. The Australian BCA is described in a scoping study called minimum energy performance requirements for incorporation into the building code of Australia

http://www.greenhouse.gov.au/energyefficiency/building/publications/pubs/s_study.pdf

The Australian ecolable program is also described in a PowerPoint presentation

http://www.aela.org.au/publications/AELA_Sydney_Sashafinal140502.pdf

Development and implementation of a scheme requires effective promotional and marketing support, as well as supporting measures such as model contracts and leases, financial incentives, disclosure of past energy costs to prospective tenants or purchasers, etc. Support for this is given in

<http://www.abgr.com.au/generic/genDocs/backgroundReport.PDF>

Finally energy labelling and standards programs throughout the world are described from the Energy Efficient Strategies, Australia in

<http://www.energyefficient.com.au/reports/Int-Label.zip>

Many other web sites related to energy calculations exist too. However most of them have only a limited lifetime. Therefore they frequently contain URLs which do not exist any longer. We regret if the user is misled by any information provided in the following.

2.7.1 Example Germany

If we search the German Net with Energie- und Anlagensimulation (energy and system simulation) about 40 entries can be found. They represent different companies and universities which offer their services.

If we go into more detail we find three classes of information

1. Brochures on simulation

Examples are :

BINE Flyer on Gebäude- und Anlagensimulation

http://idw-online.de/public/zeige_pm.html?pmid=17218

HIS the German software company for universities

http://www.his.de/Abt1/Abt1/Support/software_testen

KlimaNet supports schools in energy saving projects

<http://www.klimanet.baden-wuerttemberg.de/>

VDI Richtlinie 6020 Blatt 1 describes rules for applying simulation

Anforderungen an die Gebäude- und Anlagensimulation

<http://www.vdi.de/vdi/vrp/richtliniendetails/index.php?ID=9179983>

Comparable tools are available in other countries too. Tools to support schools in energy saving projects in the UK might be found under <http://www.tfs.org.uk/>

(see also chap. 3.7.3 for US addresses)

2. Simulation programmes based on monthly balances (mostly related to EnEV)

Examples are :

Special pages describing the EnEV

http://www.zukunft-haus.info/page/index.php?id=978_blank

General Information on EnEV

<http://www.enev-online.de/>

Energiesparcheck a tool to evaluate buildings through small and medium enterprises

<http://www.energiesparcheck.de/>

EnEV certified tools and additional information

Ennovatis <http://www.enno-enev.de/>

Zentrum für Umweltbewusstes Bauen -Kassel e.V. <http://www.enev.de/>

Deutsche Energieagentur <http://www.deutsche-energie-agentur.de/enevdirekt.htm>

3. Simulations based on higher time resolutions

Examples are

VEC (<http://www.ennovatis.de/>)

a tool based on hourly calculations according to VDI 2067 and EN 832

SMILE <http://www.smilenet.de/>

an object-oriented environment for modelling and simulation of dynamic systems with continuous/discrete behaviour. It features a wide range of applications in energy efficient engineering and building simulation, but may be adapted to other problems too.

TAS http://www.ifes-frechen.de/IFES_021205/Software.htm?Software/6.htm~cont

For a detailed description see the DOE directory (alphabetical list)

TRNSYS <http://www.transsolar.com/ts/software/trnsys/trnsys.htm>

For a detailed description see the DOE directory (alphabetical list).

In addition TU Munich started to collect information in 1999

http://www.inf.bauwesen.tu-muenchen.de/personen/christop/bsim/building_energy.htm

It includes the following topics :

1. Building Energy Simulation Programs
2. Lighting Simulation Programs
3. Information Sources on Internet
4. Research Units and Laboratories
5. Institutions and Associations
6. Companies and Manufacturers
7. Education, Training and Demonstrations
8. Projects and Programmes
9. Journals and Magazines
10. Building Energy Standards and Codes

2.7.2 Example Finland

Normally the people involved in energy calculations in Finnish Communities do use D5-requirements (according to the building code book, energy calculations) as a basis of energy calculations. A code ETANA has been developed based on these D5-instructions.

The biggest engineering offices (eg Granlund Co) have their own software, by Granlund the software products RIUSKA and RYHTI (commercial products) which both are based on Department of Energy's (USA) DOE-software. DOE and DOD (Department of Defence, USA) are the organisations which have created energy performance software, by public financing, DOE and BLAST. Now based on these software a new tool has been developed, ENERGY+. Due to this ENERGY+ ideology was developed partially on the basis of their products RIUSKA and RYHTI.

The Website of Granlund and its product family is <http://www.granlund.fi/index.htm>

The product family includes SMOG for Space Management, RYHTI for Facility Management, RIUSKA for Energy Simulation and VIVA for Lighting

2.7.3 Example USA

We have mentioned already the Department of Energy web site: http://www.eren.doe.gov/buildings/tools_directory/ in which the energy performance calculation tools and also other type of tools can be checked.

A commercial site is offered through HVACMALL.com(SM) (HVAC/R: Heating, Ventilating, Air Conditioning, and Refrigeration) with a search engine, directory of links, and portal venue for the entire HVAC/R industry and end-user market including residential, commercial, industrial, and mobile <http://www.hvacmall.com/index.htm>. To utilise this page search under software.

Most actual information on energy calculation code development can be found in the Newsletter, Building Energy Simulation User News <http://SimulationResearch.lbl.gov/un.html> of the Simulation Research Group at Lawrence Berkeley National Laboratory (LBNL). <http://SimulationResearch.lbl.gov>. It also contains updated lists of free downloads of building energy software. In addition weather data for a broad variety of locations all over the world can be found on the energy+ homepage under WEATHER (<http://www.eere.energy.gov/buildings/energyplus/weatherdata.html>).

A free e-mail list for all building energy simulation program users to ask questions to other users can be found at <http://www.gard.com/ml/bldg-sim.htm>

The Newsletter of the International Building Performance Simulation Association (IBPSA - a non-profit international society dedicated to improving the built environment) contains valuable technical articles about innovative building simulation techniques. <http://www.mae.okstate.edu/ibpsa/newslett.htm>.

ASHRAE Technical Committee 4.7 Energy Calculations — TC 4.7's can be accessed through <http://www.mae.okstate.edu/tc47/>. Its goal is: Accurate energy models at every engineer's fingertips.

The Newsletter of the Royal Architectural Institute of Canada lists building simulation activities in Canada under E & E Related & Interesting Software <http://greenbuilding.ca/GBIC.htm>.

The bi-monthly electronic newsletter from the Alliance to Save Energy is called **e-EFFICIENCY NEWS** and can be found at <http://www.ase.org/about/about.htm>

Energy User News <http://www.energyusernews.com> is a trade publication which covers energy efficiency in new and existing non-residential buildings.

Special consideration is given to lighting in the US. Examples are

IAEEL Newsletter <http://www.iaeel.org>

International Association for Energy-Efficient Lighting. Lighting research and discussions of lighting energy efficiency and safety issues.

Lighting Futures <http://www.lrc.rpi.edu/Futures/index.html>

Articles on emerging lighting technologies. Great resource list of lighting web sites and contacts.

Setting the Standard <http://www.energycodes.gov/news/> is the Newsletter of the U.S. Department of Energy's Building Standards and Guidelines Program. It offers simple tools for energy calculations for residential and non-residential buildings.

3 Models selected for the ENERGY CONCEPT ADVISER (ECA)

The ECA will help to improve the energy efficiency of new or existing buildings through the identification of deficiencies and the calculation of potential energy savings. It will also suggest systems or design elements to be considered for inclusion in the design. During the past two years data has been gathered from all members of the Annex. As a result the ECA will incorporate an interactive source book of information which will include design concepts, design advise, design and decision programs, and case studies.

Target Group

As stated before the main target group are decision makers for instance in school administrations. The target audience **is not** the group of energy advisers. Therefore the application of the tool cannot go too much into technical detail, but must nevertheless indicate the potential for retrofitting. The tool will:

- make decision makers (more) sensitive to potential energy savings and their monetary benefits.
- convince them of the need to carry out more detailed investigations, which will require some financial commitment.

On the basis of these considerations we were looking for a model which was in good agreement with international regulations, but simple enough to facilitate easy input as available in a decision phase. The following models and tools were selected.

Basic geometrical model

For the ECA we use a 1 zone model with a simplified heat balance equation. Its main components are shown in Fig. 3.1. Basically we consider for each time interval

Transmission losses Q_T

Ventilation losses Q_V

Internal gains Q_I and

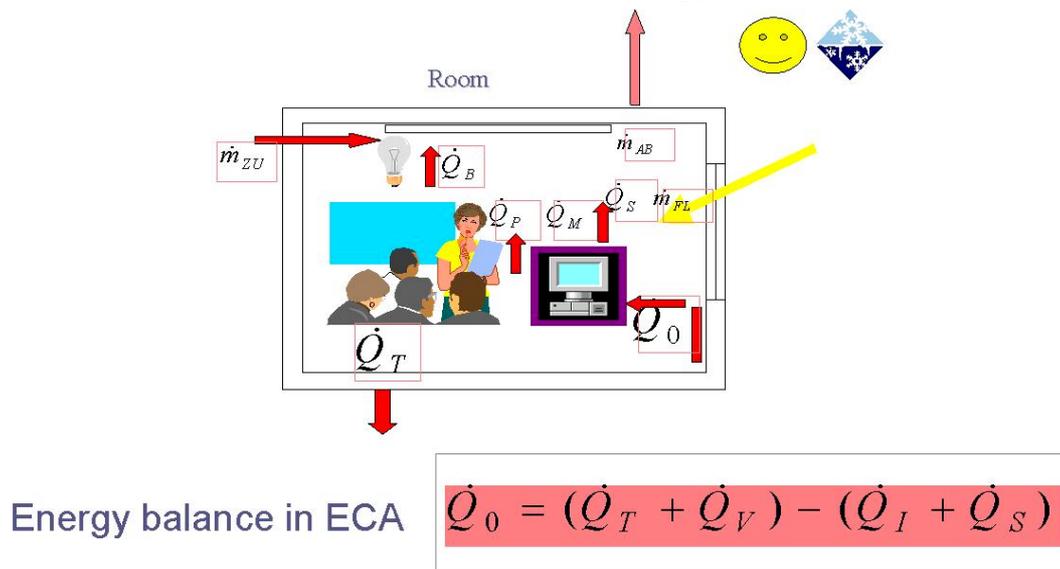
Solar gains Q_S to determine

Heating energy demand Q_0

Details are given in subchapter 3.1

Time resolution

For the time resolution a monthly basis was chosen.



Losses due to transmission and mechanical and natural ventilation
Gains due to internal energy sources (persons, equipment, lighting) and solar

Fig. 3.1: Simplified model for calculating heating demand and cooling need in the ECA

Calculation engines

The following calculation engines were implemented for the ECA:

- heating energy demand: EN 832 or ISO/DIN 13790 (draft international norm similar to EN 832 but not only for dwellings). Monthly balances.
- efficiency of the heating system: DIN 4701-10 or prEN 14335 (draft international norm similar to DIN 4701-10). Tabular values specific for school conditions will be derived from the formulas of the detailed version.
- cooling load: The basic energy balances in the ECA are calculated on a monthly base. To draw any conclusions on heating or cooling requirements from such balances requires a mapping of the monthly average values to the hourly values of each day. From this mapping conclusions can be drawn on what is necessary to meet the comfort requirements of the building users. This mapping is well understood for residential buildings under winter conditions. It can be extended to educational buildings by simple measures described in ISO/DIN 13790. It is less understood for the behaviour of building under summer conditions when additional ventilation or even cooling might be required. A procedure applicable in the frame of the ECA model will be discussed later.
- lighting: Lighting will be based on a new French regulation code which calculates the lighting energy demand from the lighting power multiplied by the lighting hours (dependent on the climate and the use hours): NF-EN 410, French Thermal Regulation 2000, X-35-103

Structure Of Calculation Part of the ECA

The calculation part consists of three steps: Input, calculation engines and output as presented in Fig. 3.2:

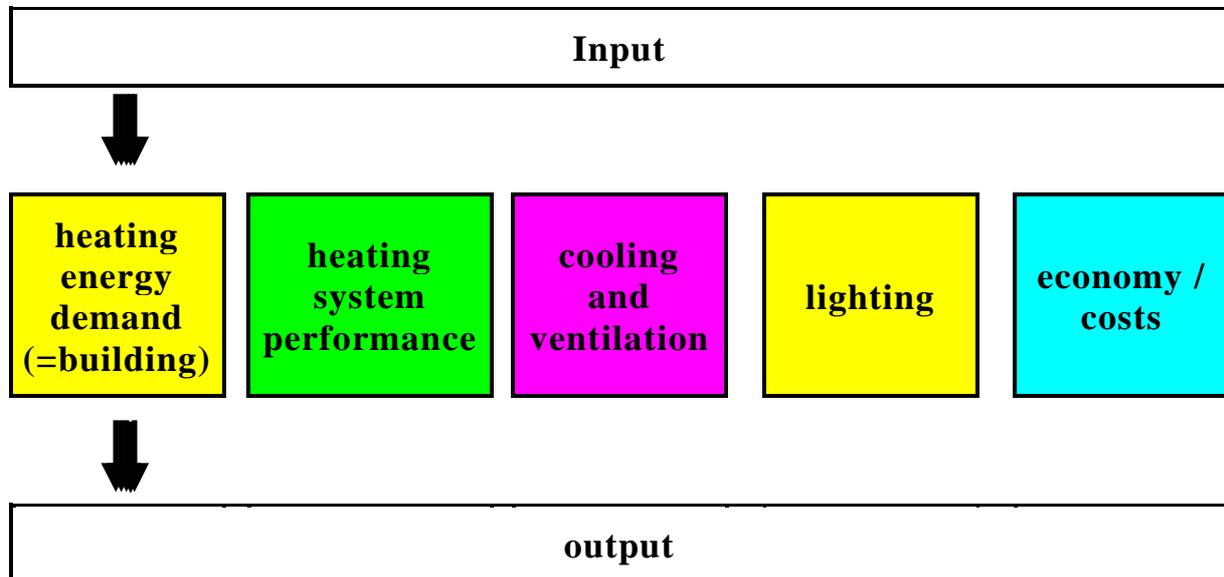


Fig. 3.2: Structure of the calculation part of the ECA

Limitations - What the concept adviser cannot do

To keep the tool as simple as possible several limitations were decided. It is therefore of interest to know what the ECA is not intended to be and therefore cannot be used for:

- No geometry editor will be provided. Geometry can only be specified according to the several typologies provided. This requires that the user maps his building onto these options.
- Only one heated zone will be considered. This requires to model average user behaviour and average utilisation. Also simulations have to be adjusted to the actual building behaviour.
- Although calculation engines will be implemented, the ECA is no classical design tool. It will serve however to evaluate alternative options according to energy savings and costs.
- Only one building can be considered at a time. No complex project managing tools will be implemented.
- No comfort evaluation is foreseen beyond the maximum summertime temperature criteria.
- The ECA is limited to energy analysis.

3.1. Heating requirements (by Simon Woessner, IBP)

At first the calculation methodology of the EN832 which is used in the Energy Concept Adviser is introduced and then the parameters and simplifications for the energy calculation of the Energy Concept Adviser are described.

3.1.1 Scope and methodology of EN 832

This European standard offers simplified calculation methods to determine the required heat energy needed to maintain a set-point internal temperature by balancing the heat gains and losses. It takes into account the variation of internal and external temperatures and through an utilisation factor the dynamic effect of internal and solar gains. The building can be divided into multiple zones with different set-point temperatures. The balancing of heat gains and losses can be done either by monthly calculation or over a defined heating period.

The energy balance includes:

- transmission and ventilation losses to external environment
- transmission and ventilation losses or gains to adjacent zones (but see 3.6.1)
- useful internal heat gains
- used solar gains
- generation, distribution, emission and control losses of the heating system
- the energy input to the heating system

The procedure to determine the energy requirement goes like:

- define the boundaries of the heated space and, if needed, the different zones and unheated spaces
- define the set-point temperature and, if any, the intermittence pattern
- for seasonal calculations, define or calculate the length and Climate data of the heating season

Then, for each calculation period:

- calculate the heat losses, Q_l
- calculate the internal heat gains, Q_i
- calculate the solar heat gains, Q_s
- calculate the utilisation factor for total gains
- calculate the heat use

Then, for the whole year:

- calculate the annual space heating use
- calculate the heating energy use taking into account the losses or the efficiency of the heating system

3.1.2 Definition of boundaries and zones

The boundaries of the heated space consists of all elements of the building envelope, that are separating the considered heated space from the external environment or

adjacent heated or unheated spaces. For purchased energy, the boundary point is at the delivery point to the building or heating plant. For exhaust air with heat recovery, the boundary is the exit of the recovery unit

The heated space can be divided into thermal zones if necessary.

3.1.3 Needed input data

The needed input data are listed below:

V	[m ³]	internal volume of heated space
C	[J/K]	internal heat capacity of heated space
τ	[s]	time constant of heated space
		Note: either C or τ is specified, not both
η_h	[-]	heating system efficiency

3.2. Input data for heat loss (by Simon Woessner, IBP)

H_T	[W/K]	transmission heat loss coefficient according to EN 13789
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For ventilation losses, the following data are required:

V	[m ³ /s]	air flow rate from heated space to exterior
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For determination of this air flow rate, some of the following quantities can be used:

n_d	[h ⁻¹]	design air change rate
n_{50}	[h ⁻¹]	air change rate at 50Pa pressure difference
V_f	[m ³ /s]	design air flow rate through ventilation fans
η_v	[-]	efficiency of the heat recovery system on exhaust air

3.3. Input data for heat gains (by Simon Woessner, IBP)

Φ_I	[W]	average internal heat gains through heating period
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For glazed envelope elements, the following data shall be collected separately for each orientation (eg horizontal and vertical south, north, etc.)

A	[m ²]	area of opening in the building envelope for each window or door
F_F	[-]	frame factor, ie transparent fraction of the area A, not occupied by a frame
F_C	[-]	curtain factor, ie fraction of the solar radiation transmitted by permanent curtains
F_S	[-]	shading correction factor, ie average shaded fraction of the area A
g	[-]	total solar energy transmittance

3.4. Climate data (by Simon Woessner, IBP)

Θ_e	[°C]	monthly or seasonal average of external temperatures
$I_{s,j}$	[W/m ²]	monthly or seasonal total solar radiation per unit area for each orientation

3.5. Occupancy data (by Simon Woessner, IBP)

Θ_i	[°C]	set-point temperature
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3.5.1 Heat losses at constant internal temperature

For taking into account an intermittent heating system, refer to EN832 5.3. The Energy Concept Adviser takes into account a constant internal temperature due to simplification reasons and because it is no design tool a constant internal temperature, that can vary because of different setback modes.

◆ Principle:

The total heat loss, Q_i , of a single zone building at uniform internal temperature, during a given time period is:

$$Q_i = H \cdot (\Theta_i - \Theta_e) \cdot t$$

with:

Θ_i	[°C]	set-point temperature
Θ_e	[°C]	average external temperature during the calculation period
t	[d]	duration of calculation period
H	[W/K]	heat loss coefficient of the building
		$H = H_T + H_V$

with:

H_T	[W/K]	transmission heat loss coefficient, calculated according to EN 13789
H_V	[W/K]	ventilation heat loss coefficient

3.5.2 Transmission heat loss coefficient:

The transmission loss is calculated by:

$$H_T = \sum (F_{xi} \cdot U_i \cdot A_i) + H_{wb}$$

with:

i	[-]	building element
F_x	[-]	temperature correction factor of envelope element i

U	[W/(m ² K)]	thermal transmittance of envelope element i
A	[m ²]	area of envelope element i
H _{wb}	[W/K]	additional heat loss through thermal bridges

with:

$$H_{wb} = \Delta U_{wb} \cdot A$$

ΔU_{wb}	[W/(m ² K)]	additional surcharge for thermal bridges
A	[m ²]	area of building envelope

3.5.3 Ventilation heat loss coefficient:

◆ Principle:

$$H_v = \dot{V} \cdot \rho_a \cdot c_a$$

with:

V	[m ³ /s]	air flow through the building
$\rho_a c_a$	[Wh/(m ³ K)]	heat capacity of the air per volume

The airflow rate, V, can be calculated from an estimate of the air change rate, n, by:

$$\dot{V} = V \cdot n,$$

where V is the volume of the heated space, calculated on the basis of the internal dimensions.

◆ Minimum ventilation:

For comfort and hygienic reasons a minimum ventilation rate is needed when the building is occupied. The minimum ventilation rate should be determined on a national basis, taking into account the building type and the pattern of occupancy for the building.

When no national information is available, the recommended value for dwellings is:

$$n_{\min} = 0,5 \text{ h}^{-1}$$

◆ Natural ventilation:

The total air flow rate shall be determined as the greater of the minimum ventilation rate V_{\min} and the design ventilation rate V_d :

$$\dot{V} = \max[\dot{V}_{\min}; \dot{V}_d]$$

◆ Mechanical ventilation systems:

The total air flow rate shall be determined as the sum of the ventilation rate determined from the average air flow through the system fans when in operation, V_f , and an additional air flow rate, V_x , induced by wind and stack effect on an untight envelope.

Note: The Energy Concept Adviser doesn't include this possibility. See EN832 for detailed descriptions on how to calculate ventilation losses by mechanical ventilation system.

◆ **Mechanical systems with heat exchangers:**

For buildings with heat recovery from the exhaust air to inlet air, the heat losses by the mechanical ventilation are reduced by the factor $(1 - \eta_v)$, where η_v is the efficiency factor of the air to air heat recovery system. Thus the effective air flow rate for heat loss calculation is determined from:

$$\dot{V} = \dot{V}_f \cdot (1 - \eta_f) + \dot{V}_x$$

with:

η_v	[-]	efficiency factor of the air to air heat recovery system
V_f	[m ³ /s]	design air flow rate due to mechanical ventilation
V_x	[m ³ /s]	additional infiltration air flow rate with fans on, due to wind and stack infiltration

3.5.4 Effect of intermittence

With intermittent heating, heat loss is reduced, due to the lowering of the average internal temperature. Heat losses with intermittent heating may be calculated by replacing the set-point temperature by the average internal temperature.

3.5.5 Heat gains

Internal heat gains, Q_i , and solar gains, Q_s , make up the total heat gain, Q_g :

$$Q_g = Q_i + Q_s$$

◆ **Internal heat gains:**

Internal heat gains, Q_i , include any heat generated in the heated space by internal sources other than the heating system (metabolic gains from occupants, the power consumption of appliances and lighting devices,...).

$$Q_i = \Phi_i \cdot t$$

with:

Φ_i	[W]	average power of internal gains
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◆ **Solar gains:**

Basic equation:

Solar gains result from the sunshine normally available in the locality concerned, the orientation of the collecting areas, the permanent shading, and the solar transmission and absorption characteristics of the collecting areas.

For a given calculation period, the solar gain is calculated as following:

$$Q_s = \sum_j I_{sj} \sum_n A_{snj}$$

with:

$I_{s,j}$	[W/m ²]	total energy of the global radiation on a unit surface having the orientation j during the calculation period
A_{snj}	[m ²]	solar effective collecting area of the surface n having orientation j

Effective collecting area:

The effective collecting area, A_s , of a glazed envelope element is given by:

$$A_s = A \cdot F_s \cdot F_C \cdot F_F \cdot g$$

with:

A	[m ²]	area of the opening of collecting surface
F_s	[-]	shading correction factor
F_C	[-]	curtain factor
F_F	[-]	frame factor, equal to the ratio of the transparent area to the total area of the glazed unit
g	[-]	total solar energy transmittance

Note: Only permanent shading is taken into account.

Solar energy transmittance of glazing:

The total solar energy transmittance g should be the time-averaged ratio of energy passing through the unshaded element to that incident on it. For windows or other glazed envelope elements, EN410 provides a method to obtain the solar energy transmittance for radiation perpendicular to the glazing. This figure, g_{\perp} , is somewhat higher than the time-averaged transmittance, and a correction factor, F_w , shall be used:

$$g = F_w \cdot g_{\perp}$$

with:

F_w	[-]	correction factor for not perpendicular solar radiation
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Shading correction factors:

The shading correction factor, F_s , which is in the range from 0 to 1, represents any reduction in incident solar radiation due to permanent shading of surface. Permanent shading may be caused by one of the following factors:

- shading by other buildings
- shading by topography (hills, trees etc.)
- overhangs
- shading by other elements of the same building

Curtain factors:

The curtain factor differs from one only when the curtains are permanent. This factor is defined as the ratio of the average solar energy entering the building with the curtain to the energy that would enter the building without curtains. The solar radiation converted into heat in the curtain is considered to enter the building.

3.5.6 Heat use

◆ Heat balance:

Heat losses, Q_l , and heat gains, Q_g , are calculated for each calculation period. The space heating use for each calculation period is obtained from:

$$Q_h = Q_l - \eta \cdot Q_g$$

setting $Q_l = 0$ and $\eta = 0$ when the average external temperature is higher than the set-point temperature.

The utilisation factor, η , is a reduction factor for the heat gain, introduced into the mean energy balance to allow for the dynamic behaviour of the building.

◆ Utilisation factor:

Assuming perfect control of the heating system, the parameters having the greatest influence on the utilisation factor are:

the gain/loss ratio, γ , which is defined as

$$\gamma = \frac{Q_g}{Q_l}$$

and a time constant, τ , characterising the internal thermal inertia of the heated space:

$$\tau = \frac{C}{H}$$

where C is the effective internal thermal capacity, that is the heat stored in the structure of the building if the internal temperature varies sinusoidally with a period of 24h and an amplitude of 1K.

The utilisation factor is then calculated by:

if $\gamma \neq 1$

$$\eta = \frac{1 \cdot \gamma^a}{1 \cdot \gamma^{a+1}}$$

if $\gamma = 1$

$$\eta = \frac{a}{a+1}$$

where α is a numerical parameter depending on the time constant, τ , defined as:

$$\alpha = \alpha_0 + \frac{\tau}{\tau_0}$$

with

	α_0	τ_0
Monthly calculation method	1	16
Seasonal calculation method	0,8	28

3.5.7 Annual heat use of the building

◆ Monthly calculation method

The length of the heating season is not specified. The annual heat use is the sum over all months for which the average external temperature is lower than the set-point temperature:

$$Q_h = \sum_n Q_{nh}$$

◆ Seasonal calculation method

The first and last day of the heating season, hence its duration and its average conditions can be fixed at a national level for a geographic zone and typical buildings. The heating season includes all days for which the heat gain, calculated with a conventional utilisation factor, η_0 , does not balance the heat loss, that is when:

$$\Theta_{ed} \leq \Theta_{id} - \frac{\eta_0 \cdot Q_{gd}}{H \cdot t_d}$$

where:

Θ_{ed}	[°C]	daily average external temperature
Θ_{id}	[°C]	daily average internal temperature
η_0	[-]	conventional utilisation factor calculated with $\gamma = 0$
Q_{gd}	[Wh]	daily average internal and solar gains
H	[W/K]	heat loss coefficient of the building
t_d	[h]	duration of the day

Heat losses, Q_l , and heat gains, Q_g , are calculated for each calculation period. The space heating use for each calculation period is obtained from:

3.5.8 Heating energy use

The building energy use is then calculated by using an efficiency factor. See chapter 3.10.7 for methodology to calculate this factor. The building energy use is:

$$Q = e(Q_h + Q_w)$$

with:

e	[-]	efficiency factor of heating system
Q_h	[kWh/a]	annual heat use for space heating
Q_w	[kWh/a]	annual heat required for hot water

3.6. Calculation methodology for energy calculation of the Energy Concept Adviser (by Simon Woessner, IBP)

The above mentioned methodology of EN832 is used for the energy calculation of the Energy Concept Adviser. Though it is an information tool and not a design tool, some simplifications were made, either due to performance reasons or missing information. The main thought behind the development was to keep the tool as simple as possible, so than one can use it without a detailed knowledge of the building. Here are the differences to the EN 832 that are applied. The given numbers for some factors can be different for some countries therefore the numbers, agreed on for an 'international'-accepted calculation are reported.

3.6.1 Definition of boundaries and zones

The boundaries of the heated space consists of all elements of the building. They are at first given by a default dataset. This dataset can be changed. All defined elements are calculated as a part of the building envelope, that are separating the heated space from the external environment and unheated spaces. It is assumed, that all rooms of the heated space have nearly the same temperature, so that there is only one zone. If there are other spaces like swimming pools or gyms, they have to be cut out.

3.6.2 Necessary data input

All necessary data input is set by default values. Some of the factors are fixed. See therefore chapter 5 where are all the presets are listed.

The Climate data are given, and can't be changed unless there is more than one climate zone for a country available.

3.6.3 Heat losses at constant internal temperature

The set-point temperature is set to 19°C. It can vary; as if there is intermittent heating the set-point temperature is replaced by an average internal temperature. There are several setback modes available:

- | | |
|-----------------|--|
| no setback | the average temperature is the same as the set-point temperature |
| night setback | the average temperature is reduced for 7 hours a day to a given temperature, that can differ form country to country. As a default value, it is reduced by 3K to 16°C. |
| weekend setback | this mode includes the night setback. The temperature two days a week to a given temperature that can differ from country to country. As a default value, it is reduced by 5K to 14°C. The other 5 days a week, the temperature is reduced is in the night setback mode. |

holiday setback for holiday weeks during the heating season, the temperature is reduced to the value of the weekend setback. In normal weeks the weekend-setback mode is applied.

As this is only an information tool and not a design tool, the influence of the building inertia while cooling down and heating up the building is left out. If it were to be considered, then much more detailed input data would be necessary.

3.6.4 Transmission heat loss coefficient:

The transmission losses are calculated as EN13789 suggests with two simplifications. First the temperature correction factor for envelope elements that separate the heated space from the ground (slab on ground) is set to $F_x = 0,6$. Usually it depends on the perimeter of the building, but this value isn't known.

The used temperature correction factors are:

Tab. 3.1: Temperature correction factors in the ECA

Element	F_x
external wall	1,0
window	1,0
pitched roof (heated attic)	1,0
pitched roof (unheated attic)	0,8
flat roof attic floor	1,0
slab on ground	0,6
basement	0,6

The second thing is the treatment of thermal bridges. As the regarded buildings are old buildings, it is assumed that there was no special care for thermal bridges, so the additional value for thermal bridges is set to $\Delta U_{wb} = 0,1 \text{ W}/(\text{m}^2\text{K})$.

3.6.5 Ventilation heat loss coefficient:

There are only two possibilities available for ventilation, either natural ventilation or mechanical ventilation with heat recovery. If there is mechanical ventilation with heat recovery the air change rate is lowered to gather the gains from the heat recovery.

The lowered air change rate is calculated by:

$$n_{hr} = 0,4 \cdot (1 - \eta_v) + (n - 0,4)$$

with:

n_{hr}	[-]	reduced air change rate with heat recovery
η_v	[-]	efficiency of the heat recovery system on exhaust air
n	$[\text{h}^{-1}]$	original air change rate

The original air change rate is the same for natural and mechanical ventilation. This value is not fixed but depends on the sealing of the windows. If all windows are sealed the original air change rate is $n = 0,6$. If all windows are not sealed the original air change rate is set to $n = 0,7$. In the case that some windows are sealed and some not, the air change rate is linearly interpolated between these two values depending on the ratio of sealed windows.

3.6.6 Heat gains

◆ Internal heat gains:

The internal gains are calculated with a defined average internal load plus the internal load from the lighting system.

The defined internal load is calculated for the classroom area. It is based on the calculation, that there are 25 pupils in each classroom with a mean size of 60m^2 . It is assumed that the classroom is occupied 75% of the mean usage time which is in German schools assumed to be 1700h. For this defined internal load, the ratio of classrooms to total heated floor area is set to 75%.

$$q_{i,\text{def}} = \left(\frac{25 \text{ pupils} \cdot 80 \text{ W/pupil}}{60 \text{ m}^2} \cdot 75\% \cdot 1700 \text{ h} \cdot f_a \right) / (365 \text{ d/a} \cdot 24 \text{ h/d}) = 3,6 \text{ W/m}^2$$

with:

$q_{i,\text{def}}$	[kWh/m ² a]	defined average internal power
f_a	[-]	ratio area of classrooms / total floor area = 75%

The lighting power is calculated according to the description in chapter 3.3. The energy consumption of light is calculated for the classroom area and the adjoining spaces. The adjoining spaces are calculated with half of the installed lighting power of the classroom areas.

$$q_{i,\text{light}} = C_{\text{light}} / (365 \text{ d/a} \cdot 24 \text{ h/d})$$

with:

$q_{i,\text{light}}$	[Wh/m ² a]	internal power of lighting system
C_{light}	[Wh/m ² a]	energy consumption for lighting of the building

The total internal loads are calculated as follows:

$$q_i = q_{i,\text{def}} + q_{i,\text{light}}$$

with:

$q_{i,\text{light}}$	[Wh/m ² a]	internal power of lighting system
$q_{i,\text{def}}$	[kWh/m ² a]	defined average internal power

◆ Solar gains:

The solar gains are calculated twice. Once for the calculation of solar gains for the energy requirement according to EN 832 without movable shading and for the calculation of possible overheating in summer times including movable shadings.

The factors for the effective collecting area for solar gains are:

Shading correction factor:

$$F_S = 0,9$$

Curtain factor:

$$F_C = 1 \quad \text{for standard calculation}$$

$$F_C = 1..0 \quad \text{for calculation of possible overheating, depending on shading system}$$

Frame factor:

$$F_F = 0,7$$

Factor for not perpendicular solar radiation

$$F_W = 0,9$$

3.6.7 Heat use

◆ Heat balance:

The heat use is calculated on a monthly basis.

◆ Utilisation factor:

As this calculation procedure is only for an information tool and there is not that much detailed knowledge about the constructions available, the calculation of the thermal inertia, τ , is done with a simplified procedure:

$$\tau = \frac{C_{\text{wirk}} \cdot V_e}{H}$$

with

V_e [m³] heated volume

C_{wirk} [Wh/(m³K)] effective heat capacity

with $C_{\text{wirk}} = 50 \text{ Wh}/(\text{m}^3\text{K})$.

3.6.8 Annual heat use of the building

The heat use is calculated on a monthly basis. The heat energy use depends on the heating system used, see therefore chapter 3.5.

heat energy use for heating:

$$Q_{\text{We,e}} = Q_h \cdot e_f$$

with

Q_h [kWh/m²a] annual heat use
 e_f [-] efficiency number for heat energy use

heat energy use for heating:

$$Q_{He,e} = Q_{He,e,heat} + Q_{He,e,light}$$

with

$Q_{He,e,heat}$ [kWh/m²a] annual help energy use of the heating system, determined according to chapter[???

$Q_{He,e,light}$ [kWh/m²a] annual help energy use of the artificial lighting, determined according chapter [???

The primary energy use is calculated by:

$$Q_p = Q_{We,e} \cdot f_{p,heat} + Q_{He,e} \cdot f_{p,el}$$

with:

$Q_{We,e}$ [kWh/m²a] annual heat energy use

$f_{p,heat}$ [-] primary energy factor for used energy source of the heating system

$Q_{He,e}$ [kWh/m²a] annual help energy use

$f_{p,el}$ [-] primary energy factor for electrical energy

Tab. 3.2: Primary energy factors used in the ECA

	primary energy factor
coal	1,1
district heating	1,3
electrical energy	3
gas	1,1
oil	1,1

3.7. Cooling needs (by F. Schmidt, IKE)

The method developed in SANIREV

Rouvel et al. have shown that there is a correlation between the probability h_{9m} of the room temperature rising above the maximum allowable temperature ϑ_m and the non usable heat load Q_{NN} which is calculated in ISO/DIN 13790. This correlation was determined by simulation of a residential building. The simulation results are shown in Fig. 3.3.

It is assumed that schools are used only 5 days a week. This allows an increase of h_{9m} by a factor of 1.4 (7/5).

From these simulations the values for maximum allowable not usable heat loads were determined. They are given in Tab.2.2. Country specific parameters which represent Climate conditions different from those valid in Germany may be derived by similar simulations or estimated by simple extrapolations. An estimation is also given in Tab.3.3.

With this information available it becomes easy to do the necessary modifications to an ISO/DIN 13790 calculation. We proceed as follows:

- Use basic information from ISO/DIN 13790 calculations
- Determine non usable heat load
- Derive maximum values for non usable heat load which guarantees room comfort through dynamic simulations (this depends on climate zone)
- If non usable heat load is greater than the maximum, consider cooling
- Determine cooling rates
- If cooling rate is greater than the maximum, modify building
- Derive maximum cooling rates as a function of internal loads

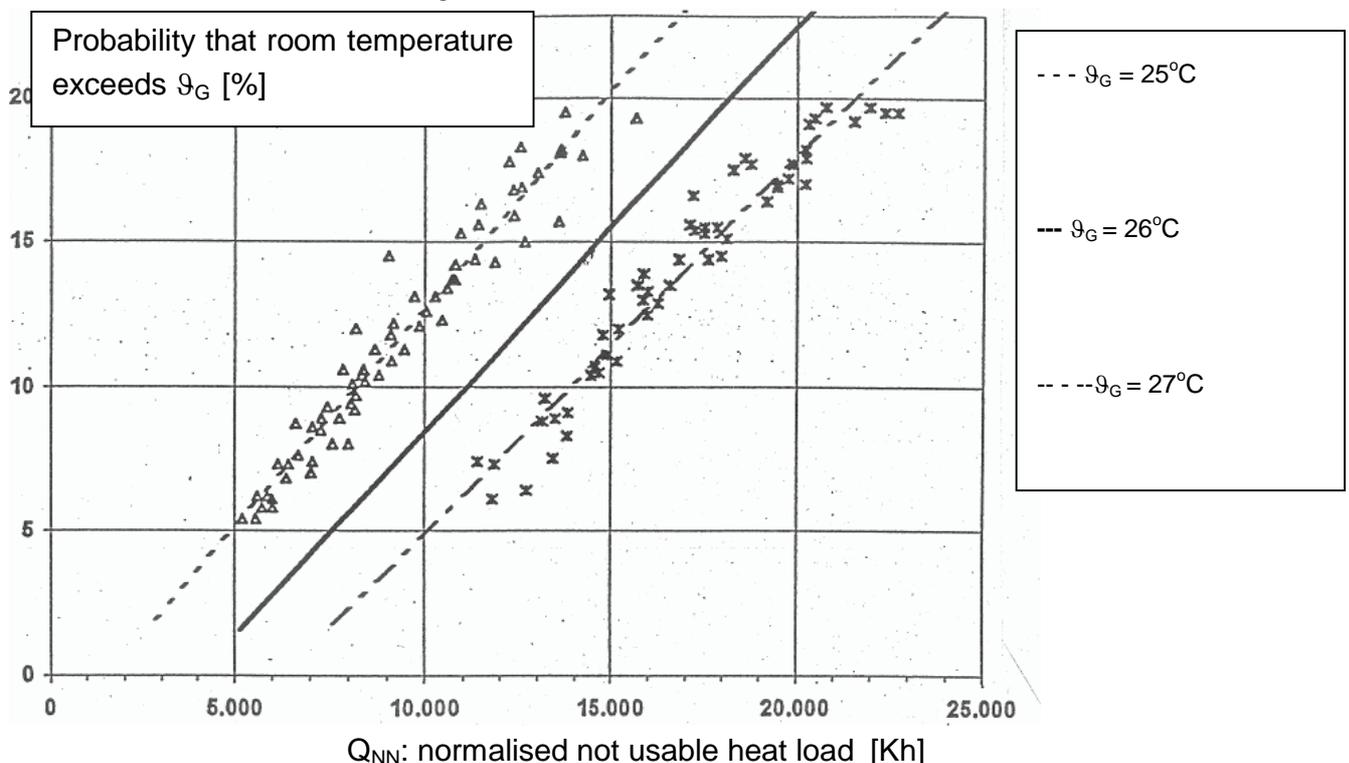


Fig. 3.3: Simulation results for the determination of normalised maximum not usable heat load

The normalised not usable heat load is calculated as follows:

A room becomes uncomfortable if $Q_{NN} > Q_{NNmax}$. As a first reaction one should modify the building or its utilisation to reduce Q_{NN} .

$$Q_{NN} = \sum_{i=1}^{12} (1 - \eta_i) \frac{Q_{G,i}}{H_i}$$

$Q_{G,i}$ = monthly heat gains as calculated from DIN/ISO 13790

H_i = monthly heat loss coefficient of DIN/ISO 13789

η_i = heat utilisation factor as calculated from DIN/ISO 13790

i = month

If the reduction of Q_{NN} is not possible, one has to care about special cooling devices and to ask an expert for support.

References

Deutscher, Elsberger, Rouvel: Vereinfachte Berechnungsverfahren für den sommerlichen Wärmeschutz. Endbericht zum AP 1.1 des SANIREV Vorhaben, Feb. 1999.

Kolmetz, S.: Thermische Bewertung von Gebäuden unter sommerlichen Randbedingungen - Ein vereinfachtes Verfahren zur Ermittlung von Raumtemperaturen in Gebäuden im Sommer und deren Häufigkeit. Diss. Universität Gesamthochschule Kassel, 1996.

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3.8. Calculation procedure of energy consumption for lighting of Educational Buildings (by Richard Cantin and Gérard Guarracino)

This calculation procedure takes into account the French Thermal Regulation 2000, the norm NF-EN-410 and the norm NF-X35-103.

The purpose of this method is to calculate the energy consumption for lighting of the educational buildings.

The following lighting should not be taken into account during the application of the method: external lighting, the lighting of housing, the lighting of the car parks, the emergency lighting and display lighting intended to emphasise objects or goods.

3.8.1 Energy consumption for lighting

The energy consumption for lighting of a building is the sum of consumption of energy of the various zones:

$$C_{\text{light}} = \sum_{\text{zones}} P_{\text{lightzones}} \times t_{\text{lightzones}}$$

with C_{light} energy consumption for lighting of the building (Watt-hours),

P_{light} installed lighting power of the building (Watt),

t_{light} operation time of lighting (hours),

and zones referring to the various areas.

3.8.2 Calculation of the lighting power

P_{light} is the installed lighting power for the interior lighting of the educational buildings. It includes the power of the lamps and accessories. All the devices of lighting installed at fixed points must be taken into account other than the emergency lighting.

If the lighting power is not known, which can be the case, for example if the installation of lighting is not envisaged to be delivered with the building, $P_{\text{lightzone}}$ will be equal to 1,5 times the values P_{lightref} defined as tables 3.3 and 3.4:

Tab. 3.3: Global determination of P_{lightref}

Destination of the zone	P_{lightref}
Offices	16 W/m ²
Educational building	15 W/m ²
Sporting Establishment	10 W/m ²
Other premises	12 W/m ²
Zone where general lighting is sufficient to ensure only visual comfort	3 W/m ² for 100 lux

Source French Thermal Regulation 2000

Tab. 3.4: Detailed determination of $P_{lightref}$

Type of room	$P_{lightref}$
Storage and archives	6 W/m ²
Reception area and circulation	12 W/m ²
Others spaces of more than 30 m ²	15 W/m ²
Others spaces of less than 30 m ²	18 W/m ²
Spaces requiring a maintained illuminance of more than 600 lux or spaces where general lighting is sufficient to ensure only the visual comfort	
- spaces of less than 30 m ²	4 W/m ² for 100 lux
- spaces of more than 30 m ²	3 W/m ² for 100 lux

Source French Thermal Regulation 2000

3.8.3 Calculation of the number of hours

If t_{light} is unknown, t_{light} is calculated as following:

$$t_{light} = C_1 \cdot t_{nighttype} + C_1 \cdot C_2 \cdot C_3 \cdot C_4 \cdot t_{daytype}$$

Thus, the number of hours depends on:

- daylight (coefficient C_3),
- management devices placed at the disposal of the occupants or managers (coefficients C_1 and C_4),
- climate area (coefficient C_2),
- use of building or with various uses of rooms in the building ($t_{daytype}$ and $t_{nighttype}$).

3.8.4 Access to daylight

C_3 is a corrective coefficient for the useful period of the day according to the access to daylight. Five types of access to daylight are distinguished:

- impossible access,
- no access,
- weak access,
- average access,
- strong access.

C_3 is given in the following table:

Tab. 3.5: Corrective coefficient for the useful period of the day

Access to daylight	C_3
Impossible or no	1
weak	1
average	0,8
strong	0,6

Source French Thermal Regulation 2000

The access to daylight is impossible if the room does not have an external wall or if, for instance, openings on of these walls is prohibited by rules of town planning.

There is no access daylight if the room does not have any windows.

For a building, part of building, or a room, the membership of one of the three other types of access depends on the light indicator I_c and the depth indicator I_p .

Tab. 3.6: Types of access to daylight

	Access to daylight of building or the part of building
$I_c - 5 I_p > 0$	Strong
$0 \geq I_c - 5 I_p > -5$	Average
$-5 \geq I_c - 5 I_p$	Weak

Source French Thermal Regulation 2000

These two indicators are calculated as follows:

1) The building is separated into two parts:

- a part which can « profit from daylight » whose surface is A_{lightnat} ,
- a part which cannot « profit from daylight » whose surface is $\sum A_{\text{loc}} - A_{\text{lightnat}}$, with A_{loc} the surface of floor of the room. This part $\sum A_{\text{loc}} - A_{\text{lightnat}}$ is regarded as blind and it is thus useless to calculate the indicators I_p and I_c . The coefficient C_3 of this part is equal to 1.

Buildings, less than 10 m deep and in which the rooms without windows are only store rooms, circulation spaces and service spaces, are considered entirely daylight

$$A_{\text{lightnat}} = \sum A_{\text{loc}}$$

For other buildings, the part being able to profit from daylight is made up:

- Rooms with windows and having less than 5 m depth,
- Parts of buildings located at less than 5 m from a window for buildings of more than 5 m deep if lamps lighting this part are independently controlled,

- Rooms with glazing uniformly distributed in the roof (zenith lighting, skylights), when the surface area of the glazing is higher than 5 % of the floor area of the room.

The depth of a room is the distance, perpendicular to the centre of the glazed wall, between this wall and the opposite wall of the room.

Particular case:

The 5 m limit, given for the depth of a room to characterise its daylight, is increased to 10 m when the room has glazed parts whose high point is located at more than 4,5 m above the floor level.

2) The light indicator of the part of the building which can profit from the daylight is defined by:

$$I_c = 100. \left(\sum_{\text{windows}} A_v \cdot \tau_{df} \right) / A_{\text{lightnat}}$$

A_v is the glazed area of windows,

τ_{df} is the factor of transmission for diffuse incidence of the glazed part of the windows and transparent and translucent walls (0,65 for not very emissive double-glazing); if the value of this factor is unknown, a value of transmission in normal incidence will be equal to 90% (NF-EN-410).

A_{lightnat} is the total surface of rooms of the building profiting from daylight.

3) The depth indicator for the part of the building which can profit from daylight is defined by:

$$I_p = A_{\text{lightnat}} / (1,3 \cdot \text{peri})$$

where peri represent the " equivalent length of facade ":

$$\text{peri} = \sum_{\text{floor}} \text{peri}(\text{floor})$$

where peri(floor) is, for one floor, the external perimeter of the part of the building profiting from daylight.

3.8.5 Management devices

The management devices are distinguished as:

- switch with manual control,
- time programming,
- time programming + switch,
- occupancy sensor,
- automatic dimming for artificial lighting,
- automatic dimming for artificial lighting + occupancy sensor.

C_1 depends on the general management device used and is given in the following table:

Tab. 3.7: Impact of the management device over the duration of lighting at night

Management device	C_1
Switch with manual control	1
Clock + switch	0,9
Switch + occupancy sensor	0,8

Source French Thermal Regulation 2000

C_4 is a nondimensional corrective coefficient which takes account of the daylight management device. C_4 is given in the following table:

Tab. 3.8: Impact of the management device over the duration of daylight

Management device	Room with daylight C_4
Switch with manual control	0,6
Regulation of interior illuminance in progressive way	0,4

Source French Thermal Regulation 2000

For buildings without daylight, $C_4 = 1$.

3.8.5.4 Climate area

C_2 is a corrective adimensional coefficient of the number of hours per day lighting isoperated according to the climate area. C_2 is given in the following table:

Tab. 3.9: Corrective coefficient according to the climate zone

Climate area	C_2
H1 – Basic temperature – 9°C	1
H2 – Basic temperature – 6°C	0,8
H3 – Basic temperature – 3°C	0,6
All zones without access to daylight	1

Source French Thermal Regulation 2000

3.8.5.4 Correlations between Climate data and lighting zones

Due to lack of time we did not investigate how the French Climate zones H1, H2 and H3 correspond to the climate zones in other countries and how C_2 should be adapted. Further investigations will be necessary here.

3.8.5.4 Duration of utilisation

$t_{\text{enighttype}}$ and t_{edaytype} depend on the use of the building or the room and are given in the following table for the global method.

Tab. 3.10: Duration of utilisation-type of lighting

Types of buildings	$t_{\text{enighttype}}$	t_{edaytype}
Office and sporting Establishment	150	2350
Educational building	100	1600
Restoration a service (midday only) in the places of teaching	0	300

Source French Thermal Regulation 2000

For a detailed calculation, the durations for each type of buildings are the same ones as for the global calculation with two exceptions:

- the durations for store rooms are taken equal to 20 % of durations used in the global method,
- the durations for circulations are taken equal to 120 % of durations used in the global method.

Thus, when installed lighting power P_{light} or operating time for lighting t_{light} is unknown, the French Thermal Regulation 2000 provides a default reference value..

3.8.5.4 References

French Thermal Regulation 2000 - Arrêté du 29 novembre 2000 relatif aux caractéristiques thermiques des bâtiments nouveaux et des parties nouvelles de bâtiments – Règles ThC.

Norme NF-EN-410 (P78-457) : Verre dans la construction. Détermination des caractéristiques lumineuses et solaires des vitrages.

Norme NF X35 103 (X35-103) : Ergonomie – Principe d’ergonomie visuelle applicable à l’éclairage des lieux de travail.

3.9. Potential HVAC systems suitable for educational buildings (by R. Haller, IKE)

In the following examples different hot water heating systems are described, which are suitable for use in educational buildings. The list originates from DIN 4701-10 supplement 1, in which altogether 71 different equipment variants are described. The structure of the examples is described according to VDI 2067 and DIN 4701-10.

3.9.1 Heating systems with decentralised water heaters, natural ventilation

The following HVAC-systems are suitable mainly for buildings which are predominantly classrooms. The energy demand for hot water is assumed therefore to be small. It is recommended to generate the hot water by decentralised systems, storage or instantaneous type water heaters, electric or gas fired. Furthermore it is assumed that there are no mechanical ventilation systems. The necessary exchange of air must be provided by natural ventilation.

3.9.2 Heating systems with decentralised, electrical storage water heaters and a mechanical ventilation system

The following HVAC-systems are suitable mainly for buildings which are predominantly classrooms. The energy demand for hot water is assumed therefore to be small. It is recommended to generate the hot water by decentralised systems, storage or instantaneous type water heaters, electric or gas fired. Furthermore it is assumed that there are mechanical ventilation systems. The necessary exchange of air is provided by the mechanical ventilation system.

3.9.3 Heating systems with central domestic hot water system and natural ventilation

The following HVAC-systems are suitable mainly for buildings with mixed use (class rooms, kitchen, laboratory and gymnasiums). The energy demand for hot water is assumed therefore to be higher than 15 litres per person. It is recommended to generate the hot water by central domestic hot water systems. Furthermore it is assumed that there are no mechanical ventilation systems. The necessary exchange of air is provided by natural ventilation.

3.9.4 Heating systems with central domestic water heating and mechanical ventilation

The following HVAC-systems are suitable mainly for buildings with mixed use (class rooms, kitchen, laboratory and gymnasiums). The energy demand for hot water is assumed therefore to be higher than 15 litres per person. It is recommended to generate the hot water by central domestic hot water systems. Furthermore it is assumed that there are mechanical ventilation systems. The necessary exchange of air is provided by the mechanical ventilation system.

3.9.5 Heating systems with central domestic hot water heating, support by a solar energy system and natural ventilation

The following HVAC-systems are suitable mainly for buildings with mixed use (class rooms, kitchen, laboratory and gymnasiums). The energy demand for hot water is assumed therefore to be higher than 15 litres per person. It is recommended to generate the hot water by central domestic hot water systems supported by a solar energy system. Furthermore it is assumed that there are no mechanical ventilation systems. The necessary exchange of air must be provided by natural ventilation.

3.9.6 Operating systems

A short description of the assumptions made on operating systems is given in the following table. For details see Subtask A working report 2.

Please note that the energy efficiency numbers given in this table assume demand driven operation. Most heating systems do not fulfil this assumption after several years of operation without continuous monitoring. In such a case the efficiency of the system decreases and the efficiency numbers increase. An audit will reveal in such a case the measures needed to adjust the system to the actual user demand.

Tab. 3.11: Energy efficiency factors for operating systems (primary energy)

Period	Heat demand in kWh/m ² a	Default systems: Description	Energy efficiency factor e*
Before 1960	360 ... 400	Steam boiler, Steam heating, 105 °C, cast iron heating elements, no room regulation, natural ventilation	2,0 ... 1,7
1960 - 1977	280 ... 360	High temperature boiler, hot water heating, 95 °C, gravitational force, mechanical room regulation, natural ventilation	1,8 ... 1,6
1977 – 1983	180 ... 260	High temperature boiler, pumped hot water for heating, 90/70 °C, thermostatic room regulation, natural ventilation	1,7 ... 1,4
		District heating, supply from heat generation, pumped hot water for heating, 90/70 °C, thermostatic room regulation, natural ventilation	1,5 ... 1,3
		District heating, supply from combined heat and power generation, pumped hot water for heating, 90/70 °C, thermostatic room regulation, natural ventilation	1,5 ... 1,3
1984 – 1995 (WSVO 84)	140 ... 180	High temperature boiler, pumped hot water for heating, 80/60 °C, thermostatic room regulation, natural ventilation	1,6 ... 1,4
1995 – 2002 (WSVO 95)	100 ... 140	Low temperature boiler, pumped hot water for heating, 75/65 °C and lower, thermostatic room regulation, natural ventilation	1,5 ... 1,3

* estimated values All values were estimated with the fact in mind that energy efficiency is strongly coupled to the heat demand of the building. Influences of non optimal operation are not included. Experiences show, due to improper operation, increases of the efficiency factors up to a value of 3 occur.

The efficiency factors given relate to end-energy. Therefore they can be applied to both systems with natural and with mechanical ventilation. These systems differ only due to the different amounts of auxiliary energy they need.

3.9.7 Method to determine efficiency numbers for HVAC systems

Two different methods for determining efficiency numbers for HVAC systems were developed.

The first method handles existing systems. The starting point is the ranges for each system given in Tab. 3.9. Variations according to the heat demand and the heated area were modelled through simple correlations..

For the heat demand a linear interpolation between the corresponding efficiency numbers is assumed as the basis of the correlation.

The variation factor with the heated area is calculated through a quadratic variation:

$$f_{area} = a_0 + a_1 / x + a_2 / x^2$$

with $x = area / 1000$,

$$f_{area}(500) = 1.1, f_{area}(2000) = 1.0 \text{ and } f_{area}(10000) = 0.9$$

From this we obtain:

$$f_{area} = 0.8702 + 0.3709 / x + 0.0965 / x^2$$

The efficiency number is computed by multiplying both approximations. Due to the limited validity of the basic assumptions the estimated values are restricted. They can not be less than the minimal value given in Tab. 3.9 decreased by 10% of average value. Also the approximation as a whole should only be applied for educational buildings with an area greater 500m² and heating demand of less than 750 kWh/m²a. As an example we give the resulting efficiency numbers for the steam heating.

The auxiliary energy is assumed to be constant for each system and depends on the heated area. The assumed values are shown in Tab 3.12. In case of the heating system with mechanical ventilation the auxiliary energy is increased by an additional factor of 5 kWh/m²a.

Tab. 3.12: Auxiliary energy for existing systems

Heated area [m ²]	Auxiliary Energy natural ventilation [kWh/m ² a]	Auxiliary Energy mechanical ventilation [kWh/m ² a]
2500	1.0	6.0
7500	0.9	5.9
30000	0.8	5.8

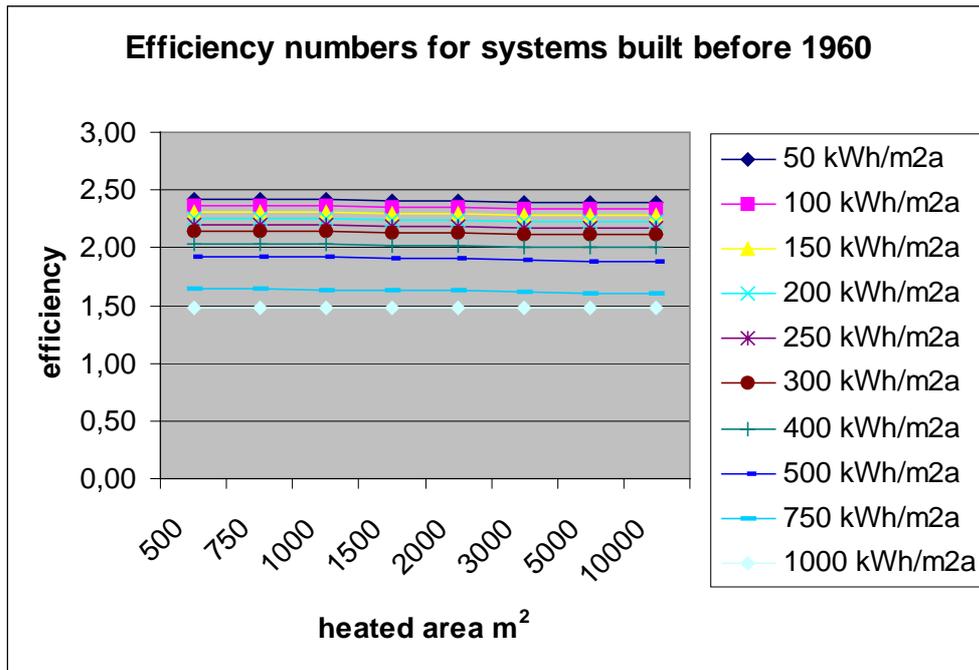


Fig. 3.4: Efficiency number for steam heating systems built before 1960 as a function of heated area and heating demand

The second method is used to determine the efficiency numbers for retrofitted systems. The basic calculation was done in accordance with German VDI guideline 4701 part 10. For each system 18 efficiency numbers were calculated (for details see Subtask A report):

Tab. 3.13: Calculated efficiency numbers for retrofitted system Nr. 4.

e [-]		A [m²]		
		2400	7800	30000
qh Q [kWh/m²a]	40	1,28	1,26	1,25
	80	1,18	1,17	1,17
	120	1,15	1,14	1,14
	160	1,14	1,12	1,12
	200	1,13	1,12	1,11
	240	1,12	1,11	1,11

The actual efficiency number is computed by a linear interpolation (extrapolation) from this table

3.10. Economic calculations (by T. M. Mroz, PUT)

The ECA uses a simple scheme. It assumes a lifetime of 50 years for all investments and an interest rate of 6%. The assumed inflation rate is 6% too.

4 Adaptation of ECA models to schools (by Fritz Schmidt IKE)

4.1. Comparison of alternative methods - Preliminary studies

Before deciding on the methods mentioned in the last chapter we have performed simulation of heating energy demand and primary energy demand for various types of buildings including schools. We used different methods including yearly methods (WSch V095), monthly methods (MoBi, HPBi) and hourly methods (TRNSYS). Some of the methods were applied with different parameterisations or in different implementations. A short description is given in Table 4.1.

Tab. 4.1: Methods used for the initial comparisons

	Name	Model	Time interval	Comments
1	WSch VO 95	Simple method	Year	Old German standard
2	MoBi (monthly balance)	Design method EnEV	Month	With heat bridges
3	MoBi DIN 4108	Design method EnEV/DIN 4108	Month	Without heat bridges
4	HPBi (heating period balance)	EnEV	Month	Heating period only
5	TRNSYS V1	Research method TRNSYS-EnEV	Hour	Internal gains 7 Air change rate 0,8
6	TRNSYS V2	Research method TRNSYS-EWU	Hour	Internal gains 3,36 Air change rate 0,6

First these methods were used to carry out calculations for an apartment building, which had about the size of building 2 of the MOSES project (see Fig.4.1 and App.0). To do this we choose an area of 10m by 55m with 2 floors.

The results of the comparison calculations are summarised in Fig. 4.2.

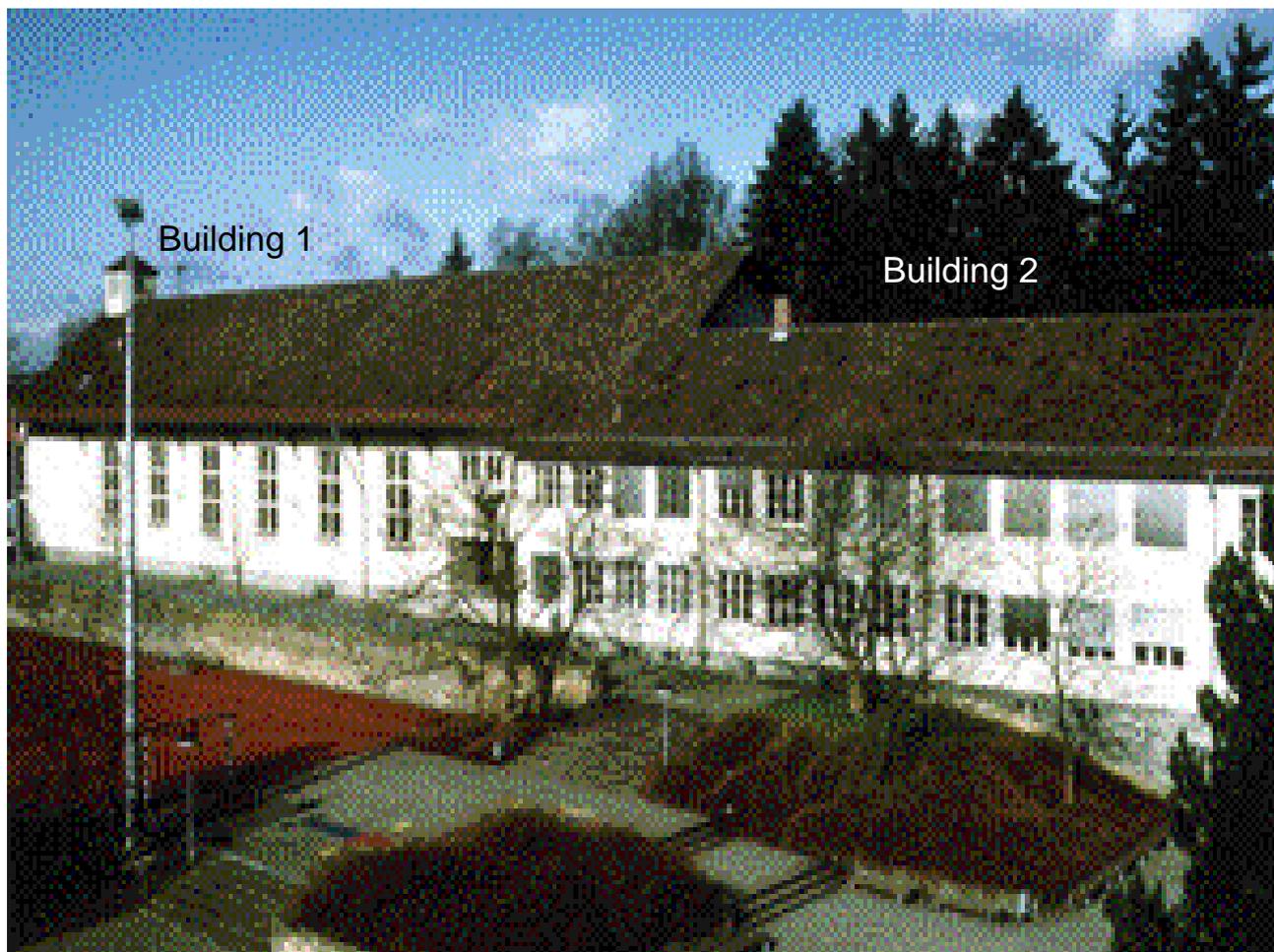


Fig. 4.1: School building for comparison calculations

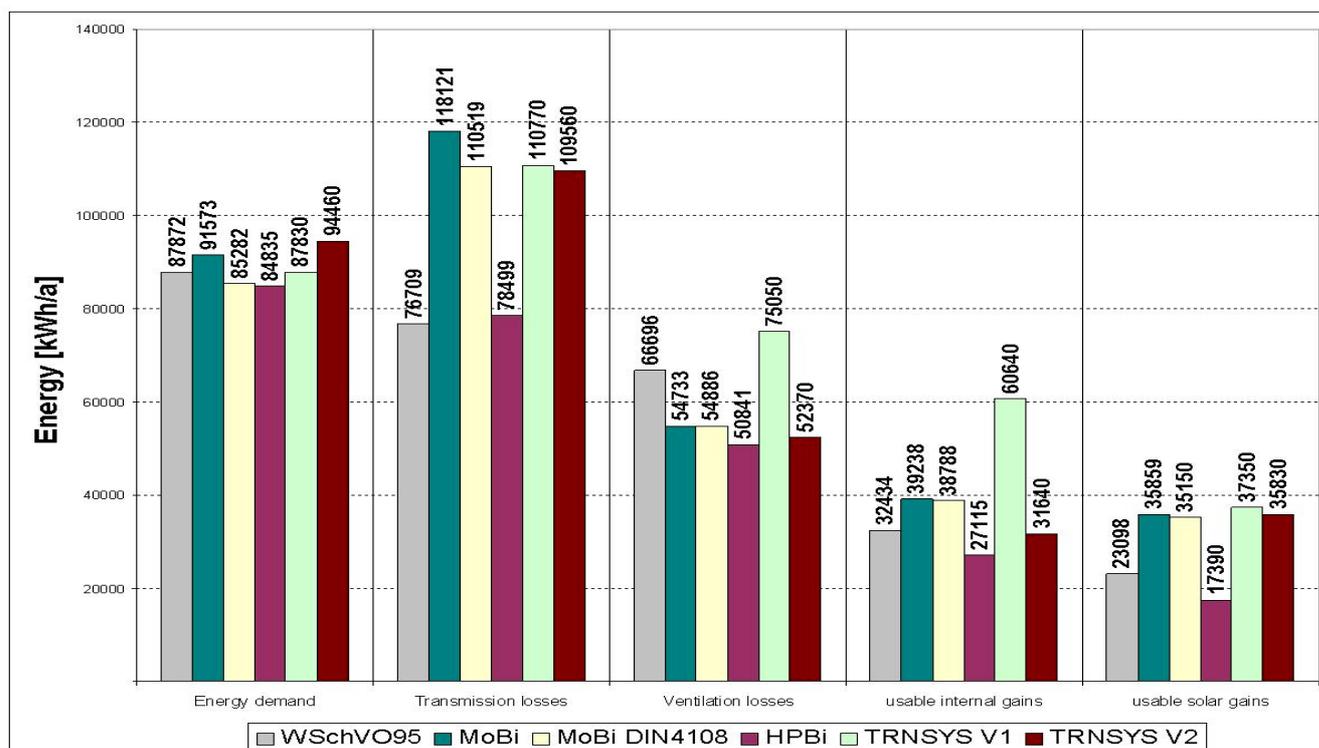


Fig. 4.2: Energy balances according to the different calculation methods

One easily can see, that the heating energy demand is predicted nearly the same from all methods. Therefore both monthly and hourly methods would be applicable to predict potential energy savings due to retrofit measures concerning the building envelope and changes in technical systems. After eliminating methods 1, 4 and 5 reasonable agreement was found also for transmission and ventilation losses and solar and internal loads. This can be seen in Fig. 4.3.

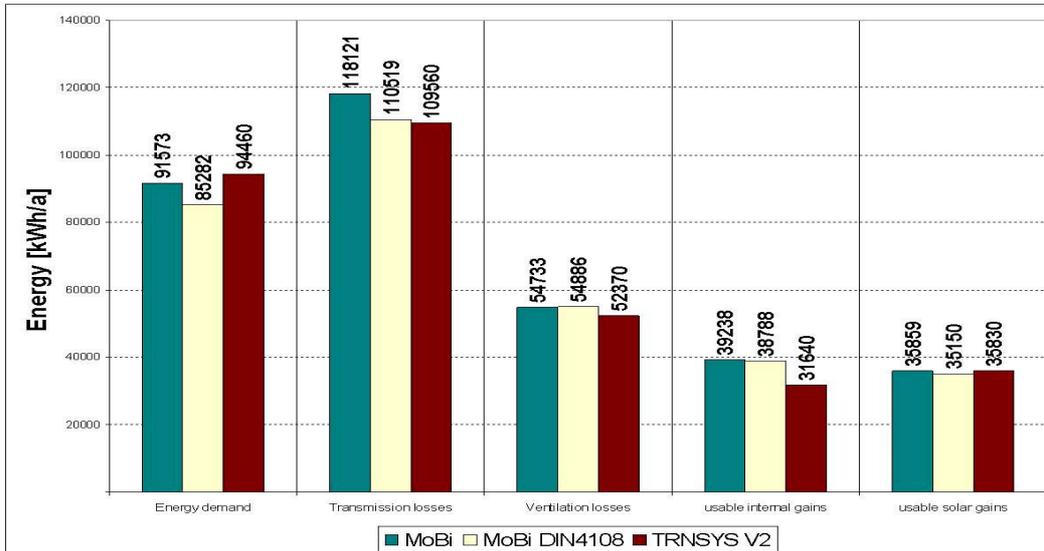


Fig. 4.3: Energy balances according to the selected calculation methods

Next a more detailed analysis was done, to see which effects are most important in the energy balance. Two cases were considered:

1. The apartment building with isolations corresponding to the German standard of 1995 (WschVO)
2. The apartment building with isolations corresponding to the German standard of 2002 (EnEV)

The results are presented in the following figures:

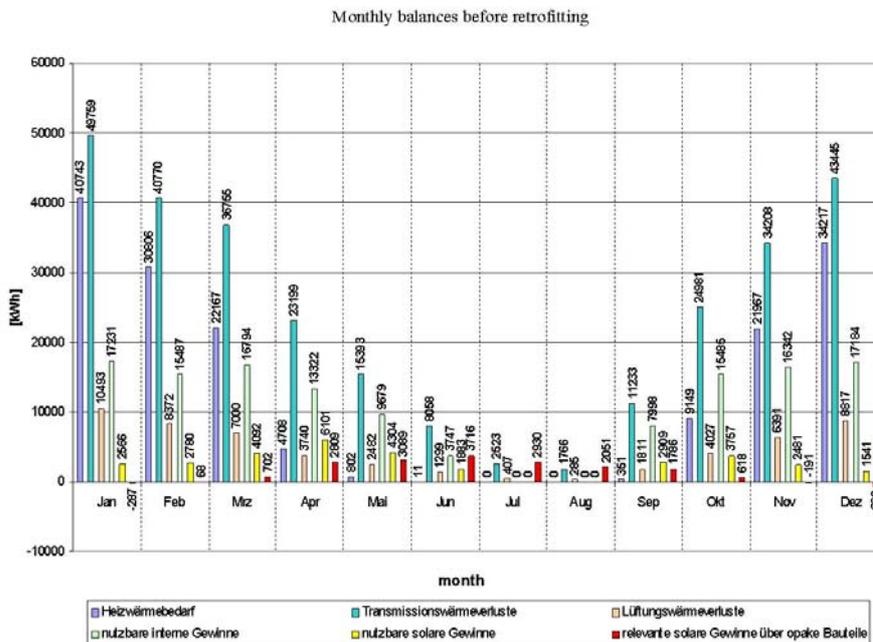


Fig. 4.4: Monthly balances for an apartment building before retrofit

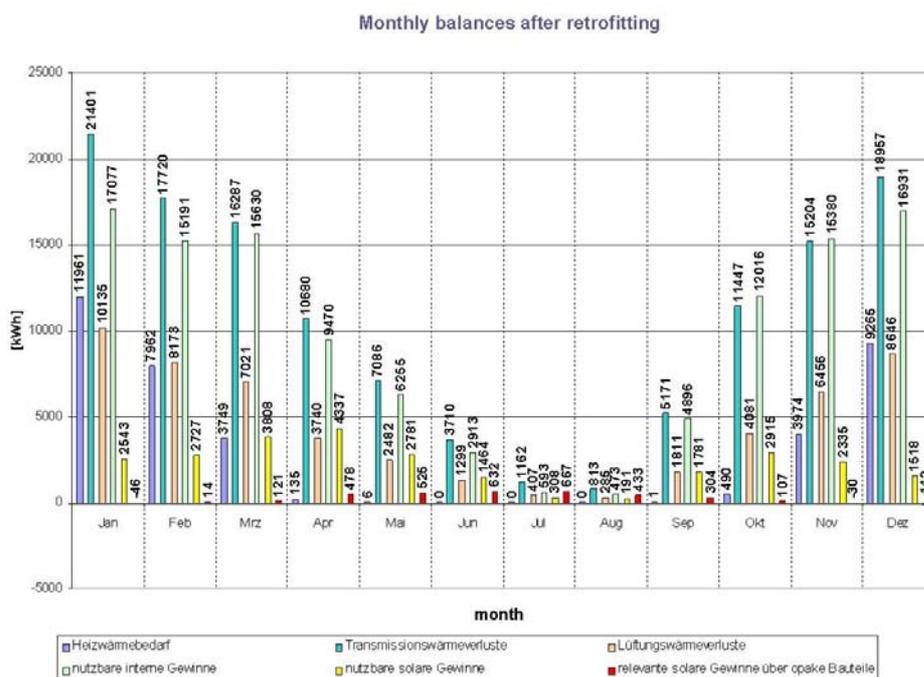


Fig. 4.5: Monthly balances for an apartment building after retrofit

The situations before and after retrofit differ considerably. In both cases transmission losses give the largest contribution to the heat balance equation. Heat demand however is calculated before retrofit from the transmission losses with minor corrections due to the other effects and after retrofit as a difference of almost equal quantities. As a conclusion we have to consider in the ECA transmission most accurately and have to be aware that after retrofit its results might be of limited value only.

We then used the monthly and the hourly method to go into a more detailed analysis and to perform various sensitivity investigations. The same cases (apartment building) as before were considered. In addition a first extrapolation towards a school building was investigated.

The goal of these investigations was to check the following assumptions:

Assumption 1

Typology of a building is less important: a one zone model based on the correct volume to surface area ratio should be sufficient for ECA applications.

Assumption 2

Were possible U-values should be adapted to the values of the building.

Assumption 3

Most influences could be approximated before retrofit by a linear correlation

Assumption 4

The HVAC system has to be adapted after retrofit.

The results are described in more detail in the next subchapter.

4.2. Sensitivity of parameters influencing the energy consumption of school buildings

As mentioned before sensitivity studies were performed to get a better feeling for the various parameters which are necessary to describe a school building in a way consistent with the monthly balance model. The sensitivity studies include:

- U-Values of walls to see the influence of assumption 2
- A/V to see the influence of assumption 1
- Internal loads to see the influence of assumption 3
- Glazing factor to see the influence of solar loads
- Efficiency numbers to see the necessity of commissioning and continuous control (assumption 4)

The investigations were made using the methods

- TRNSYS - V2 (method 6)
- MoBi (method 2)

4.2.1 Influence of U values

Before retrofit transmission losses are by far the largest contribution to the heat balance equation. These losses are strongly dependent from the U-values of the building walls and windows. A first approach could be a linear one. To check this assumption we analysed the transmission losses before and after retrofit

From the known values of changes in the U-values (see Tab.4.2) of different building parts we estimated the expected reductions of the corresponding losses (see Tab. 4.4) The values obtained were in good agreement with those obtained from the balance calculation.

The reduction of transmission losses will result directly in a reduction of heating energy demand, if there are buildings with large energy losses due to insufficient insulation. This is in good agreement with assumption 2.

Tab. 4.2: Correlation between reduction in U-values and transmission losses

	% before	total	Reduction factor U value	Expected loss	Total after	% after
Wall	36	144	0,14	20	22	11
Window	23	92	0,4	37	38	19
Ventilation	16	64	-	64	60	29
Floor	14	56	-	56	56	28
Roof	7	28	0,2	6	6	3
other	4	17	-	17	18	10
Sum	100	401		200	198	100

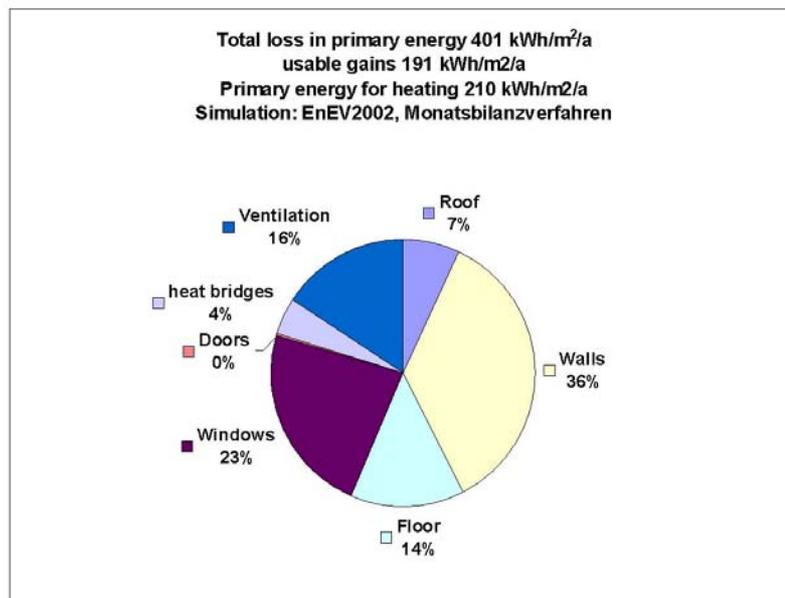


Fig. 4.6: Distribution of losses before retrofit as calculated with monthly balances

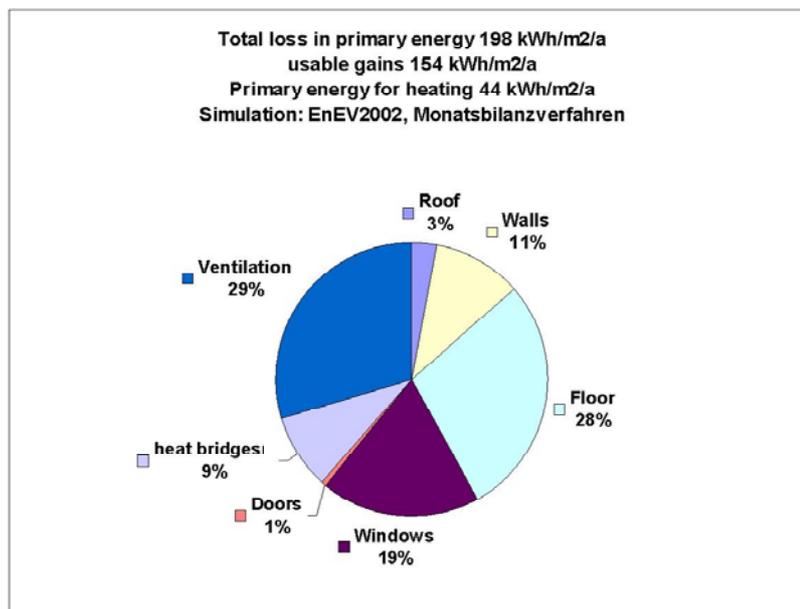


Fig. 4.7: Distribution of losses after retrofit as calculated with monthly balances

It is possible to see from this comparison that

- a linear correlation is a good approximation for predicting transmission losses
- usable gains are reduced through retrofit
- gains and losses other than through transmission have to be determined again after retrofit

4.2.2 Influence of the A/V ratio

In assumption 1 we stated: *Typology is not important: a one zone model based on the correct volume to surface area ratio should be sufficient for ECA applications.* To check this assumption several calculations were performed with buildings with different A/V ratios. The results are given in the following figure (Before retrofit WschVO, After retrofit EnEV):

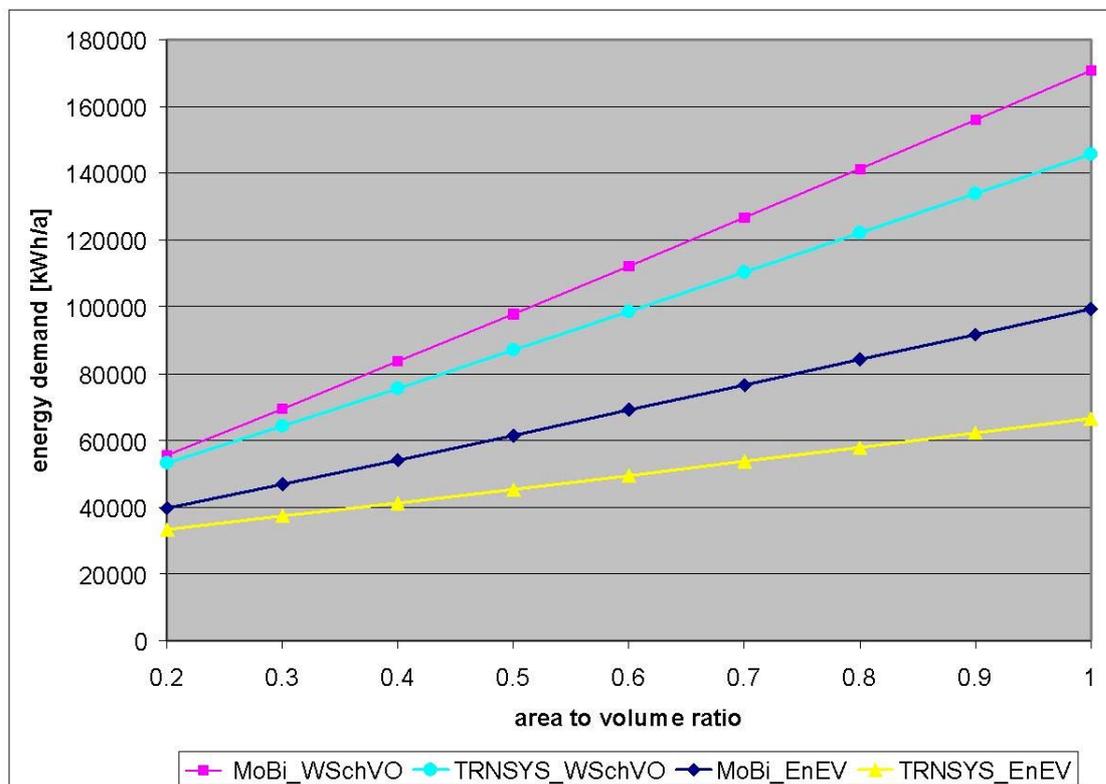


Fig. 4.8: Influence of variation of A/V ratio

Here and in the following figures we describe the influence of the variation of the selected parameters on the energy demand. The energy demand however is determined not only by the parameter investigated. Therefore our conclusions are drawn from the shapes of the curves rather than from the absolute values.

For schools we expect an A/V ratio of well below 0.5. Again we can see reasonable agreement between the two quite different methods especially before retrofit. As expected differences become more important if we approach low energy housing cases.

4.2.3 Influence of the internal loads

Internal loads for the apartment building were estimated at 3 W/m^2 . In schools we expect much higher loads applicable to shorter time periods. The influence of increasing internal loads is shown in Fig. 4.9.

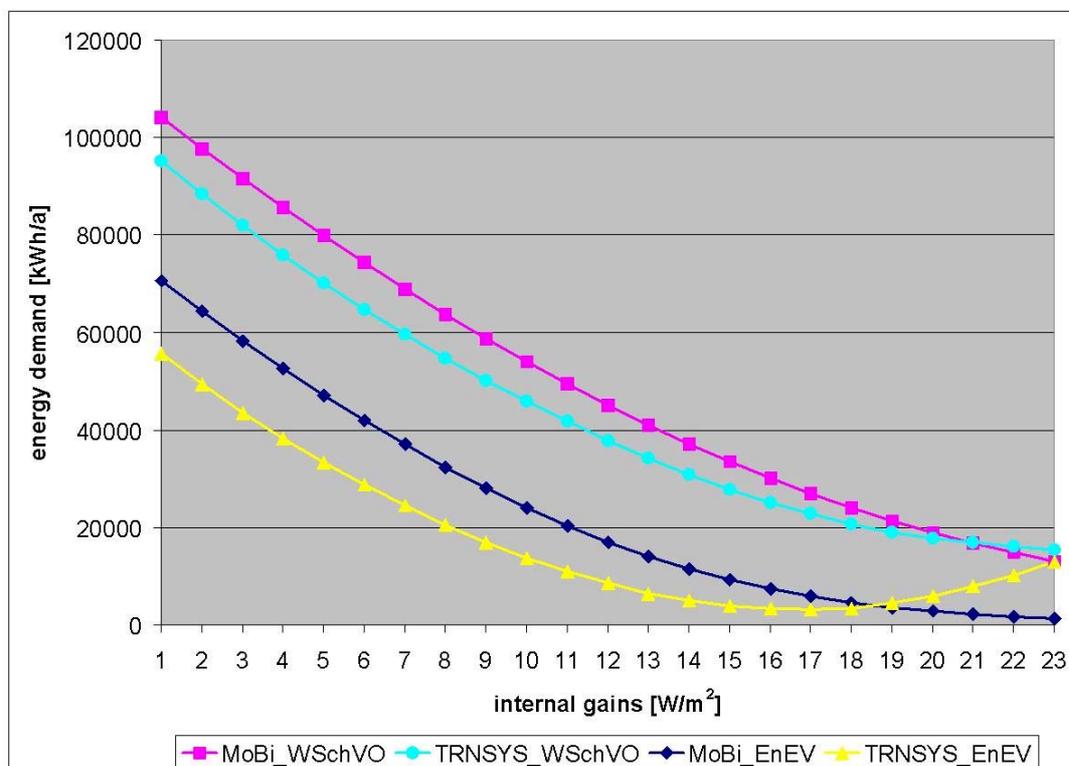


Fig. 4.9: Influence of variation of internal loads

A linear variation can be seen up to about 10 W/m^2 . With such an internal load internal gains are about the same as transmission losses in the building considered. Additional internal gains can hardly be used to reduce heating demand. Instead they become unusable and would contribute to cooling demand. In addition for low energy buildings the TRNSYS calculations become instable and require additional changes in modelling.

4.2.4 Influence of the glazing factor

To investigate the influence of the solar energy we have varied the glazing factor of the southern wall of the building. We can see some differences in the behaviour of monthly and hourly balances. However they are small if we neglect glazing factors greater 0.7.

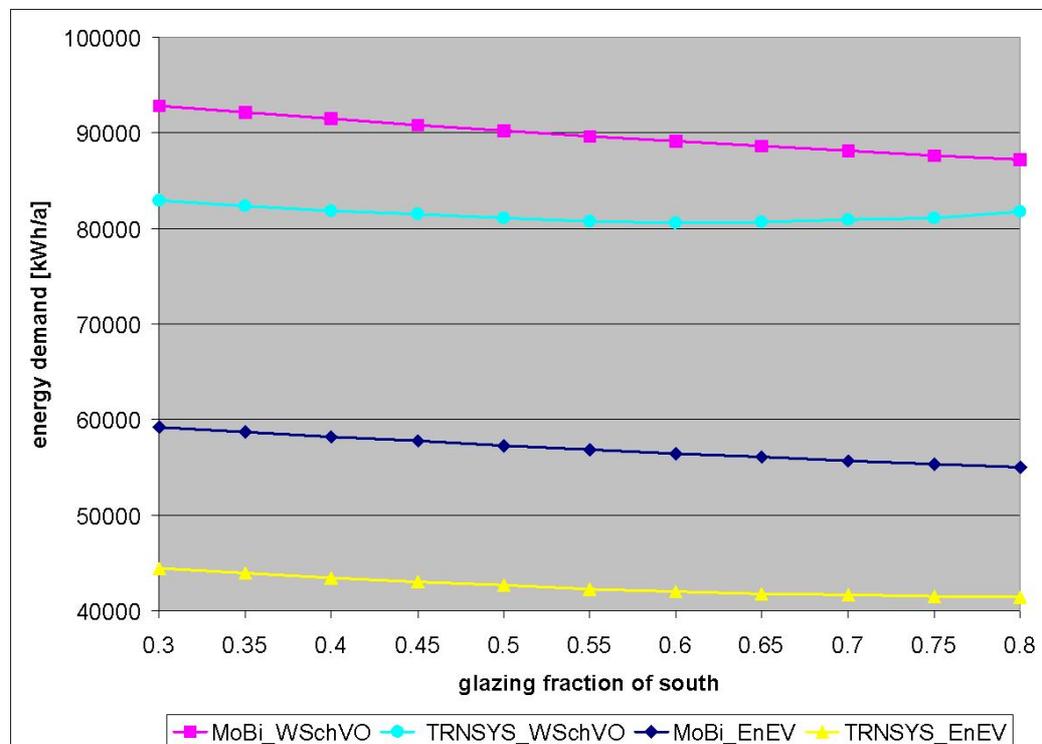


Fig. 4.10: Influence of variation of glazing factor

4.2.5 Modelling of building 2 of the MOSES project

We then applied the monthly balance method to do calculations for a school building. The building is shown in Fig. 4.1 it is located in Stuttgart Germany and was retrofitted in the frame of the MOSES project in 1996 (see also case study D1).

During retrofit insulation of windows, walls and roof were introduced which resulted in improved U-values (Table 4.2). In addition the heating system was adapted to both the old and the new building. Because of this special situation the efficiency number of the heating system could be determined before and after renovation as 1.5 and 1.22

As a result of these measures the Primary Energy Demand could be reduced from 210 kWh/m²/a to about 40-45 kWh/m²/a. To simulate the building with the monthly balance method internal loads were adjusted to meet the actual energy consumption (compensation of uncertain internal and solar loads) before retrofit.

Building 2 was modelled as follows

Tab. 4.3: Parameters to describe model school for preliminary investigations

U-values	before retrofit	after retrofit
Windows	3.5	1.4
Walls	1.73	0.25
Roof	0.85	0.18
Basement	2.35	2.35
Efficiency number	1.5	1.22
Heated area	1110 m ²	
Internal Temperature	20C	
Internal load	19 W/m ²	

Based on this model we performed calculations for the building before and after retrofit. The primary energy consumption after retrofit than could be predicted quite well using the above described data.

Tab. 4.4: Change in primary energy consumption due to retrofit as measured and

	Primary Energy Consumption in kWh/m ² /a	
	Before retrofit	After retrofit
Measured	210	40-45
Calculated	210	42

calculated (note internal loads were adapted to meet measured results before retrofit)

This confirmed our decision to use the calculation methods described in DIN 4108-6, which corresponds to a monthly balance method.

4.2.6 Need of commissioning after retrofit

Finally we would like to point out the need to commission the HVAC-System before and after retrofit. Fig. 4.11 shows measured primary energy consumption during and after retrofit. Retrofit took place in 1996. No adjustment of the HVAC system controls was done after retrofit. Therefore the primary energy consumption did not reduce as expected. Only after additional commissioning of the measures could the expected target be reached. Of course, this affect can also be seen in buildings which have been in operation for several years. Therefore, we recommend to start a retrofit by closely looking at the HVAC system and its operation. Recommissioning the HVAC system can often achieve savings of as much as 30% .

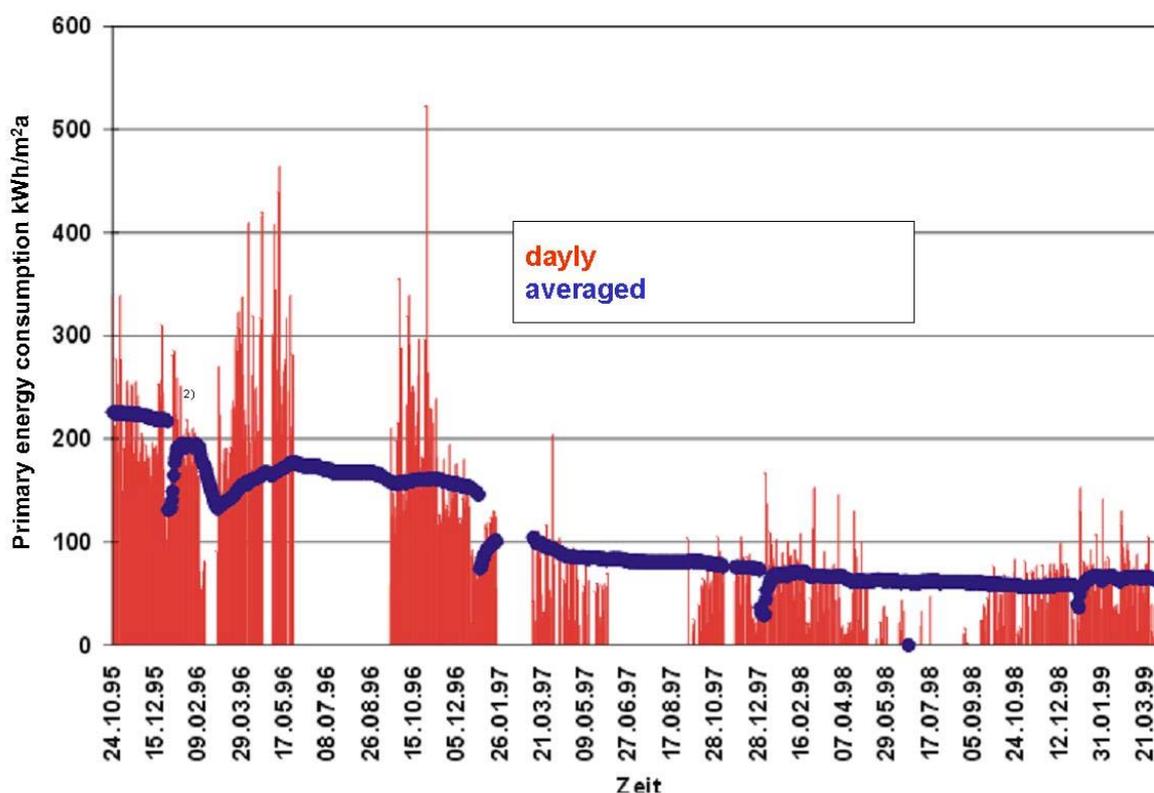


Fig. 4.11: Measured primary energy consumption in building 2

4.3. Conclusions for the selection of calculation methods in the ECA

4.3.1 Monthly balance methods are applicable for schools

Our conclusions from this work were summarised as follows

- Monthly balances allow a reasonable estimation of potential energy savings for schools
- Dynamic calculations use less conservative assumptions (average parameters) which results in lower energy demands. However such methods should be used only by experts due to the great number of parameters which have to be adapted to the actual situation.
- Monthly balances need the adaptation of average parameters to school conditions

4.3.2 Adaptation of Parameters

All the methods to be implemented in the ECA have to be adapted to the operating conditions of the educational buildings under consideration. This includes the integration of new calculation methods (see chapter 3) as well as the adaptation of certain parameters. The adaptation of parameters was done using the detailed hourly methods and is described in the next chapter on validation. The following General Procedure was derived during the work on sensitivities

1. Define school
2. Define profiles
3. Do detailed calculation
4. Do ECA calculation
5. Compare
 - Heating demand
 - Transmission losses
 - Ventilation losses
 - Solar Heat gains
 - Internal heat gains
6. Compare cooling needs
7. Adapt Parameters which determine internal loads, solar gains and ventilation losses.

4.3.3 How to use the calculation methods in the context of the ECA

To fulfil EnEV requirements for school buildings one should

- ⇒ Check for appropriate operation
- ⇒ Examine the potential of improving the HVAC system (effort number should be around or better less than 1.2)
- ⇒ Determine energy balances using monthly balance calculations following the European norm En 832 including
 - Blower door test which allows to reduce the air leakage rate to 0,6
 - Reduce heat bridges according to DIN 4801-2
- ⇒ Improve insulation (windows, walls)
- ⇒ Adapt the operation of HVAC system and lighting to the retrofitted building

4.3.4 How to estimate energy consumption from energy demand simulations

Unfortunately energy demand cannot be correlated directly to energy consumption. Major reasons are:

1. The efficiency numbers of the HVAC systems do only apply for optimal operation of the systems.
2. The utilisation of the building differs from the one assumed for the simulation.
3. The meteorological conditions differ from those assumed in the simulation.
4. The building description differs from those assumed for the simulation.

The energy concept adviser allows to reduce differences due to the last 3 points by inputting more detailed information. If after such detailed descriptions still major differences occur between measured and calculated consumptions they are assumed to be due to non optimal operation of the systems. Non optimal operations of HVAC systems result in efficiency numbers much higher than those expected from optimal operation. In such cases the ECA recommends to ask for an energy audit and a subsequent adjustment of the system's operation to the actual user needs. The following procedure describes how we recommend using the ECA

- **Model** Building
 - HVAC System
 - Usage
- **State Limitations** of model eg no kitchen, no swimming hall, etc.
- **Perform Calculation**
- **Compare** calculated Energy Requirement and measured energy consumption
- For **differences greater 20%**
 - Recommend audit to adjust usage and/or operation
- For **differences less than 20%**
 - Use model to evaluate retrofit measures

4.4. References

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5 Validation of the ECA Models (by Fritz Schmidt, Darko Sucic and Jawed Khan, IKE)

The validation of the simulation part of the ECA was undertaken in several steps.

1. A set of general parameters to describe educational buildings for the ECA was derived from theoretical considerations
2. Based on this a model (Moses project building 1 in case study DE1) was derived and experimented with several calculation programs including TRNSYS, VEC-En-832 and VEC-VDI-2067 The results agreed well thus proving the correct implementation of the ECA code.
3. Profiles describing the usage of typical schools (internal temperature, air change, internal loads) were defined and experimented with the hourly codes TRNSYS, VEC-En-832 VEC-VDI-2067 and EnergyPlus.. From these calculations slight modifications of the general ECA parameters could be derived. As a result good agreement was achieved between ECA and hourly determinations of the energy demand.
4. Finally we applied the ECA to the schools in the 34 school project of the city of Ludwigshafen (new case study) to get a feeling for the practical relevance of the ECA approach and for the relevance of the efficiency numbers available there. The agreement between measured and predicted energy consumptions seems to be acceptable. The comparison also gives an impression how to interpret both measured and predicted consumption data and the uncertainties related to both.

5.1. General data describing educational buildings for the ECA

The following data are used internally to describe the behaviour of educational buildings for the ECA

Tab. 5.1: General values used in the ECA to model educational buildings in Germany

Name	Value estimated	Value corrected	Dimension
Surcharge Heat Bridges	0.1		
AirChangeNoSeal	0.7		factor
AirChangeSeal	0.6		factor
Internal Load	6		W/m ²
Internal Temp	19		°C
Temp diff NightSetback	3		°C
Internal Temp NightSetback	18,1		°C
Temp diff WeekendSetback	5		°C
Internal NightandWeekendSetback Temp	17		°C
Holiday weeks	8		weeks
TmpCorr External wall	1		factor
TmpCorr Pitched roof	1		factor
TmpCorr Flat roof	1		factor
TmpCorr AtticFloor	0.8		factor
TmpCorr Cellar ceiling	0.6		factor
TmpCorr Ground plate	0.6		factor
TmpCorr Window	1		factor
modeUnit	2		
Period of Analysis	50		years
Inflation Rate	6		%
Interest Rate	6		%
Test Discount Rate	0		

5.2. Development of an ECA Model of MOSES Building No. 1

The ECA model for the MOSES building no. 1 is described in the following table.

Tab. 5.2: Description of the MOSES school building Nr. 1 in the ECA

General Values:					
A_n	2090				
heated vol	9621				
Number of storeys	3				
Building Envelope					
name	area	U before retrofit	g before retrofit	U after retrofit	g after retrofit
external wall	1138	1.5	-	0.25	-
roof	1338	2	-	0.18	-
groundplate	1301	2.1	-	0.75	-
window north	111	3.2	0.78	1.1	0.58
window east	48	3.2	0.78	1.1	0.58
windows south	111	3.2	0.78	1.1	0.58
window west	48	3.2	0.78	1.1	0.58
A_{surface}	4095				
Plant	Steam Heating		natural ventilation		HVRM 1

We calculated the heat demand using the methods IKE (IKE version of EnEV), TRNSYS, VEC-En-832, VEC-VDI-2067, EnergyPlus and the ECA on the basis of this model (no profiles but average monthly values). Two cases were studied: no set back of temperatures during night, weekends or holidays and night and weekend setback.

The results are given in the following figures:

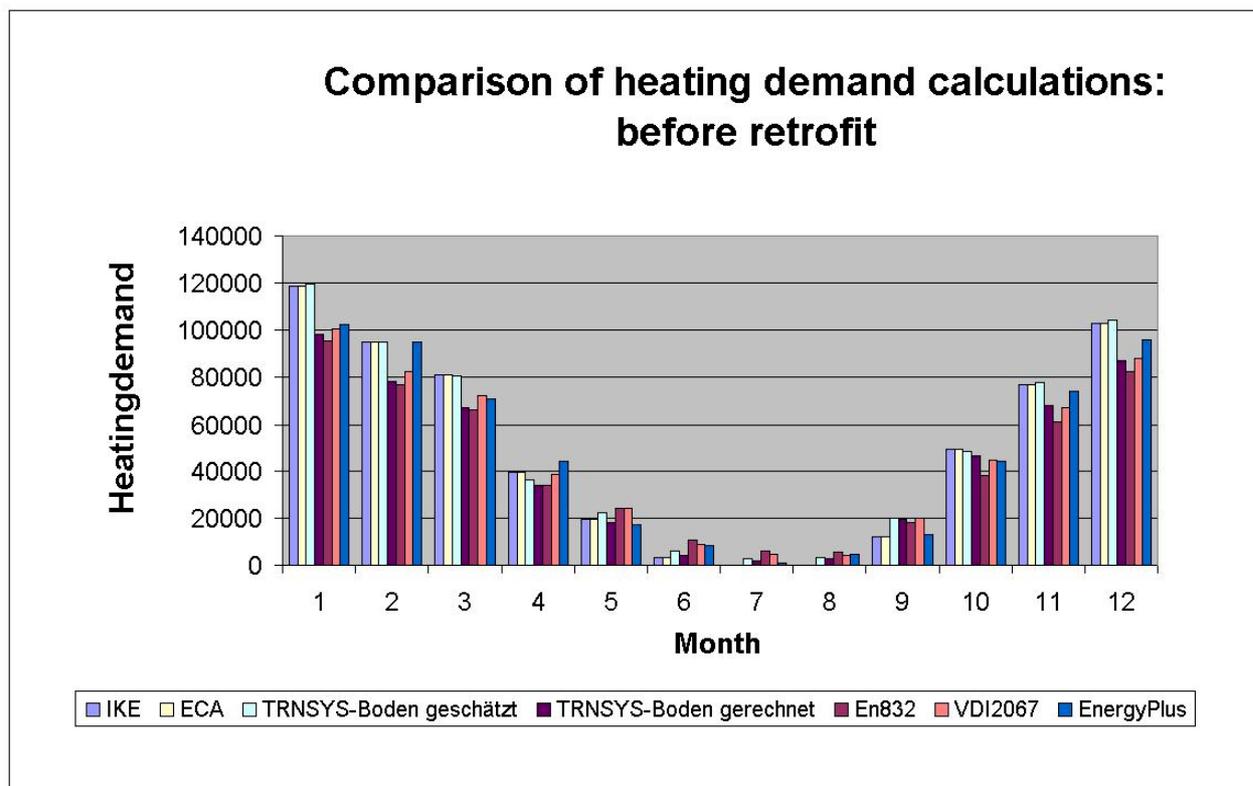


Fig. 5.1: Heating demand for the MOSES Building Nr. 1 as calculated with different methods. Case: before retrofit + no setback

Calculation with 8 different methods and programs are compared. It can be seen that even with small modelling differences in the different codes we got two different classes of results. The differences are primarily due to different ways to model the ground temperatures and therefore the heat losses through the floor. Two models are available in the literature.

The ECA model assumes that the ground temperature is the same as the outside temperature. To correct for the errors in this assumption the k-value of the floor is reduced by a factor of 0,6.

TRNSYS , VEC and EnergyPlus try to calculate the temperature of the ground according to a formula (taken from ENISO 13370)

$$T_{\text{Ground}} = -3 \cdot \cos([\text{TIME} \cdot 3 / 73]) + 17$$

TIME indicates the hour from the beginning of the year.

The difference in modelling causes the differences in transmission through the floor which account in the differences seen in the heat demand calculations for the Moses building (Note that the floor area is quite large for school buildings. Therefore any deficiencies in modelling have a great impact on the results). TRNSYS allows to apply both models. We therefore included two TRNSYS calculations in Fig. 5.1 and show the differences explicitly in Fig. 5.2.

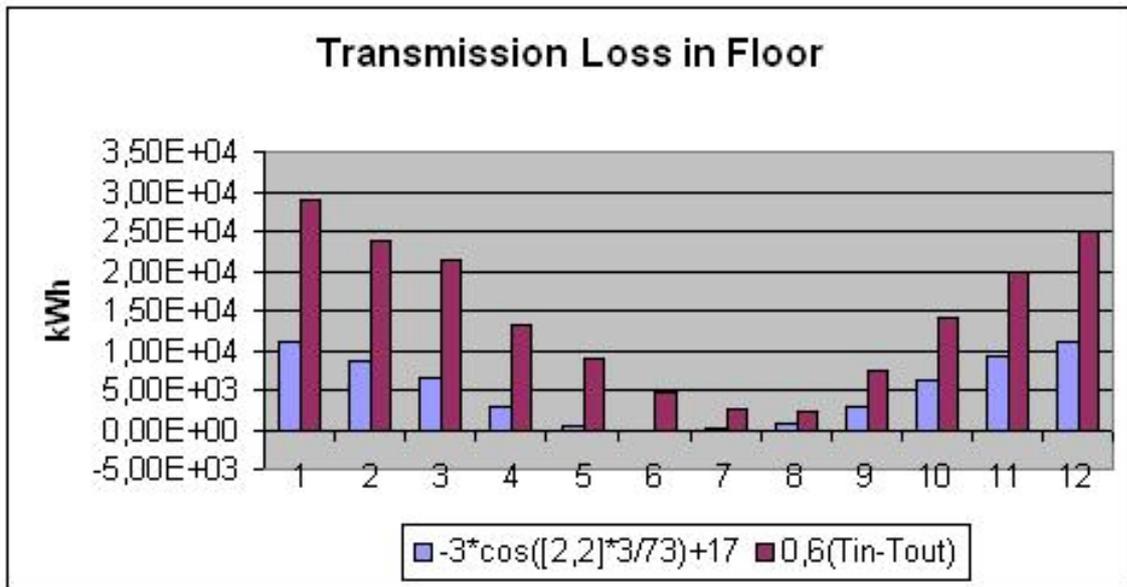


Fig. 5.2: Transmission losses through floor of the MOSES Building No. 1 as calculated with different models for the ground temperature

Similar experiences can be made if we activate the setback option. This can be seen from the following Fig- We also see that the monthly and the hourly methods react differently to the reduction of average temperatures. To understand this the influence of more detailed profiles was investigated (see next subchapter)

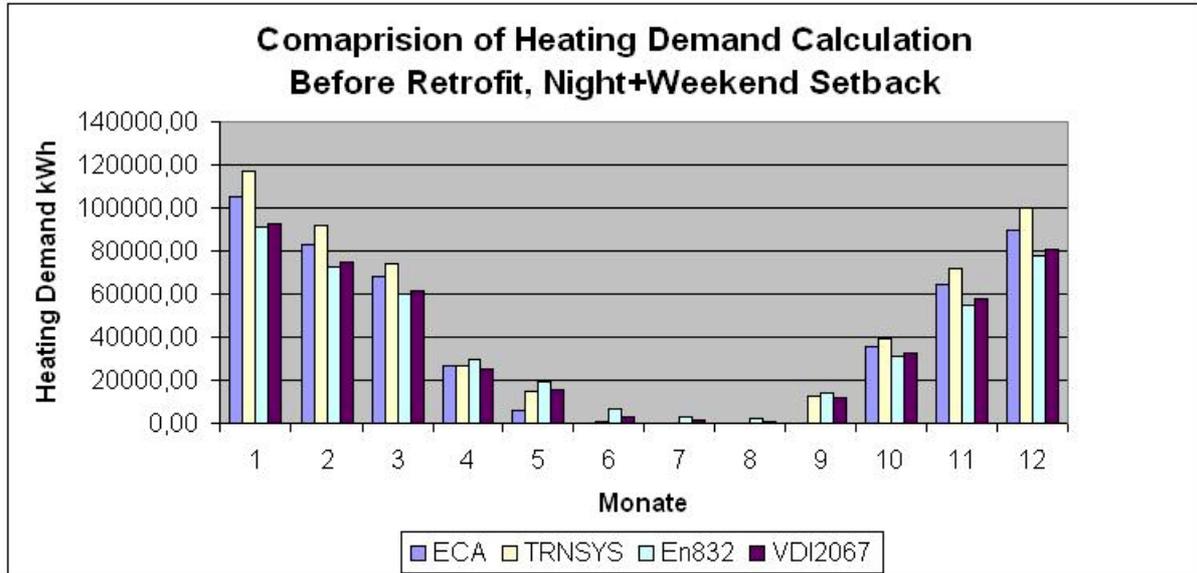


Fig. 5.3: Heating demand for the MOSES Building No. 1 as calculated with different methods. Case: before retrofit + night and weekend setback

In cases were transmission losses through the floor become less important (summer or after floor retrofit) this effect becomes less important or even disappears. This can be seen from the calculations after retrofit.

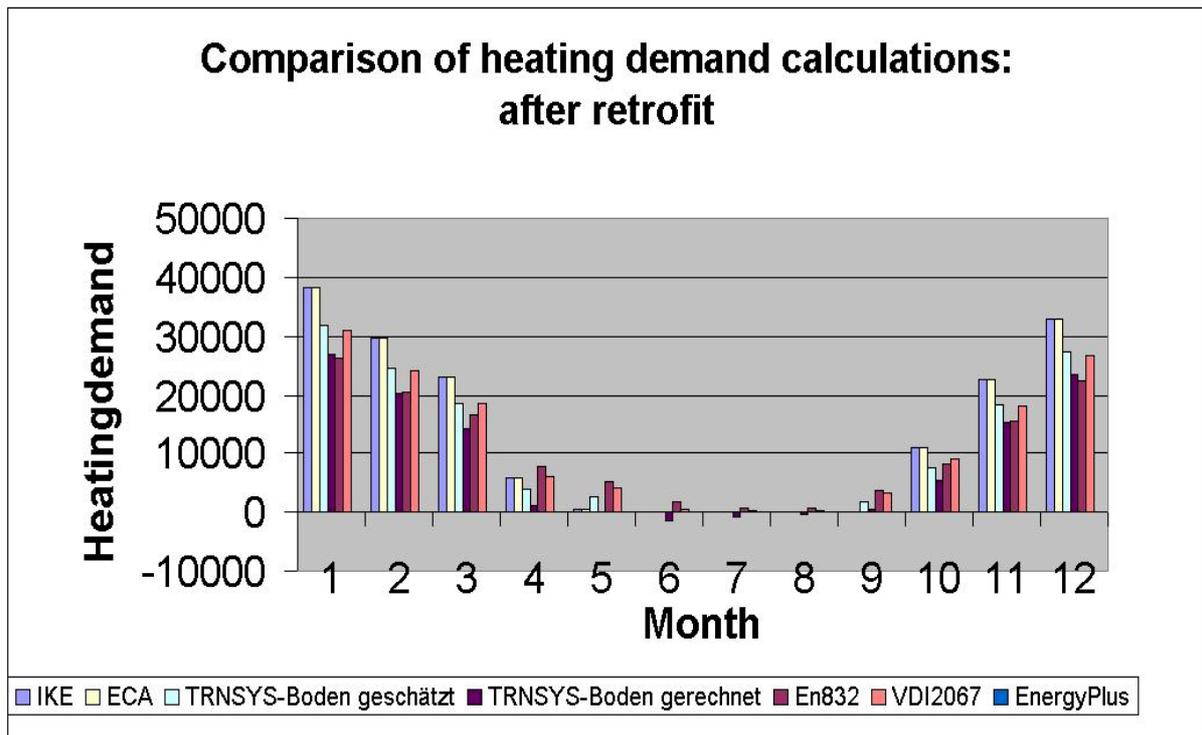


Fig. 5.4: Heating demand for the MOSES Building No. 1 as calculated with different methods. Case: after retrofit + no setback

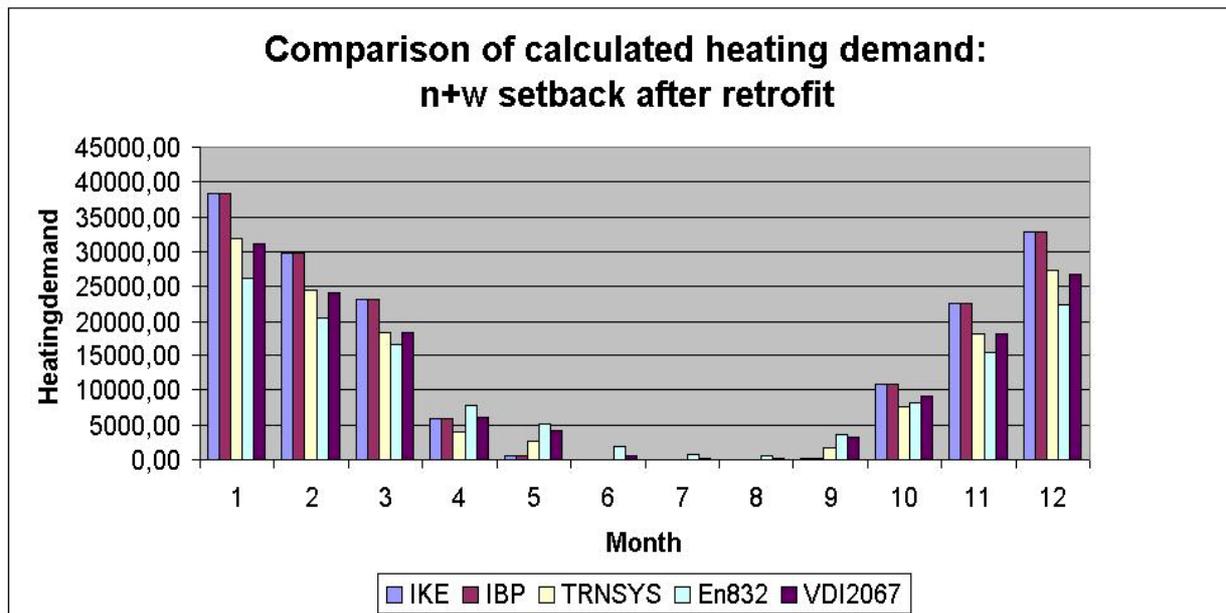


Fig. 5.5: Heating demand for the MOSES Building No. 1 as calculated with different methods. Case: after retrofit + night and weekend setback (IBP identical ECA)

After retrofit transmission losses are less determining. Thus differences in the other contributions become more obvious.

As a result we concluded that the implementation of methods in the ECA was correct.

5.2.1 Adaptation of yearly averaged Parameters

Next we investigated the different assumptions which lead to the averaged parameters given in Tab. 5.1.

To do this we utilised the options for hourly calculations available in VEC and TRNSYS. Again all three methods were utilised to avoid misinterpretations. The following time dependent data were used:

- Meteorological data: Test reference year Nr. 5 (Würzburg)
- Profiles as shown on the next page
with 10 hour occupancy we choose
 - internal temperature during occupancy 21C
 - internal temperature during night 16C
 - internal temperature during weekends 14C
 - internal temperature during vacations 11C
- Internal loads during occupancy 25 W/m²
- Air change rate during occupancy 1.3 1/l

For the ECA we selected the night and weekend setback results

Two different calculations were performed. They include both the original and the retrofitted building.

Good agreement was reached between the 3 hourly methods as can be seen from the following comparisons.

The results concerning the ECA might be summarised as follows:

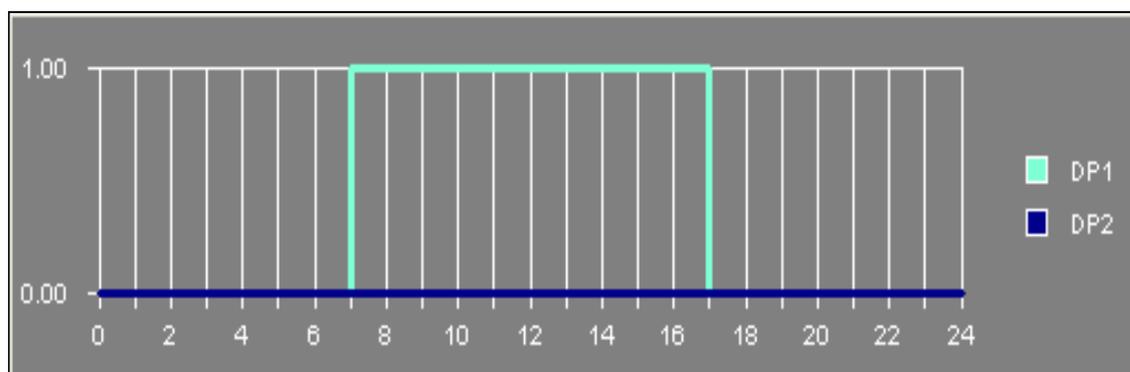
- Before retrofit
 - Transmission losses are calculated from the ECA slightly higher than from the other methods We have identified the reason for this already (different calculation of ground temperature)
 - Ventilation losses are less than in the hourly calculations. The assumptions made in both approaches should be reconsidered.
 - Internal gains are less than in the hourly calculations. The assumptions made in both approaches should be reconsidered.
 - Solar gains are of less importance. However the monthly averaged values taken from the norm seem not to be adequate for any month.
 - Good agreement was reached for the heating demand. It could be even better, if the modelling of the ground temperature could be improved.
- After retrofit

Transmission losses decrease drastically due to the retrofit measures. The losses through the floor become less important. Thus three of the codes give very similar results. En832 has known deficiencies for hourly calculations of low energy buildings.

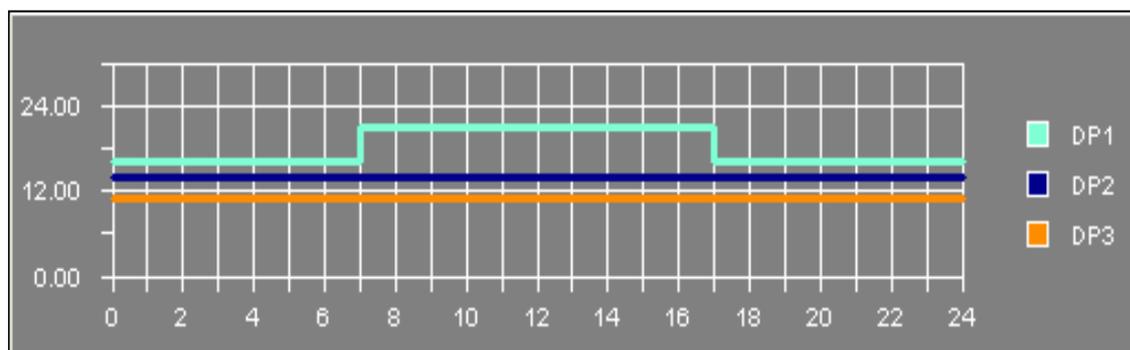
Ventilation losses and internal gains remain the same (utilisation changes however) but increase in their relative importance.

- Heating demand is calculated as the difference of several quantities of the same order of magnitude. Nevertheless we found good agreement between all codes applied. This is promising but has not have to remain valid under all conditions.

Profiles for occupancy



Profiles for internal temperature



Profiles for ventilation

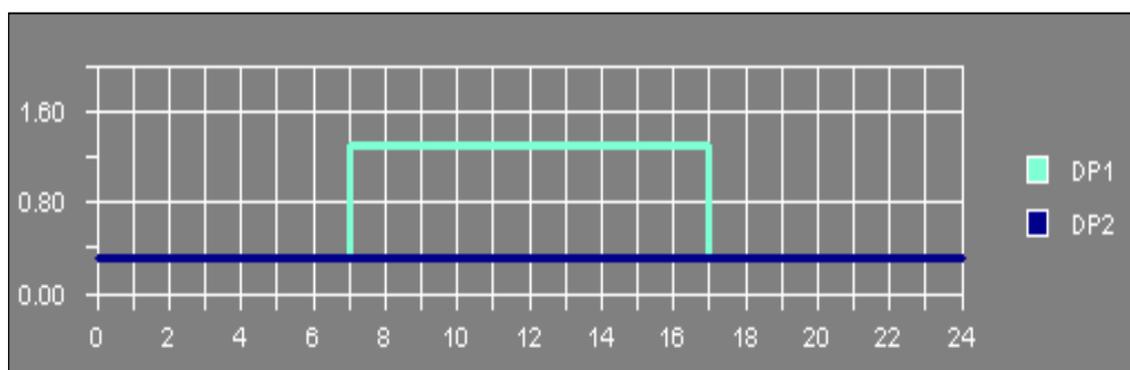


Fig. 5.6: Profiles used in the hourly calculations

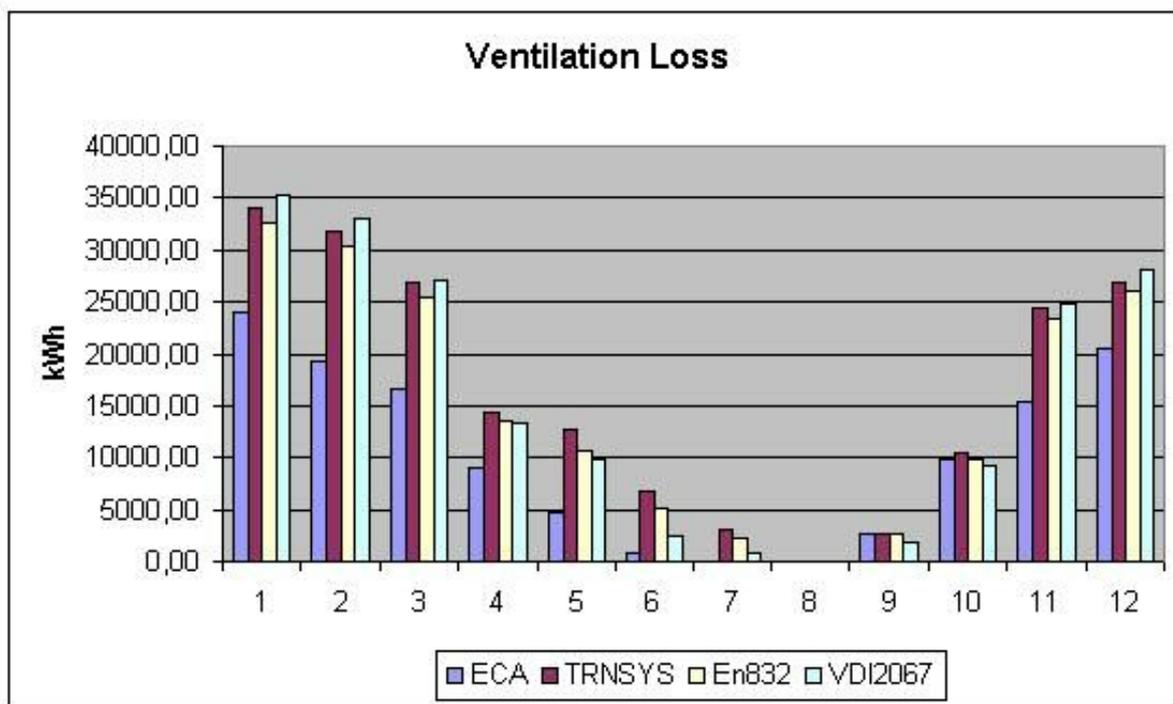
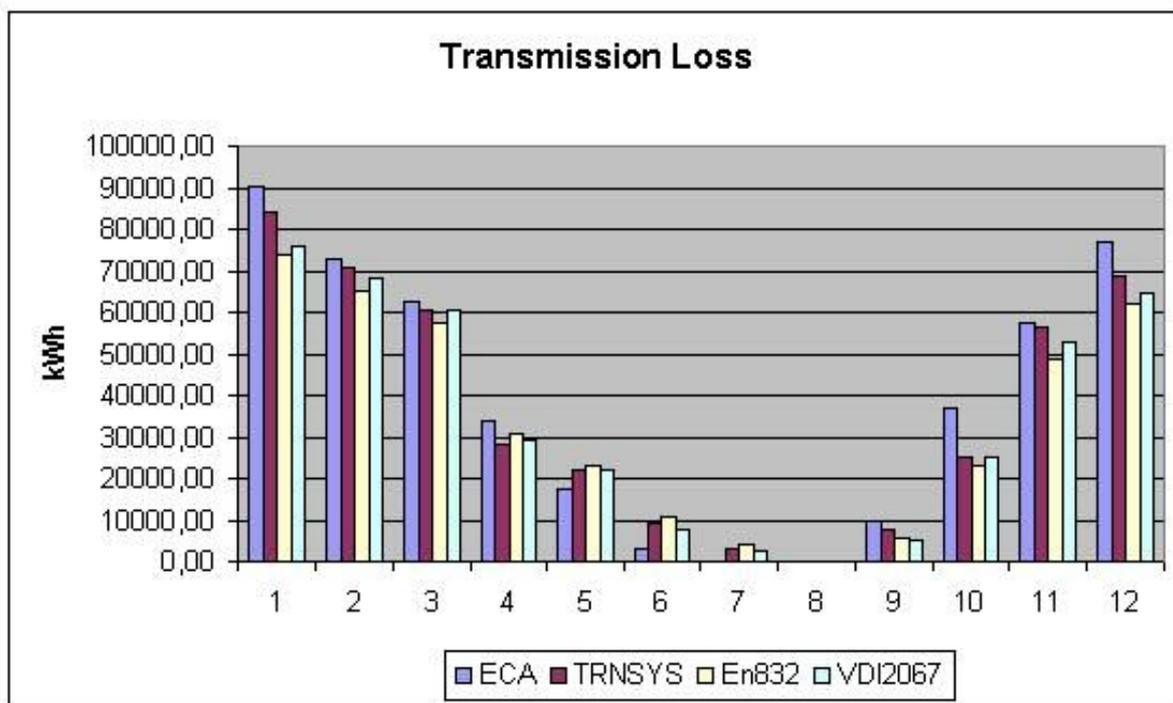


Fig. 5.7: Comparison of losses - case 10 h profile before retrofit

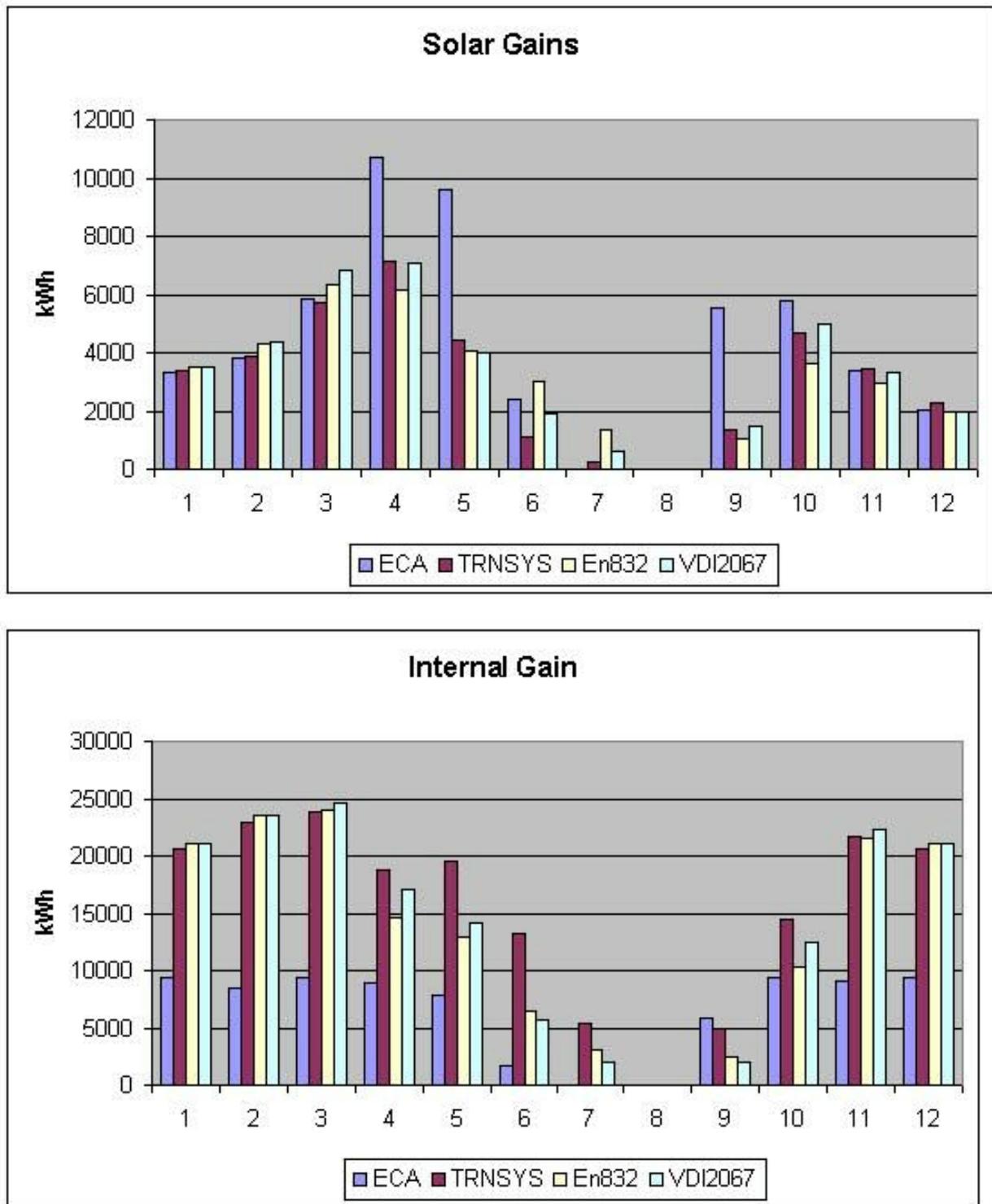


Fig. 5.8: Comparison of gains case 10 h profile before retrofit

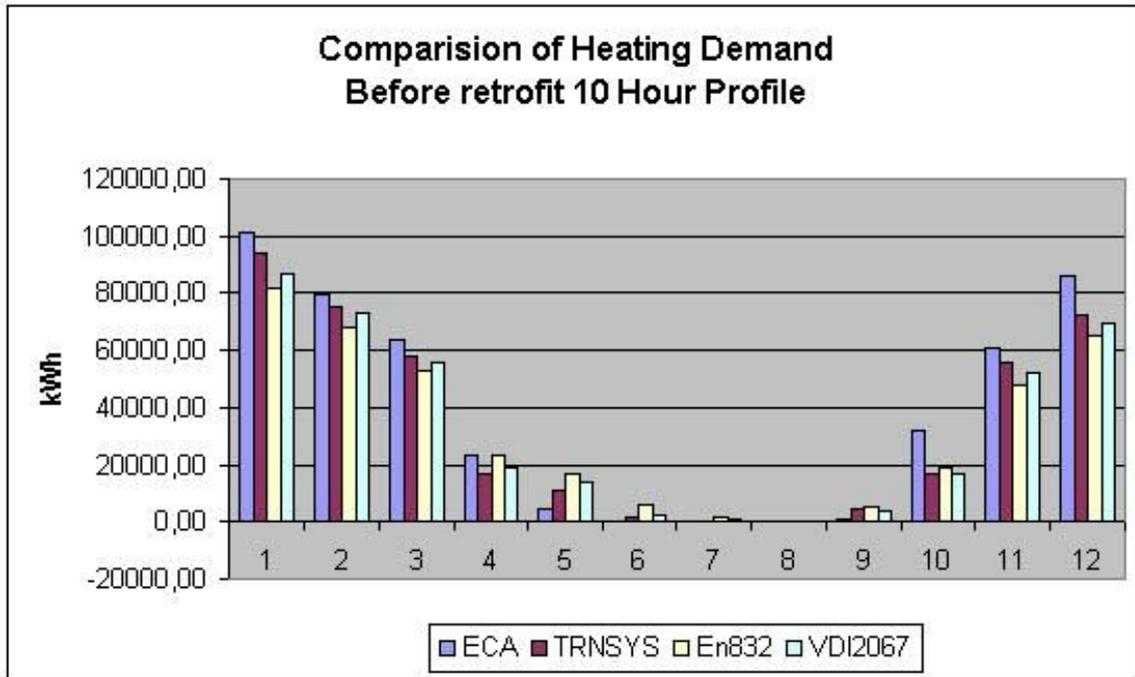


Fig. 5.9: Comparison of heating load - case 10 h profile before retrofit

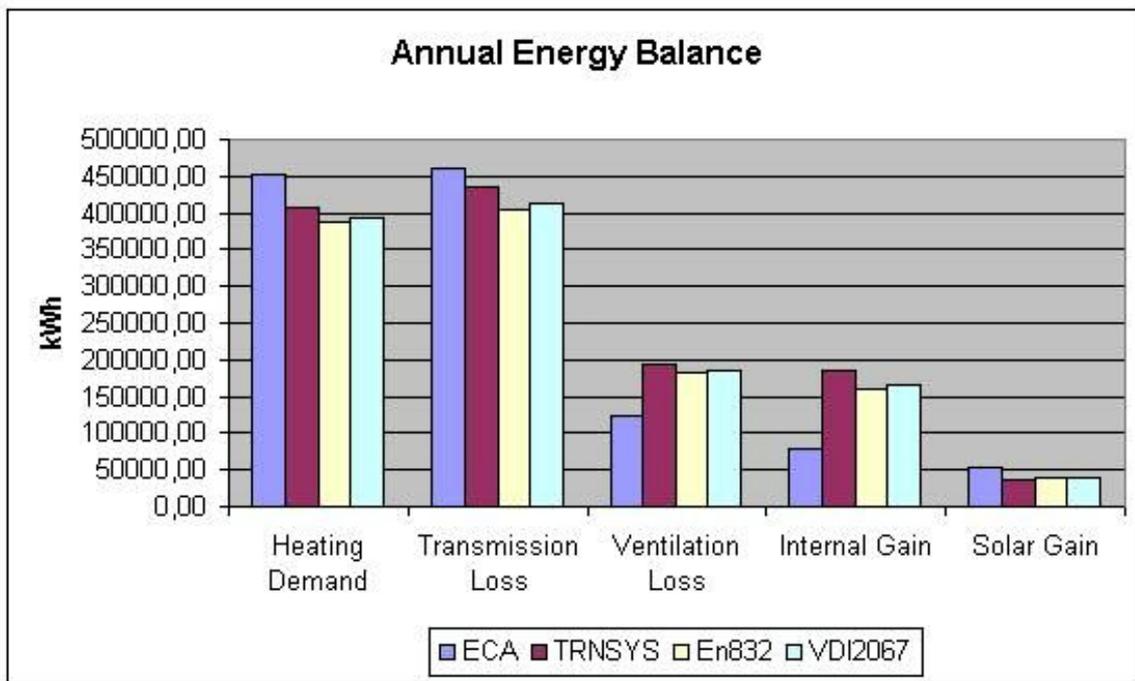


Fig. 5.10: Comparison of yearly balances - case 10 h profile before retrofit

Good agreement was reached between the three hourly methods as can be seen from the following comparisons. However slight changes in the ECA parameters for airchange and internal loads seem to be desirable. To investigate these effects in more detail seems to be necessary. Due to the late finishing of the ECA it was not possible during this project.

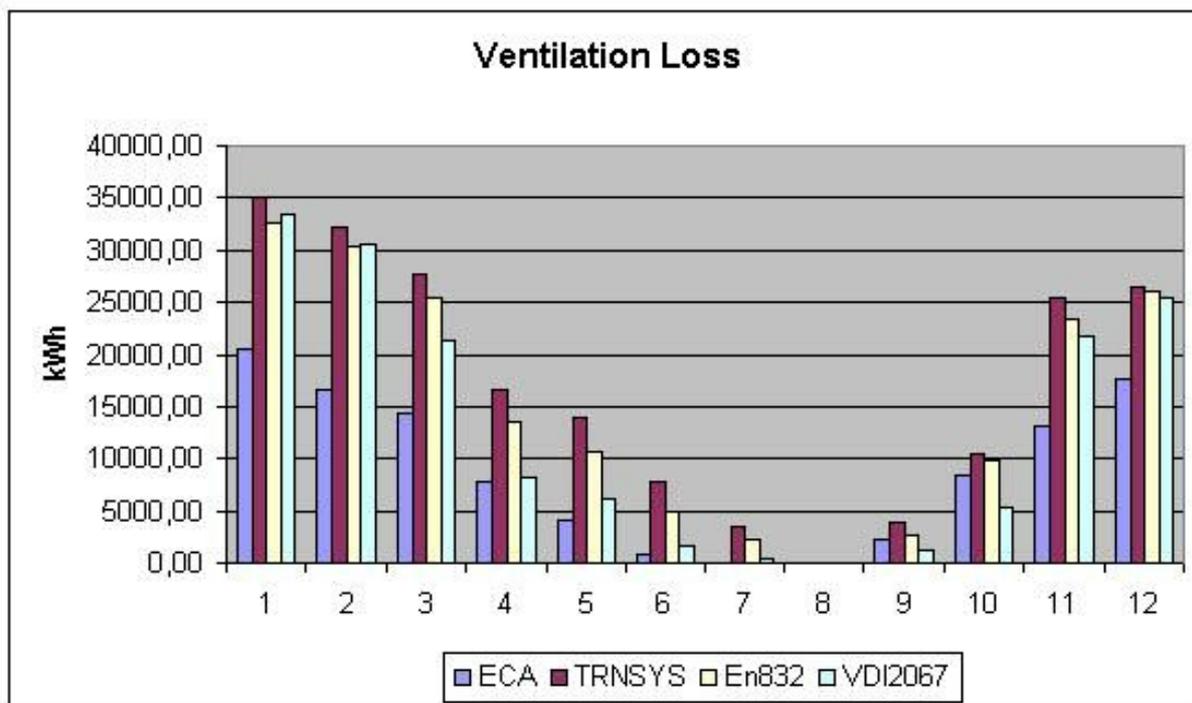
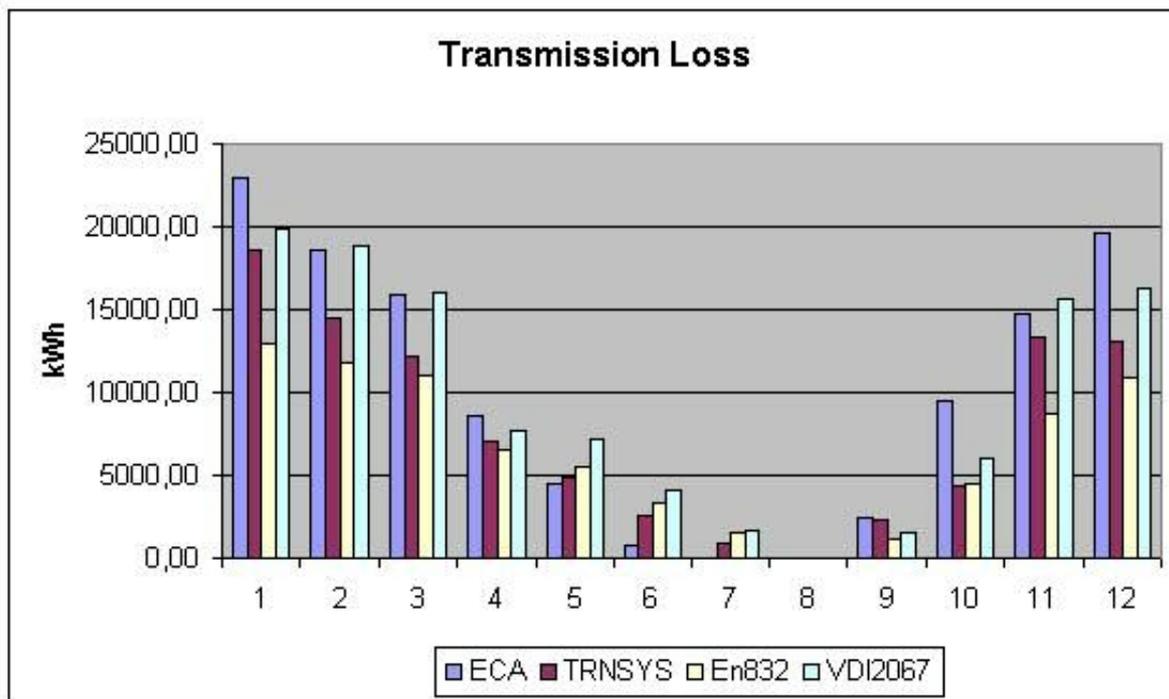


Fig. 5.11: Comparison of losses - case 10 h profile after retrofit

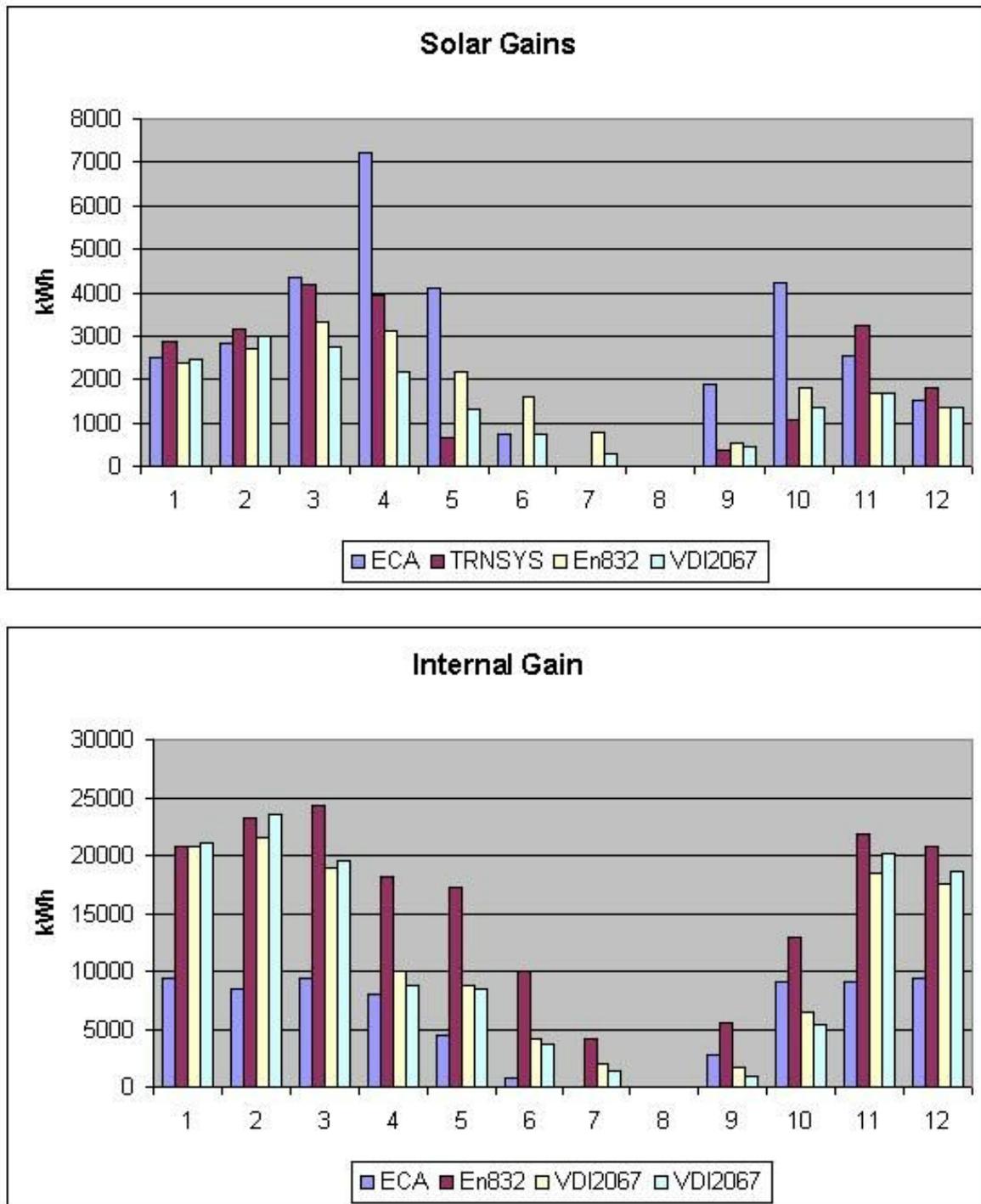


Fig. 5.12: Comparison of gains - case 10 h profile after retrofit

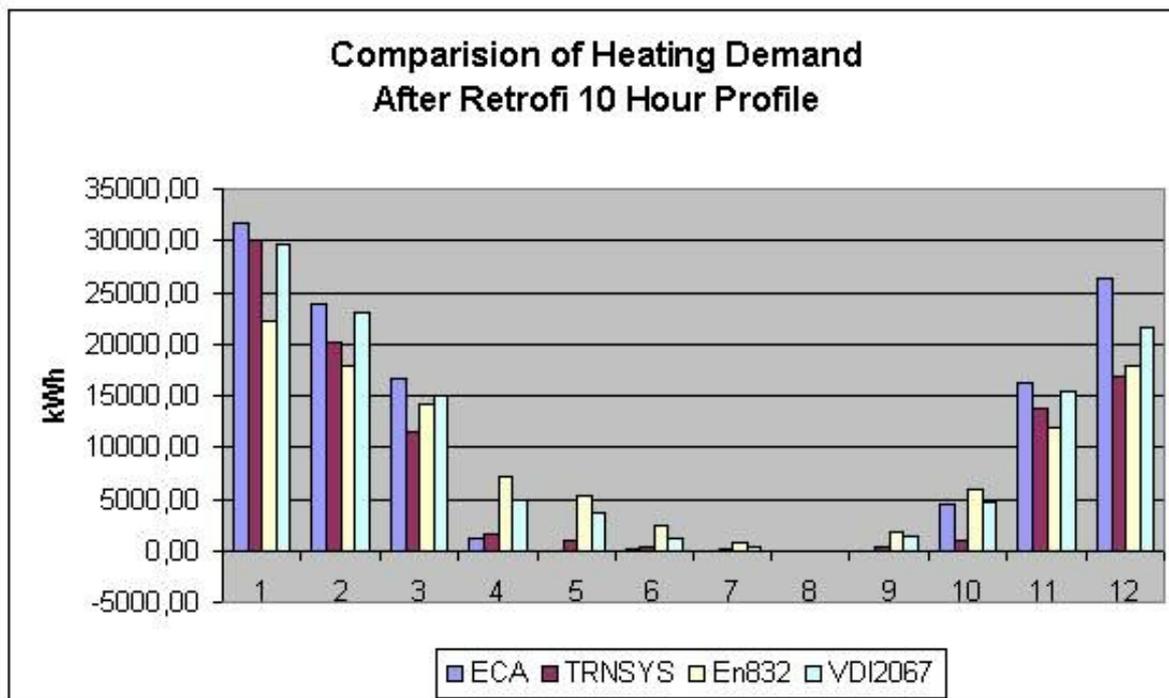


Fig. 5.13: Comparison of heating load - case 10 h profile after retrofit

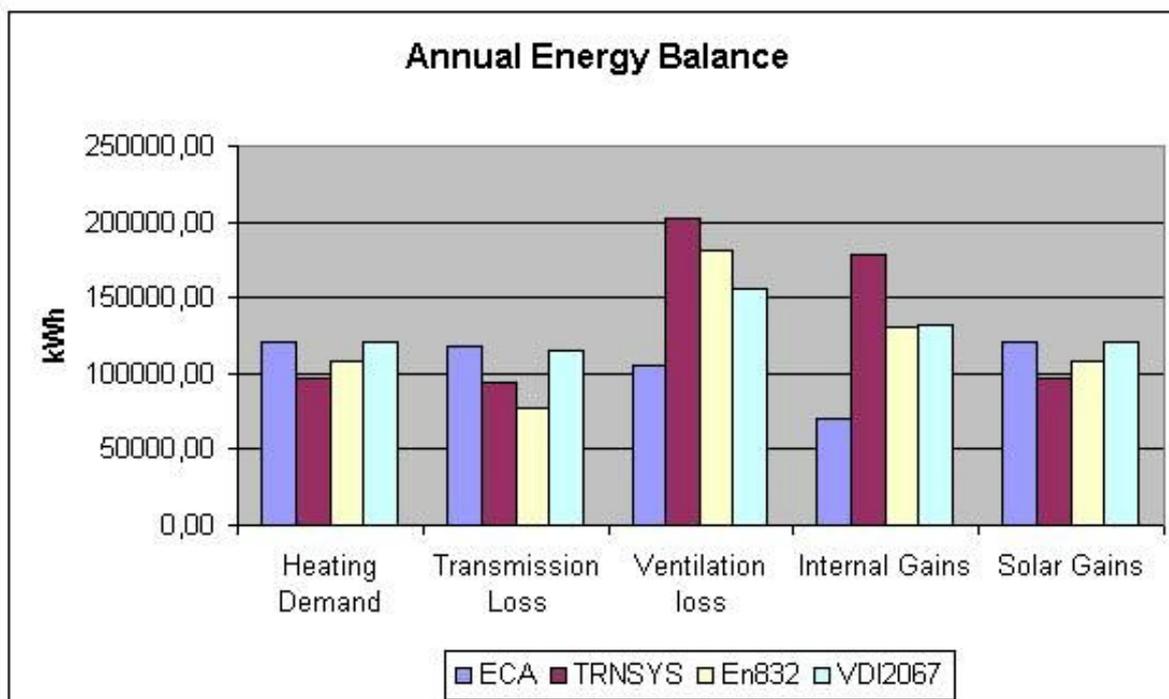


Fig. 5.14: Comparison of yearly balances - case 10 h profile after retrofit

As expected the differences noted for the case before retrofit become even more important for the retrofitted case.

5.2.2 Influence of Utilisation

For the work in this subchapter we varied the parameters to describe utilisation. First we choose different time spans for occupation. (10h and 15h). The results are compared against the no setback and the night and weekend setback calculations.

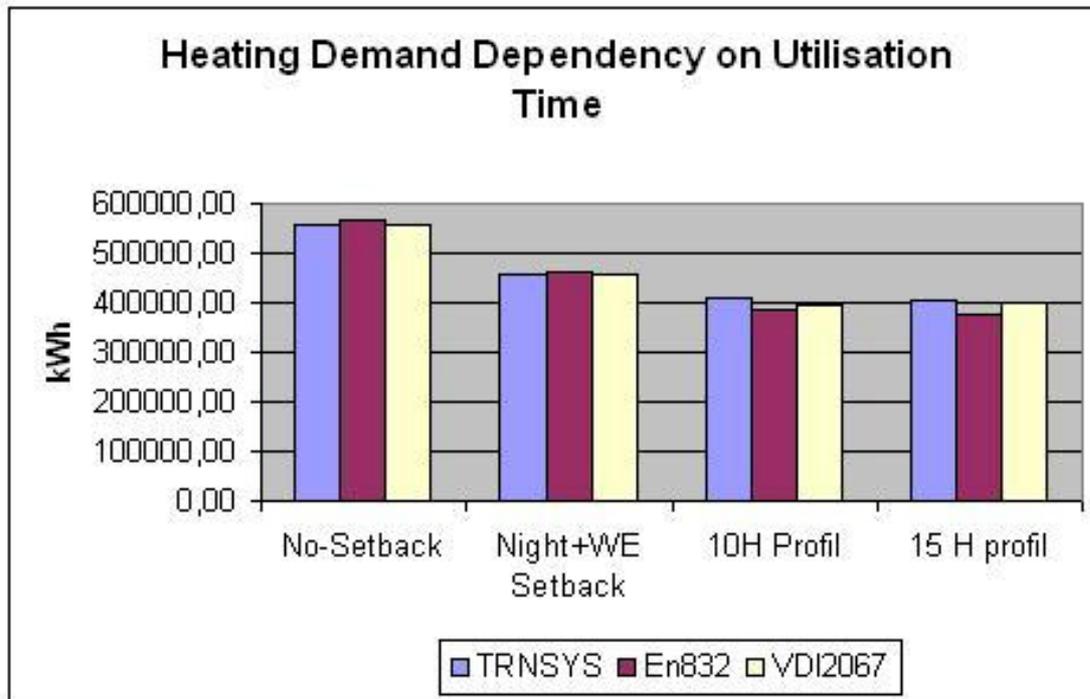


Fig. 5.15: Influence of occupation time

No major influence could be seen due the prolongation of utilisation time. This becomes understandable if we consider hourly values of a typical winter day. Only a very small heating energy is necessary to cover the prolonged utilisation.

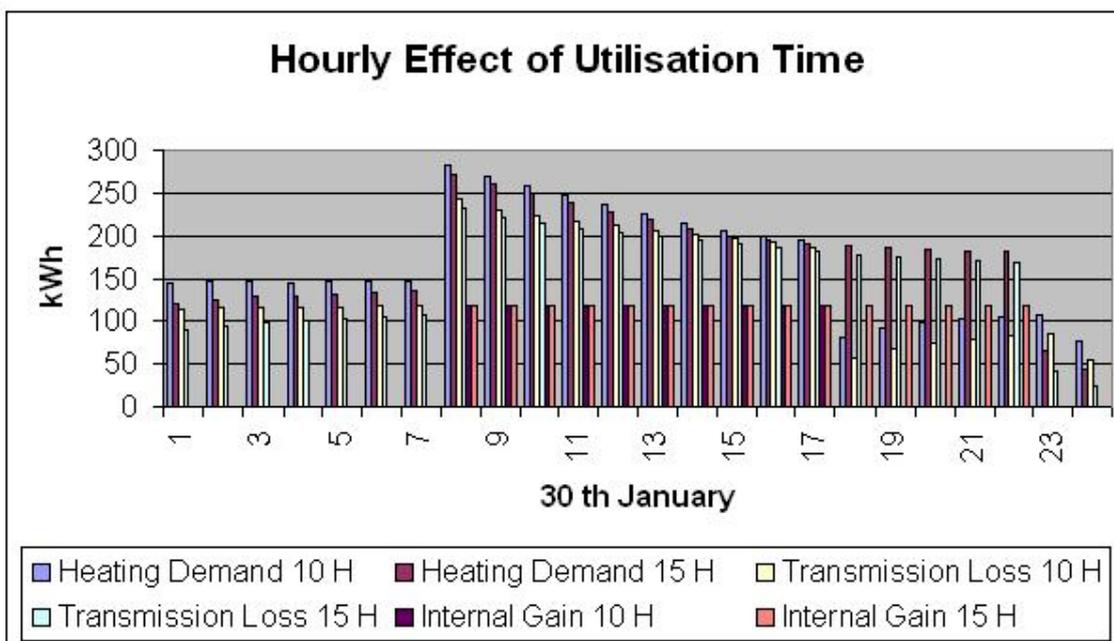


Fig 5.16: Influence of occupation time

This is different if we increase or decrease the internal temperature during occupation times. It is well known that in such a case both transmission and ventilation losses are influenced linearly. This can be seen for the school case too. And might be a further reason for differences between measured and predicted consumption values.

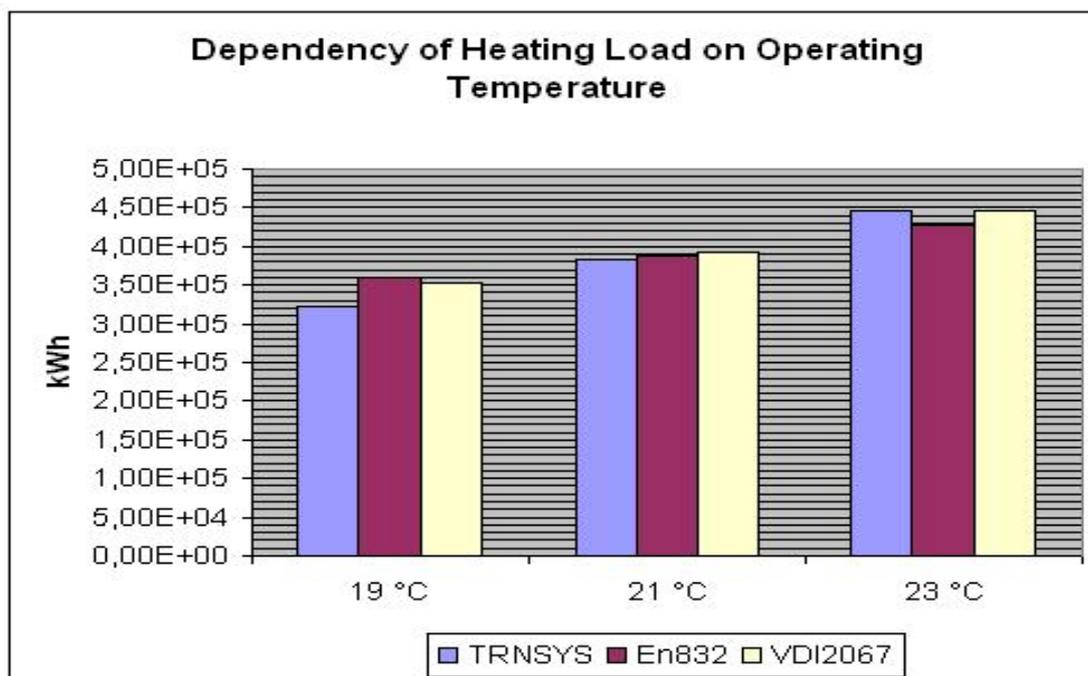


Fig. 5.16: Influence of internal temperature

5.2.3 Cooling and Lighting

At the end of the Annex 36 project (end of January 2004) we had only access to two versions of the ECA.

1. The first one was the official version submitted to the ExCo in December 2003. This version was based on meteorological data from UK and building data from Germany.
2. The second one was the unofficial German version which we used for our testing.

Cooling is not required for German schools. Instead one should modify the building to avoid uncomfortable conditions in summer. The ECA gives a message if uncomfortable conditions become probable due to retrofit measures.

Lighting was only tested qualitatively against the experiences of IBP with Adeline and similar programs.

5.2.4 Comparison - Moses - Results and Measurements

Measurements were performed at the Moses building before and after retrofit. The results are described in the case study report. We compare them in the following table, with results calculated from the ECA.

Tab. 5.3: Comparison - Moses - Results and Measurements

Existing Building	Q_h	Q_h'	Q_h''	e	Q_p'
	MWh/a	kWh/m ³ a	kWh/m ² a	-	kWh/m ³ a
no setbacks	662.6	68.9	317.1	1.58	109
night- and weekend setback	463.1	48.1	221.6	1.59	76.5
all setbacks	445.2	46.3	213.0	1.60	74.1
measurement					81.1

Retrofit Concept 1	Q_h	Q_h'	Q_h''	e	Q_p'
	MWh/a	kWh/m ³ a	kWh/m ² a	-	kWh/m ³ a
no setbacks	327.4	34.0	156.7	1.35	45.8
night- and weekend setback	220.8	23.0	105.7	1.37	31.4
all setbacks	212.2	22.1	101.5	1.37	30.3
measurement					45.0

Reasonable agreement was found considering the crude modelling of operation.

As already indicated in the Moses report it was not possible to reach the anticipated efficiency numbers during actual operation. This resulted in an increase rather than a decrease of e. Therefore the measured heat consumption is more than 40% higher than the predicted value (the measured efficiency numbers include losses due to non ideal operation. This conflicts with the assumption of ideal utilisation which is the basis for determining efficiency numbers).

5.3. Influence of selected input parameters

The ECA offers two levels of building description

- Default building
- Refinements to describe a specific building

The purpose of this section is to give some information on the importance of the parameters describing the default buildings. (Arguments for the selection of geometric parameters are given in Appendix D)

The following information is required:

Tab. 5.4: Parameters describing default building

Parameter	Options			
Type of building	school	nursery	university	
Type of school	Multi storey	Central corridor	Side corridor	Pavilion
	Main hall	Central	Comp-shaped	Open plan
	Cluster			
Construction year	Pre 1950	1950-1970	1970-1990	Post 1990
Type of roof	Pitched heated	Pitched unheated	flat	
Type of basement	Slab on ground	Basement		
Heated floor area	Give value			
Number of storeys	Give value			
Orientation	Give orientation			
Two additional parameters seem to be of general interest				
From Climate zones: Holiday weeks during heating season: default	8			
From heating and ventilation system: set back mode default no setback	night	weekend	holiday	

We have performed a series of calculations to determine the influence of these parameters. Only linear variations are considered. As a starting point we choose a building constructed between 1950 and 1970 and located in an average German climate. The following table shows the results.

We were not able to test the influence of different Climate zones or different countries. The reason is as mentioned before that at the end of the Annex 36 project (end of January 2004) we had only access to two versions of the ECA.

1. The first one was the official version submitted to the ExCo in December 2003. This version was based on meteorological data from UK and building data from Germany.
2. The second one was the unofficial German version which we used for our testing.

It seems to be necessary to repeat most of our tests for country specific conditions in the follow up projects.

Parameter Type	Dummy school	Variation	Nursery School	School	University	Main hall school	Central school	Comp shaped school	Open plan school	Clustered school
Type of school		0	534	534	534					
Construction Year	1970-1990		Central corridor school	Side corridor school	Pavilion School	Main hall school	Central school	Comp shaped school	Open plan school	Clustered school
Type of Roof	pitched(heated attic)	232	Pre 1950	1950-70	1970-90	After 90				
Type of Basement	basement	72	Pitched(heated attic)	Pitched (unheated attic)	Flat					
Heated Floor Area	6180	50	slab on ground	basement						
No. Of Storeys.	3	7	500	1000	2000	6180	10000	18000		
Orientation	east-west	63	540	539	538	534	533	533		
		1	1	2	3	4	5	6		
		1	534	534	534	471	471	428		
		1	east-west	NE-SW	north -south	NW-SE				
		1	534	535	535	535				
Heating System	steam heating	93	steam heating	gravitational forced heating	pump hot water heating 90/70 °C	district heating 90/70 °C	pump hot water heating 80/60	low temperature boiler		
Holiday Weeks	6	0	534	484	441	458	410	382		
		0	6	8	10	12				
		0	534	534	534	534				
Adjusted setback Mode	no setback	92	no setback	night setback	weekend setback	holiday setback				
		92	534	501	458	442				

Tab. 5.5: Influence of the variation of general input parameters on the calculation results of the ECA

Some comments seem to be necessary to interpret these findings correctly

1. The variation of the type of educational buildings does not result in any changes. This reflects the fact that no meaningful descriptions for buildings other than schools became available. Thus in its present state the ECA should only be applied to schools.
2. The influence of the construction year is most important. Also it reflects the fact that in Germany most school buildings built before 1950 are buildings which were erected before World War 2.
3. The influences of the roof and the basement are in the order of 10% each. They therefore should be included into any modelling.
4. The influence of the number of storeys seems to be surprising. However the numbers reflect the empirical findings described in Appendix D.
5. Besides renovating the building envelope adjusting the heating system seems to be the most important retrofit measure. This holds for both adjusting the operation to the actual demand and adapting the heating system to the status of the building. Usually the numbers given are conservative because they do assume an ideal operation of the plant. Comparison with measured data show that this assumption is not always valid

Main conclusions are that the construction year and the correct choice of the heating system are the most important parameters. If absolute consumptions are necessary we have to give a good estimation for the heated area too.

Modifications of average parameters

We have identified three main means for improvements. They include

- ◆ the calculation of the ground temperature,
- ◆ the calculation of the internal load,
- ◆ the calculation of the ventilation losses.

In the present project we could not improve the model to calculate the ground temperature. We increased the ECA parameter for the calculation of the internal load. We also decreased the ventilation rate in the hourly calculations to account for floor space.

5.4. Comparison with results from 34 school project

The city of Ludwigshafen operates most of the schools in Ludwigshafen. The schools differ in size, year of construction, age of the heating system and usage. As in many other cities maintenance of HVAC systems only guarantee basic operation. As a result most of the buildings need too much energy compared to their actual state and the usage of the building. Therefore through appropriate technical measures and mostly minor technical improvements one can realise considerable saving potentials both for energy and costs. To activate these savings a performance contract was established with the local energy supplier (Technische Werke Ludwigshafen, TWL, http://www.twl.de/geschaeftskunden/edl_anlagen.shtml). Thirty four of the schools were included into the contract. Twenty four of them needed some retrofit of the heating system. Ten of them were quite new thus only optimisation measures during regular maintenance are expected to be necessary.

The primary goals of the contract are:

1. Fixing the energy related costs of the schools under consideration (including primary energy, investments and personnel) at the present level
2. Financing of all investments concerning the heating systems through the contractor
3. Reduction of heat consumption and peak heat demand which can finance both investment and future maintenance
4. Reductions of CO₂ emissions

A detailed description of the project, the schools involved and the measures undertaken is available on the homepage of TWL.

A more detailed analysis of the results and a description of the lessons learned will be given in the frame of the new case study "**34 school project**"



Fig. 5.17: Sample of schools included into the 34 school project

Tab. 5.6: General information on the schools and the heating systems

	Name of school	construction	Heated area (m ²):	Nr. storeys	system renovation	Primary energy	Generation	Hours of operation
1	Hans-Loschky-Schule	1971	9.300	3	1978	oil	SB	15
2	Maxschule	2002	2.000	3	1952	oil	SB	15
3	Schulzentrum Edigheim	1975	6.300	2	-	gas	SB	15
4	Niederfeldschule	1975	5.100	3	-	oil	SB	15
5	Schlossschule Oggersheim	1975	3.000	2	-	gas	SB	8
6	Hauswirtschaft u. Sozialpädagogik	1980	4.200	5	-	gas	SB	12
7	Gräfenauschule	1980	4.000	3	-	gas	SB	15
8	Lessingschule	1978	3.100	2	-	gas	SB	15
9	Karl-Kreuter-Schule	1966	3.000	2	-	oil	SB	11
10	Brüder-Grimm-Schule	1967	3.500	2	-	oil	SB	14
11	Theodor-Heuss-Gym.	1967	9.200	4	-	district	DH	15
12	Anne-Frank-Realschule	1967	6.400	4	-	district	DH	8
13	Schillersch.-Mundenheim	1979	7.900	2	-	gas	SB	14
14	Max-Planck-Gym.	1980	7.100	3	1965	gas	SB	15
15	Wittelsbachschule		5.800	3	1976	gas	SB	17
16	BBS Werkstatt	1965	5.300	4	-	gas	SB	15
17	Grundsch. Pfingstweide	1970	4.300	2	-	district	DH	11
18	IGSLO	1980	10.000		-	district	DH	15
19	Langgewannschule	1970	4.000	2	-	district	DH	11
20	Rheinschule	1969	6.400	4	-	oil	SB	15
21	Mozartschule	2001	2.900	2	2001	gas/oil	LTB	18
22	Geschwister-Scholl Gym.	1986	10.300	4	-	gas	CD	10
23	BBS Technik I+II	1970	22.000	5	-	gas	SB	14
24	W.-von-Humboldt-Gymn.	1980	4.900	3	-	gas	SB	10
25	Adolf-Diesterweg-Schule	1978	4.000	2	-	oil	SB	15
26	Albert-Schweitzer-Schule	1975	3.300	2	-	gas	SB	16
27	Alfred-Delp-Schule	1995	1.700	2	-	gas	LTB	15
28	Carl-Bosch-Gym.	1974	4.700	5	-	district	DH	15
29	Ernst-Reuter-Schule	1998	4.000	2	-	gas	CD	15
30	Georgenschule	1989	2.600	3	-	gas	SB	12
31	Goetheschule-Nord	1970	2.700	3	-	oil	SB	13
32	Hochfeldschule	1998	3.000	3	-	gas	CD	15
33	Schillerschule	1998	1.800	2	-	gas	CD	15
34	Schulzentrum Mundenheim	1998	12.500	2	-	gas	LTB	10

DH District Heating; LTB low-temperature boiler; CD Condensing Boiler; SB Standard Boiler

Tab. 5.7: Parameters used for the ECA calculations

	Name of school	construc tion	Basem ent	Roof	system renovation	Heated area (m ²):	Nr. storeys	Heating system
1	Hans-Loschky-Schule	1971	Flat		1978	9.300	3	SB
2	Maxschule	2002	Inclined		1952	2.000	3	SB
3	Schulzentrum Edigheim	1975	Flat		-	6.300	2	SB
4	Niederfeldschule	1975	Flat		-	5.100	3	SB
5	Schlossschule Oggersheim	1975	Inclined		-	3.000	2	SB
6	Hauswirtschaft u. Sozialpädagogik	1980	Inclined		-	4.200	5	SB
7	Gräfenauschule	1980	Flat		-	4.000	3	SB
8	Lessingschule	1978	Inclined		-	3.100	2	SB
9	Karl-Kreuter-Schule	1966	Inclined		-	3.000	2	SB
10	Brüder-Grimm-Schule	1967	Flat		-	3.500	2	SB
11	Theodor-Heuss-Gym.	1967	Flat		-	9.200	4	DH
12	Anne-Frank-Realschule	1967	Flat		-	6.400	4	DH
13	Schillersch.-Mundenheim	1979	Inclined		-	7.900	2	SB
14	Max-Planck-Gym.	1980	Flat		1965	7.100	3	SB
15	Wittelsbachschule		Inclined		1976	5.800	3	SB
16	BBS Werkstatt	1965	Flat		-	5.300	4	SB
17	Grundsch. Pfingstweide	1970	Flat		-	4.300	2	DH
18	IGSLO	1980	Flat		-	10.000		DH
19	Langgewannschule	1970	Inclined		-	4.000	2	DH
20	Rheinschule	1969	Inclined		-	6.400	4	SB
21	Mozartschule	2001	Inclined		2001	2.900	2	LTB
22	Geschwister-Scholl Gym.	1986	Inclined		-	10.300	4	CD
23	BBS Technik I+II	1970	Flat		-	22.000	5	SB
24	W.-von-Humboldt-Gymn.	1980	Flat		-	4.900	3	SB
25	Adolf-Diesterweg-Schule	1978	Flat		-	4.000	2	SB
26	Albert-Schweitzer-Schule	1975	Flat		-	3.300	2	SB
27	Alfred-Delp-Schule	1995	Flat		-	1.700	2	LTB
28	Carl-Bosch-Gym.	1974	Flat		-	4.700	5	DH
29	Ernst-Reuter-Schule	1998	Flat		-	4.000	2	CD
30	Georgenschule	1989	Flat		-	2.600	3	SB
31	Goetheschule-Nord	1970	Flat		-	2.700	3	SB
32	Hochfeldschule	1998	Inclined		-	3.000	3	CD
33	Schillerschule	1998	Inclined		-	1.800	2	CD
34	Schulzentrum Mundenheim	1998	Flat		-	12.500	2	LTB

DH District Heating; LTB low-temperature boiler; CD Condensing Boiler; SB Standard Boiler

Tab. 5.8: Energy consumption as measured and predicted by ECA

	Name of school	Baseline		2002			Estimation with ECA	
		Energy kWh/a	kWh/a m ²	measures	Energy kWh/a	kWh/a m ²	No set back	All set backs
1	Hans-Loschky-Schule	1.416.443	152	2, 3,	1'270'445	143	461	384
2	Maxschule	1.163.958	582	2, 3,	822'601	432	432	360
3	Schulzentrum Edigheim	2.741.779	435	2, 3,	2'574'383	429	461	384
4	Niederfeldschule	976.560	191	2, 3,	979'892	202	461	384
5	Schlossschule Oggersheim	550.862	184	2, 3,	472'331	165	443	368
6	Hauswirtschaft u. Sozialpädagogik	889.314	212	1, 3,	738'406	184	394	329
7	Gräfenauschule	904.555	226	2, 3,	742'896	195	407	339
8	Lessingschule	590.916	191	2, 3,	696'063	236	442	368
9	Karl-Kreuter-Schule	940.329	313	2, 3,	948'452	332	433	368
10	Brüder-Grimm-Schule	787.825	225	2, 3,	728'228	218	407	339
11	Theodor-Heuss-Gym.	2.495.094	271	1, 3,	2'508'362	286	407	339
12	Anne-Frank-Realschule	1.163.240	182	1, 3,	1'310'846	215	407	339
13	Schillerschule Mundenheim	1.588.544	201	2, 3,	1'399'040	186	441	367
14	Max-Planck-Gym.	1.179.429	166	1, 3,	925'340	137	462	384
15	Wittelsbachschule	1.381.263	238	1, 3,	1'146'445	207	441	367
16	BBS Werkstatt	924.318	174	2, 3,	950'254	188	484	402
17	Grundschule Pfingstweide	782.124	182	1, 3,	387'839	95	556	463
18	IGSLO	2.426.218	243	2, 3,	2'404'057	252	461	384
19	Langgewannschule	1.010.376	253	1, 3,	792'153	208	458	381
20	Rheinschule	1.772.569	277	2, 3,	1'671'894	274	518	430
21	Mozartschule	845.883	292	2, 3,	480'398	174	362	306
22	Geschwister-Scholl-Gym.	1.537.690	149	1, 3,	1'468'177	150	393	328
23	BBS Technik I+II	4.850.282	220	1, 3,	4'830'674	230	405	338
24	Wilhelm-von-Humboldt-Gym.	1.535.863	313	1, 3,	1'583'954	339	462	384
25	Adolf-Diesterweg-Schule	1.566.815	392	1, 3,	1'228'548	322	463	385
26	Albert-Schweitzer-Schule	1.196.252	363	1, 3,	1'204'842	383	463	385
27	Alfred-Delp-Schule	562.727	331	1, 3,	597'389	369	379	320
28	Carl-Bosch-Gym.	1.127.974	240	1, 3,	1'204'022	269	422	352
29	Ernst-Reuter-Schule	1.483.110	371	1, 3,	1'247'305	327	452	377
30	Georgenschule	1.087.406	418	1, 3,	875'472	353	464	386
31	Goetheschule-Nord	1.114.212	413	2, 3,	876'808	341	539	448
32	Hochfeldschule	376.066	125	1, 3,	379'863	133	431	359
33	Schillerschule Oggersheim	335.494	186	1, 3,	404'038	236	432	360
34	Schulzentrum Mundenheim	3.738.634	299	1, 3,	3'327'080	279	410	345
	Total	47.044.124			37197025			

The following measures were taken

1. Retrofit of DDC Control
2. Installation of new DDC/GLT System
3. Installation of temperature and humidity sensors to measure heating needs

The energy consumption was corrected according to the number of degree-days in 2002 in Ludwigshafen (factor 1.05) to become comparable with the data in the baseline

Several comments seem to be necessary

1. The description of the schools is quite general. Nevertheless the information which is most important for ECA calculations using dummy parameters is available
2. From the results presented in the last chapter we would expect primary energy consumptions between 300 and 700 kWh/m² and a potential reduction due to optimising operation of 92/534 or 17%
3. The energy consumption before retrofit varies between 125 and 582 kWh/a m². This clearly indicates that considerable improvements of the envelope were made since the construction year. In such cases the dummy option is not sufficient and a more detailed description of the envelope is necessary. We have learned from the Moses investigations that we can achieve quite good agreement in such a case. However in such a case **the decision maker might need some help from an experienced person.**
4. All the measures applied in the 34 school project aim towards increasing the efficiency of the heating system. This is achieved primarily through an adaptation of the operation to the actual needs. If we compare consumption before and after retrofit we can see in most cases an improvement in the predicted order. In some cases the reduction is higher. In other cases we even got an increase in the consumption. Both effects indicate major changes in the utilisation of the buildings. Some of these changes are known, others are still under investigation through the contractor TWL.

5.5. Comments about the calculation procedure of energy consumption for lighting of educational building IEA 36 – ECA (by R. Cantin and G. Guarracino, LASH - ENTPE)

In order to calculate the energy consumption for lighting of a building, the sum of energy consumption of the various zones can be defined by the following formula:

$$C_{\text{light}} = \sum_{\text{zones}} P_{\text{light_zones}} \times t_{\text{light_zones}}$$

with C_{light} energy consumption for lighting of the building (Watt-hours),

P_{light} installed lighting power of the building (Watt),

t_{light} operation time of lighting (hours), and

zones referring to the various areas.

Obviously, the accurate input data of P_{light} and t_{light} are difficult to identify. A complex monitoring diagnosis, over a long period, is required if exact values are to be identified for an existing educational building.

The calculation procedure of energy consumption for lighting of educational building, based on the French Thermal Regulation 2000, provides default values. These default values were obtained by crossing data coming from various sources: bibliographical analysis and simulations made by the CSTB (Centre Scientifique et Technique du Bâtiment - France). However, it appears there are important differences between these various sources.

For some educational buildings in France, a range of accuracy of 20% about P_{light} and 30% about t_{light} , gives an indication but not a validation of the calculation procedure. It is difficult to extend these default values to each case study, because of the diversity of lighting energy consumption. Each default value will be a source of uncertainty.

This calculation procedure provides an indication of energy consumption for lighting of educational buildings, but, for accurate results, input information from important monitoring diagnoses should be consulted in order to use the formula above, without default values.

6 Conclusion (by Fritz Schmidt IKE)

The ECA is a tool to support decision makers in taking into account energy related considerations during the planning of retrofit measures for educational buildings. In this situation two effects determine energy consumption most heavily. They are:

1. Transmission losses due to poorly insulated building envelopes
2. Operation losses due to HVAC systems which are poorly operated or should be replaced due to their age.

Both effects can be estimated quite well with the methods provided by the ECA provided the building description is adequate (unfortunately this needs in most cases an expert).

Areas where further developments seem to be necessary include

1. Decoupling times of renovation of building and of heating system
2. Development of parameters describing other educational buildings
3. Replacement of formula to calculate transmission losses through floor by the one given in ENISO 13370

To use monthly models in the way the ECA recommends it requires intensive adaptation of the monthly parameters to the actual meteorological and local conditions and to the building usage. This was done in great detail for Germany. Similar efforts seem to be necessary for application under other climate conditions. Additional work is necessary in this area.

The monthly parameters up to now are applicable quite well for schools which need considerable retrofit. For retrofitted schools new parameter sets might become necessary if one wants to improve the accuracy of any predictions of heating or other demands.

Special attention has to be given to the efficiency numbers. They were calculated on the basis of an ideal demand driven operation of the HVAC systems. Such an operation seems not to be reachable under all conditions. As a consequence primary energy demands and therefore cost estimates might differ considerably from what was expected from ECA estimates.

We were not able to test the influence of different Climate zones or different countries. The reason is as mentioned before that at the end of the Annex 36 project (end of January 2004) we had only access to two versions of the ECA.

The first one was the official version submitted to the ExCo in December 2003. This version was based on meteorological data from UK and building data from Germany.

The second one was the unofficial German version which we used for our testing.

It therefore seems to be necessary to repeat most of our tests for country specific conditions in the follow up projects.

Appendix A: Climate Areas for calculation of Lighting Energy Consumption in the French Thermal Regulation (by Richard Cantin and Gérard Guarracino *Lash - ENTPE*)

The calculation procedure of energy consumption for lighting of Educational Buildings uses a corrective no-dimensional coefficient (C_2) which depends on a Climate area (H1, H2 or H3).

These three areas are defined for the French Thermal Regulation.

Table 1: Corrective coefficient according to the Climate zone (Source French Thermal Regulation 2000)

Climate area	C_2
H1 – Basic temperature – 9°C	1
H2 – Basic temperature – 6°C	0,8
H3 – Basic temperature – 3°C	0,6
All zones without access in the light of the day	1

These values were obtained by crossing information coming from various sources: bibliographical analysis, statistical approaches and empirical measurements.

Data defined for each month (Table 2)

- Temperatures :
 - θ_e average monthly temperature, °C.
 - θ_{cw} cold water temperature, °C.
- Radiation :
 - I_S monthly average south vertical radiation, W/m^2 .
 - I_O monthly average west vertical radiation, W/m^2 .
 - I_N monthly average north vertical radiation, W/m^2 .
 - I_E monthly average east vertical radiation, W/m^2 .
 - I_H monthly average horizontal radiation, W/m^2 .
- Statistical repartition of wind speeds defined by:
 - A first parameter of the Weibull rule, m/s.
 - K second parameter of the Weibull rule (-).

In the following table, there are the Climate monthly data for each Climate area:

Table 2. French monthly Climate data (Source French Thermal Regulation 2000)

Zone H₁	Jan.	Feb.	Mars	April	May	June	July.	Aug	Sept.	Oct.	Nov.	Dec.
θ_e (°C)	3,5	4	7,1	10,5	13,1	16,3	20,6	18,9	16	10,6	4,8	3,7
A (m/s)	2,4	3,5	3,6	3,5	3,1	3,2	3,1	2,9	2,8	2,7	2	3
K	1,25	1,77	1,83	1,82	2,11	1,72	1,75	1,96	2	1,7	1,24	1,53
I_S (W/m ²)	44,3	76,2	99,5	94,1	99,4	107,4	123,5	127,9	117,6	81,6	40,2	37,9
I_O (W/m ²)	23,4	46,4	72,4	80,2	97,4	116,8	129	116,4	82,3	52,5	26,3	19,6
I_N (W/m ²)	18,4	30,9	46,7	60	75,7	86,5	86,1	71,2	55,7	35,5	18,6	14,8
I_E (W/m ²)	25	42,6	71	83,8	101,7	116,8	136,5	119,8	85,5	47,7	21,7	19,8
I_H (W/m ²)	38,9	72,6	114,3	144,7	177,2	209,9	242,9	208,5	144,1	83,7	38,4	30,8
θ_{cw} (°C)	5,7	5,7	7,0	9,2	11,8	14,0	15,3	15,3	14,0	11,8	9,2	7,0
Zone H₂	Jan.	Feb.	Mar	April	May	June	July.	Aug	Sept.	Oct.	Nov.	Dec.
θ_e (°C)	3,6	7,8	8,6	10,4	13,8	17,3	20,7	19	16,8	13	6,7	5,8
A (m/s)	2,3	3,6	4,1	3,1	3	3	2,6	2,4	2	3,4	2,4	3,2
K	1,45	1,65	1,87	1,75	1,71	1,7	1,76	1,75	1,23	1,66	1,81	1,6
I_S (W/m ²)	84,5	109,2	104,1	117	108,7	115,3	124,6	139,1	119	82,9	82,1	58,9
I_O (W/m ²)	37,8	59,3	74,5	102,9	114,8	135,2	148,5	133,7	88,6	52,6	42,1	30
I_N (W/m ²)	21,8	32,4	49,3	66	78,6	90	88	74,1	55,3	37,8	27,2	16,8
I_E (W/m ²)	37	55,9	80,4	102,4	106,5	129,6	135,9	134	83,9	51,6	41,7	24,7
I_H (W/m ²)	57,7	90,4	123,7	179,5	203,4	243,8	257,9	227	154,1	88,4	64,7	40,3
θ_{cw} (°C)	7,2	7,2	8,5	10,7	13,3	15,5	16,8	16,8	15,5	13,3	10,7	8,5
Zone H₃	Jan.	Feb.	Mar	April	May	June	July.	Aug	Sept.	Oct.	Nov.	Dec.
θ_e (°C)	8	9,6	10,9	12,7	16,2	19,8	23,5	22,4	20	15,9	11,1	8,7
A (m/s)	4,1	5,4	4,5	3,9	3,8	3,6	3,6	3,6	3,3	3,7	4	4,3
K	2,07	1,7	1,8	1,77	1,59	1,82	1,86	1,79	1,62	2,3	2,62	2,66
I_S (W/m ²)	82,2	71,3	130,1	133,4	138	122,8	136,6	135,4	139,2	132,8	141,8	109,8
I_O (W/m ²)	39,4	42,7	86,4	106,3	140,6	140,5	146,6	115,3	92,3	70,3	61,2	44,4
I_N (W/m ²)	23,3	31,2	49,2	69,5	83,1	90,6	86,7	72,3	60,4	41,1	29,9	22
I_E (W/m ²)	39,3	42,2	94,5	119,5	143	141,4	156	132,8	101,4	71,9	59,8	39,7
I_H (W/m ²)	59,2	72,5	146,6	203,3	272,2	268,6	290,4	226,8	175,1	120,8	90,7	63,9
θ_{cw} (°C)	9,7	9,7	11,0	13,2	15,8	18,0	19,3	19,3	18,0	15,8	13,2	11

Data defined one time (Table 3)

θ_{eb} basic temperature, °C.

This temperature θ_{eb} calls for statistics of low temperature and fits to 5 days accrued frequency by year (between November 15th and March 15th). The choice of 5 days results from empirical measurements and statistics based on more 50 years.

Table 3: French yearly Climate data (Source French Thermal Regulation 2000)

	θ_{eb}
Zone H ₁	- 9 °C
Zone H ₂	- 6 °C
Zone H ₃	- 3 °C

For instance, this table 3 means, with the empirical approach, that, in the zone H1, the low temperatures are under -9°C more than 5 days, per year, between November 15th and March 15th.

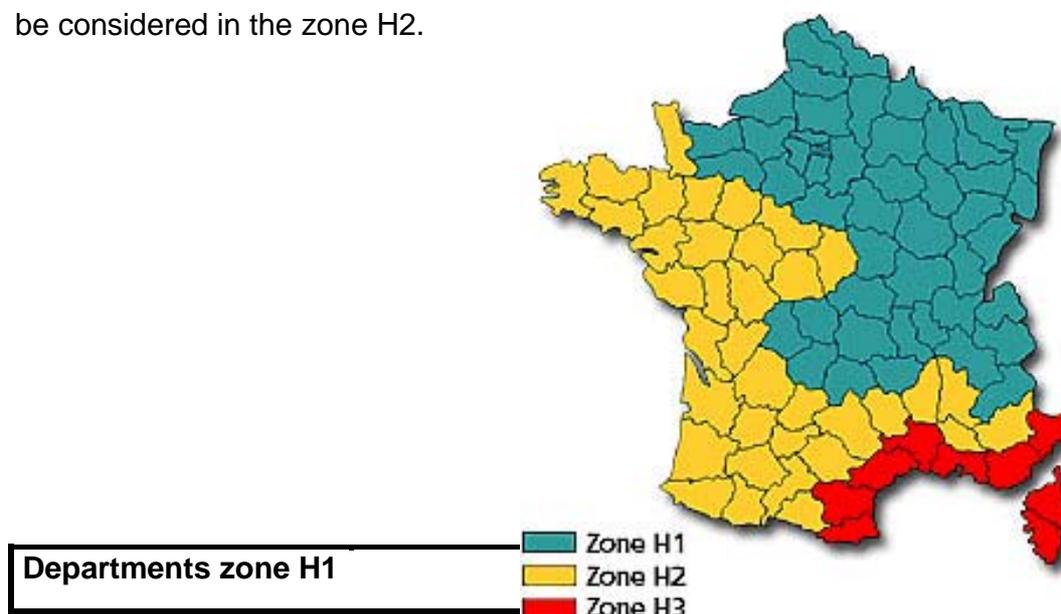
A correction about the identification of the zone is also defined with the altitude of buildings (Alt):

Table 4: Corrections with Altitude (Source French Thermal Regulation 2000)

if Alt<800m	if Alt>800m
H1	H1
H2	H1
H3	H2

With this table 4, a map of the France can be useful (see below).

For instance, an educational building located in the zone H3, but at 1000 m (altitude), must be considered in the zone H2.



62, 59, 80, 76, 60, 02, 08, Paris et region parisienne, 14, 27, 95, 78, 91, 77, 51, 55, 54, 57, 67, 68, 90, 61, 28, 45, 89, 10, 52, 88, 70, 25, 21, 58, 71, 39, 03, 23, 63, 42, 69, 01, 74, 73, 38, 05, 87, 19, 15, 43
--

Departments zone H2

50, 29, 22, 35, 53, 72, 56, 44, 49, 37, 41, 85, 79, 86, 36, 18, 17, 16, 24, 33, 40, 32, 82, 46, 64, 65, 31, 09, 81, 12, 48, 07, 26, 84, 04
--

Departments zone H3

66, 11, 34, 30, 13, 83, 06, 2A, 2B

Extrapolation to other climate areas

An extrapolation to other climate areas requires detailed investigations which have to be performed by each country separately. As can be seen from the discussions above there seems to be some correlation with temperature during winter time. Based on such a correlation the following values for C2 were estimated for the different climate areas treated in the ECA:

Country		France			Germany	
Zone		Lyon (H1)	H2	H3	Reference	
Unit of temperature		°C			°C	
January		3.5	3.6	8	-1.3	
February		4	7.8	9.6	0.6	
March		7.1	8.6	10.9	4.1	
April		10.5	10.4	12.7	9.5	
May		13.1			12.9	
June		16.3			15.7	
July		20.6			18	
August		18.9			18.3	
Sept.		16			14.4	
Oct.		10.6	13	15.9	9.1	
Nov.		4.8	6.7	11.1	4.7	
Dec.		3.7	5.8	8.7	1.3	
	aver	4.2875	6.2125	9.325	1.25	
	Temp H	-7.9	-6.0	-2.9	-11.0	
	H	1	2	3		
	C2	1	0.8	0.6	1.15	

References:

French Thermal Regulation 2000 - Arrêté du 29 novembre 2000 relatif aux caractéristiques thermiques des bâtiments nouveaux et des parties nouvelles de construction - Règles de calcul.

Norme NF-EN-410 (P78-457): Verre dans la construction.

Norme NF X35 103 (X35-103): Ergonomie.

Appendix B: KULU WINDOW Instructions (by Jorma Pietilainen, VTT)

The Kulu window consists of three parts: READINGLIST, GRAPH and REPORT. In the readinglist there is shown data (dates, readings and consumptions) already entered into the database. You can scroll the list up and down with the scroll bar on the right side of the readinglist. The **row below the readinglist is for updating**: there you can enter a new date and reading (or consumption). By default monthly consumptions are shown in the graph and in the report.

Above the readinglist (beside the drop-symbol) there are two fields PROPERTY and METER. In the property-field the name and code of the property will be shown. By clicking the name (or the arrow) the list of all properties entered into the database will be displayed. In the meter field there is shown the name and number of the meter. By clicking the name (or the arrow) the list of the meters of the property in property field will be displayed. The active property and/or meter can be chosen by clicking from the lists mentioned.

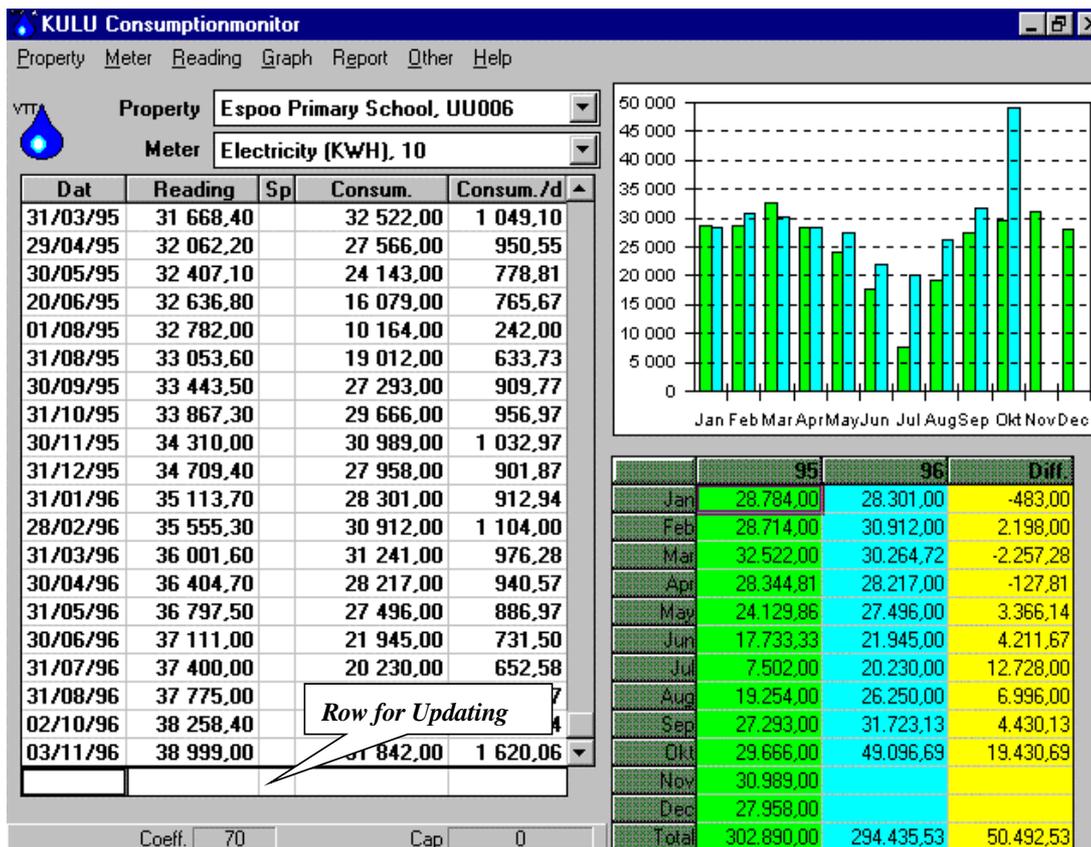
On the top of the Kulu window there are the following drop-down menus:

'Property' 'Meter' Reading' 'Graph' 'Report' 'Other' 'Help'

On the bottom of the Kulu window there is shown the coefficient and the capacity of the active (chosen) meter. Depending on the resolution of the display and the size of the Kulu window the graph will take less or more space and the readinglist and report will be scaled correspondingly.

TYPICAL PHASES IN THE USE OF KULU :

1. CREATING PROPERTIES (drop-down menu 'Property'/'Add')
2. " METERS (" 'Meter'/'Add')
3. ENTERING CONSUMPTION DATA (add-row of the readinglist)
4. " WEATHER DATA (drop-down menu 'Other/Weather information')
5. GRAPHS AND REPORTS (drop-down menus 'Graph` and 'Report')
6. BACKUP OF DATABASES (drop-down menu 'Other'/'Backup')



1. CREATING PROPERTIES

Before entering consumption data you have to set up the properties and their meters. A property can be created in a form which you will get by clicking 'Add' on the drop-down menu 'Property'.

(ATTENTION! While creating properties put upper case '**CAPS LOCK**' ON)

1.1 'PROPERTY' / 'ADD'

Click Add on the 'Property' menu to indicate that you want to add a new property into the database, a new form will be displayed with the information of the property in the property field of Kulu-window. Cursor is ready in property code field of the form. You can enter information of a new property without deleting old ones. When you have entered the first character the existing data will disappear.

When creating a new property the following data is essential and must be entered:

PROPERTY CODE and PROPERTY NAME (and WEATHER AREA to get weather corrections done).

Other information for the property can be added later on when needed by clicking Change on 'Property' menu.

PROPERTY CODE is the most essential key-information in the program. Almost all the data in the database will be arranged according to this code. Therefore it is important to note the following rules when forming the code:

- Each property code must be unique within the file (database).

- The code is 5 character long, numbers and/or letters can both be used. Blank characters are not permitted.
- Write code with upper case (**CAPS LOCK ON**).
- You cannot easily change the code later, that's why it is important to plan the principles of the code beforehand.
- When having a great number of properties it is easier to use Kulu, if the code is formed logically.

The most simple way to form the code is to number properties running from 00001. More advanced way is to reserve the first 2-3 characters of the code for classifying the properties according to the needs of the user (type, administration, area/region, etc.) and to use the rest of the code for numbering.

PROPERTY NAME contains essential information for the user and will be used eg in the headings of the reports. Name can have max. 40 characters. Properties will be sorted alphabetically in the list of properties. In the long list the certain one can be found rapidly by clicking the first letter of the property name.

WEATHER AREA of a property is 3 characters long code. Weather database includes the same code. The application will use this code to join the property to the weather database when calculating weather corrections for the heating energy consumption. This code can be added later when corresponding weather data is available.

A new property with all given information will be added into the database by clicking 'Add' on the 'Property' menu.

1.2 'PROPERTY' / 'CHANGE'

By clicking Change on 'Property' menu you can update/change existing data of the property (not the code however). The changes will be added into the database by clicking the change button.

1.3 'PROPERTY' / 'DELETE'

By clicking Delete on 'Property' menu you can delete the chosen property. Be careful however because when deleting a property all the existing data including meter readings, consumptions etc. will disappear.

2. CREATING METERS

When creating a meter you must choose the property from the list of properties. Then you can create a meter for this property in a form, which you will get by clicking 'Add' on the 'Meter' drop-down menu.

(ATTENTION ! While creating meters put upper case '**CAPS LOCK ON**')

2.1 'METER' / 'ADD'

You can click Add on 'Meter' menu to indicate that you want to add a new meter into the database for the chosen property and a new form will be displayed.

You must always enter the following essential data when creating a new meter:

METER NUMBER, METER NAME, CONSUMPTION TYPE, UNIT and COEFFICIENT.

Other information of a meter can be added later on when needed. For the existing meters the data can be added or changed by clicking Change on 'Meter' menu.

METER NUMBER is important "key" information for the meter and has to be unique within the property. The field is numeric and 2 digits long. Therefore there can be maximum 99 meters in each property. You can number meters free, but it can be useful to reserve for each consumption type its own decade, for example for heating meters/numbers 1-9, for electricity 10-19, for water 20-29 etc. Meter number must **not be left blank!**

METER NAME is essential information for the user. Meters will be sorted alphabetically in the list of meters and that's why the names should be suitable. The name can be max. 20 characters long. Typically meter name specifies the consumption type and can give some additional information as well. (For example: heating, electricity day, electricity night, electricity for cooling, water 1, water of kitchen, etc.)

CONSUMPTION TYPE and UNIT can be chosen from the list, which is displayed by clicking the arrow on the right side of the field. Also, other codes than those in the list can be used. However apply the following rules when entering consumption type:

- Consumption type code is maximum 2 characters long.
- First character in the code defines the main consumption type in the following way:
L=heating, S=electricity, V=water, H=hot water, J=district heating water, K=users/persons
- Kulu will use the first characters mentioned when calculating eg the Total property consumption in the Report menu (= sum of the consumption of all the meters having the same main consumption type as the active/chosen one)
- Kulu will make weather corrections only for the meters, which have the code of consumption type beginning with character 'L' (=heating).
- Consumption type code for the energy meter of district heating must be 'LK' and unit 'MWH'.
- Code for other consumption types can be chosen from the characters mentioned above. The second character in the code can be used for different kind of other purposes if needed (eg to identify certain type of consumption, for advanced reporting, analyses etc.).
- User can define his own consumption types and codes as well. Only the code will be updated into the Kulu's database. Using Windows/Notepad new codes and names for

consumption types can be added into the file **Mikuluti.dat** located in the same folder as where Kulu is installed (usually C:\Kulu)

COEFFICIENT is by default 1, unless some other value will be entered by user. Especially coefficients of electricity meters are usually higher than 1 depending on the type of the meter. When a meter will be changed, remember to check the possible change of the coefficient too. If the coefficient will be changed, enter the date of the change in the Change date field - then the new/changed coefficient will be used only for the readings after this date (not working in this version yet). Normally when creating a meter, leave the Change date field blank. While using Kulu the value of coefficient is shown at the bottom of the Kulu window.

CAPACITY is needed to calculate consumptions when meter readings “rotate around” and start again from 0 (see also entering consumptions special character ‘Y’). Data for Capacity can be entered when readings reach this phase - before that moment the value of capacity will be not used. While using Kulu the value of capacity will be shown at the bottom of the Kulu window next to the coefficient.

Enter letter ‘A’ in ‘**Sub meter**’ field, if the meter is a submeter (= the consumption has been already measured by another meter of the property), otherwise leave it blank. The consumptions of submeters will be not summed up when Kulu calculates eg the Total property consumption.

The new meter with its information will be added into the database by clicking the add button.

2.2 ‘METER’ / ‘CHANGE’

By choosing Change on ‘Meter’ menu you can update information of an existing meter (not the meter number however). Changes will be added into the database by clicking the change button.

2.3 ‘METER’ / ‘DELETE’

By choosing Delete on ‘Meter’ menu you can delete the meter with all the data (including readings etc.) of it. Before deleting a meter be sure you will not need its data anymore!

3. ENTERING CONSUMPTION DATA

Before you can enter meter readings (or consumptions etc.) you must choose the property and the meter from the lists, which will open when clicking the Property or Meter fields (or arrows) in the Kulu window. The existing consumption data for the chosen property and meter will be shown in the reading list if there is any. The dates (and readings) in the list are sorted according the latest as the lowest. You can scroll the list up and down with the scroll bar on the right side of the list.

3.1 ADDING READINGS AND CONSUMPTIONS

You can enter new consumption data in the add-row below the reading list. The add-row is separated from the reading list with a stronger line. The readinglist and the add-row consist of the following fields:

DAT	READING	SP	CONSUM.	CONSUM./D
(date)	(meter reading)	(special character)	(consumption)	(consumption per day)

There are two ways to enter consumption data :

1. Most typical is to update meter readings. They will be entered in the reading field, then Kulu will calculate consumption by subtracting from the reading entered the previous one and by multiplying the result with the coefficient of the meter
2. Another way is to enter consumptions directly. They will be entered into the consumption field. In this case the reading field will be left blank and the character 'K' will be entered in the 'Sp' field. So it is also possible to monitor and control other than typical meters like heating, electricity and water. For example users, clients, units of production, hours of use, costs etc. can have their own meters of daily, weekly, monthly or yearly data entered directly as consumption. When you start to enter readings or consumptions for a meter, you must enter the date and (for the first/starting reading) 'A' -letter into the Sp-field. For the first day the consumption-field will be left blank (and the consumption cannot be calculated).

- Entering DATE

You can enter one reading for each date for each meter. There are no other restrictions and the reading period can be a day, a week, a month, a year or whatever intermediate time is required. The period can also change during the monitoring. Dates will be normally entered in ascending date order, but it is also possible (but not recommended) to add a new date and reading between old ones. The explanation of how to enter dates will be explained in the following:

- Activate the date field on the add-row by clicking it (line around the field will become stronger).
- Enter the date in the field in format **ddmmyyyy** (for example. 31012000). Date separators will be written automatically (and can be changed in the Windows Control Panel).
- The latest date entered will be stored in the memory and for the next readings you can get the date into the date field by pressing the **F12-key**. When entering the date for the first time in a session the F12-key will obtain the current date directly from the computer's clock/calendar. So if you enter readings (or consumptions) on the same day as the meters have been read, you will get the date **simply by pressing the F12-key**. When using the F12- key you do not need to activate the date field. By triple clicking the date field the **calendar** will pop out and you can choose the date there as well.

- Entering READING

- Move the cursor from the date field to the reading field by pressing the **TAB-key** or by clicking the mouse.

- Enter the reading. The reading can have a maximum of 10 digits. Two of these digits are for decimals. If you enter a decimal, you have to use comma (',' not a decimal point) to separate the decimals.
- If the reading entered was the start reading move the cursor to the next field ('sp'-field) and enter 'A'- character in that field. (See next description about 'special character'.)
- Add data into the database by pressing the *Enter*-key.
- After that, the data entered will be moved automatically to its own place in the readinglist. Simultaneously Kulu will calculate values for the consumption and consumption/day except for the first reading. Also the graph and the report will be updated according to the data entered.

NOTE: CONSUMPTIONS IN THE READINGLIST ARE CONSUMPTIONS BETWEEN TWO SEQUENTIAL DATES, BUT CONSUMPTIONS IN THE REPORT AND GRAPH ARE MONTHLY CONSUMPTIONS CALCULATED FROM THE DAILY CONSUMPTIONS OF READING PERIODS.

- The **SPECIAL CHARACTER**-field is one character long and can be used for the following purposes:

(ATTENTION! All Sp. Characters must be entered with **capital letters**)

- Blank (no character). **Usually** the field will be left **empty** when entering a reading. There are however some situations where you must enter the following character in the Sp Field:
- -character **A**, when you give the first reading or a start date when entering consumptions.

The 'special character' must be 'A' in the following cases:

- the first reading of a meter or a start date with consumption.
- when you enter the first reading after a meter change.
- when you have entered consumptions and after that you will enter first reading.
- Always when you start a new reading series.
- -character **K**, when you enter consumptions. Consumption will be entered in the consumption field and the reading field will be left blank.
- -character **Y**, when you update readings for a meter, which has rotated around beginning again from 0. Only with 'Y' in the sp. field will Kulu accept a reading, which is smaller than the previous one. **Also** the value of **capacity** in the meter data must be updated in this phase (otherwise Kulu cannot calculate the right value for the consumption).

- **CONSUMPTION**

If you enter readings, Kulu calculates the consumption automatically. Another way is to enter directly the consumption in the consumption field. In this case the reading

field will be left blank and the character 'K' will be entered in the 'Sp' field. Daily consumption between the given and previous dates will be calculated when pressing the **Enter key**. Simultaneously monthly consumptions in the graph and report will be updated (if the period is long enough).

- **CONSUMPTION / D(ay)**

Kulu will calculate the consumption/day automatically. In the add-row this field will be always left blank (untouched).

When updating readings (or consumptions directly) Kulu calculates into the database the consumption for a period of sequential dates/readings, the daily consumption for this period and the monthly consumption (shown in the report and graph). The monthly consumption will be calculated when the reading period is long enough ie, there are consumptions for (at least) twenty days of the month. If there are no consumptions for the rest of the days, at the end of the month corrections will be made when the new data (next reading) is entered.

3.2 CHANGING READINGS

Although all new readings will be given via the add-row, you can change an existing reading in the reading list (or consumption if entered) in the following way:

- Activate the reading by clicking it with the mouse.
- Enter the new reading . (You don't need to delete the existing reading, it will disappear automatically.)
- Update changes into the database by pressing the *Enter*-key **TWICE**.

3.3 DELETING DATES (READINGS)

The date with the reading and all consumption data (the whole row in the form) can be deleted in the following way:

- Activate the date you want to delete by clicking the date field
- Choose 'Delete' on Reading menu (or just push Delete button)

You can clear the add-row in the same way but choose 'Empty add-row' on Reading menu (or just push Delete button after activating the date field in the add-row).

You can not change dates in the readinglist. (The only way is to delete the date first and then add the new one in the add-row.)

If there are some problems/errors when entering a date or reading, just simply delete the whole row and then add a new one (with the correct data) via the add-row.

4. ENTERING WEATHER DATA AND CALCULATING WEATHERCORRECTIONS

When calculating the monthly consumption Kulu can make also so called weather corrections for the heating energy. This presupposes that monthly heating degree days are updated into the weather database and right the weather area is chosen in the property data. Based on the monthly degree days weather corrected monthly consumption of heating energy will be calculated for meters which have the consumption type beginning with letter L (look the meter data). Whether degreedays are updated or not Kulu calculates anyhow monthly consumptions for all meters of the property. So the weather correction can be seen just as an additional option for heating (cooling) energy meters. Because needs and practices of weather correction, statistics, etc. vary from country to country this option must be developed further in collaboration with the users. At the moment Kulu offers however some tools for recording the very basic monthly weather data, which then will be used for some calculations as described below.

4.1 ENTERING WEATHER DATA

You can update some weather data in the form, in which you will get by choosing 'Weather information' on 'Other' menu.

Data already entered into the database is shown in the form. You can scroll the list up and down with the scroll bar on the right hand side of the list. At the top of the form there is the field 'weather area'. Weather data of a certain area (weather station) is joined with the help of this code to the weather code included in the property information. By clicking the field the list of weather areas entered into the database will be displayed. By clicking some code in the list you can change the weather area (station). Basically there is no limit to the number of weather areas (stations) but because the current version is developed originally for Finnish circumstances no routines for creating new areas are included yet and new codes (weather stations) can not be added by the user. For most users the existing number of codes is enough and can be used if the weather data are updated.

You can enter new weather data in the add-row below the list separated with a stronger line. The list and the add-row consist of the following fields:

Mon	Avg. temp.	Grade day
(month)	(average temperature)	(Degree day)

Weather data will be entered in the following way:

- Choose weather area from the list you will get by clicking the field weather area.
- Activate 'Mon' field in the add-row (the line around the field will became stronger).
- Enter month in format yymm (for example 9901).
- Move cursor to the next field (Avg. temp.) by mouse click or by pressing the *TAB* key.

- Enter the outdoor average temperature. (At the moment Kulu does not use average temperature so you can also leave this field blank)
- Move cursor to the next field 'Grade day'.
- Enter the value of monthly degree days.
- Add the data into the database by pressing the *Enter* key. After that the data entered will be moved automatically to its own place in the list.

A month with weather data can be deleted in the following way:

- Choose the weather area.
- Activate the month to be deleted in the list by clicking it.
- Delete the month by clicking the 'Delete' button at the bottom of the form.

Quit the form by clicking the 'Exit' button at the bottom of the form.

4.2 CALCULATING WEATHER CORRECTION

If the values for the monthly heating degree days are entered before updating a reading/consumption, Kulu calculates the weather corrected value for heating consumption simultaneously with the monthly consumption. Usually however the weather data (degree days) will be updated later on and in this case weather corrections can be calculated in the following way:

- Choose the property and the meter for heating.
- Corrections will be calculated for one year at a time. Activate some date in the year by clicking it in the readinglist. (Line around the field will become stronger.)
- Choose 'Calculate weather corrections for year.' on 'Other' menu. After that Kulu calculates weather corrections for the chosen meter and year.

The calculation of weather corrected (normalised) heating energy is made according to the common Finnish practice where heating dereedays, eg are based on the indoor temperature of 17 degrees centigrade. As discussed above, this option can be left without use too. How to look at the normalised values will be explained in the next chapter.

The function 'Calculate weather corrections for year ...' can be applied also for other than heating energy meters. In this case consumptions for all meter readings inside the selected year will be recalculated. This function must be used for instance when an existing reading in the reading list is deleted. Recalculation of consumption will produce the right value in the next row following the deleted one.

5. GRAPHS AND REPORTS

5.1 CHOICES OF GRAPHS AND REPORTS

In the Kulu window there are the graph and the report besides the readinglist. By default in the graph and in the report monthly consumptions (without weather corrections) of the two latest years will be shown. In the report also the difference between the years will be shown. You can control changes in the consumptions with the help of differences visualised also in the graphs.

You can change the content of the graph and the report by the following choices:

- Property
- Meter
- Year (Month in daily graph)
- Yearly / Monthly / Monthly accumulated / Daily / Daily accumulated
- Not weather corrected / weather corrected
- Graph type

Property and meter

You can get into the graph and report consumptions of all the properties and meters in the database by changing the property and/or meter in the respective fields.

Year

By default in the graph and in the report **monthly** consumptions of the two latest years will be shown. You can change the year (or month in daily graph) by clicking the date in the readinglist.

Yearly / Monthly / Monthly accumulated / Daily / Daily accumulated

By clicking the menu bar item 'Graph' you will get a new menu including the choices:

- Yearly
- Monthly
- Monthly accumulated
- Daily
- Daily accumulated

Daily graphs and reports are useful only if there are several readings/consumptions inside a month. When meter readings are updated eg on daily or weekly cycle these views can be used in order to visualise and control the development of consumption within a month.

Not weather corrected / Weather corrected

By default consumptions in the graph and in the report are the "normal" measured consumption. As discussed before you can get also weather corrected values for

heating consumptions if degree days are entered into the database before entering readings or consumptions. If you update degree days later than consumption data, you can calculate weather corrections separately as explained in the section 4.2.

In the menu 'Graph' you can find items 'First series, contents' and 'Second series, contents'. **First series** means consumptions of **previous year** and **second series** consumptions of **active year**. The displayed years can be changed by clicking some date inside the desired year in the reading list.

By clicking item 'First series, contents' you will get a new menu including items 'Previous year, weather corrected', 'Previous year, not weather corrected' and 'Active year, weather corrected'. The choice Forecast (designed or estimated) is not yet supported in the current version of Kulu. By clicking the item 'second series, contents' you will get the new menu including items 'Active year, not weather corrected' and 'Active year, weather corrected'. By clicking those choices you can compare either weather corrected and/or measured values of heating energy consumption.

Graph type

By choosing the items 'Graph type, 1st column' or 'Graph type, 2nd column' on the 'Graph' menu you will get the new menu including items 'Bar', 'Area', 'Line', 'Pie' and 'Hide'. By clicking the choices you will get different graph types. When choosing the item 'Hide', only the consumptions of the current year will be shown in the graph. Especially when the yearly view is chosen the hide alternative can be useful.

5.2 PRINTING

The menu bar item 'Graph' includes items 'Print', 'Copy' and 'Copy to file'. By those choices you can print the graph, copy it to the clipboard or into a file.

You can also copy chosen figures from the readinglist or from the report to the clipboard. Activate the area by pressing the left mouse button and "paint" the desired values. The activated area will be copied to the clipboard by simultaneously pressing *Ctrl* and *Insert* keys (or *Ctrl+C*).

5.3 REPORTS

The report menu includes the following reports:

- Consumption report 12 months
- Meter reading form
- Print screen
- Total property consumption
- Costs of the meter
- Costs of the whole property

CONSUMPTION REPORT 12 MONTH includes monthly consumptions of all meters of the property chosen in the property field of Kulu window.

METER READING FORM is the form for collecting readings of all the meters of the property in the property field (or all properties in the database). You will be prompted to type the month for which you would like to produce the form. In the form also the previous date and reading from Kulu's database will be shown. They will function as directions for the reader and help to avoid reading errors.

TOTAL PROPERTY CONSUMPTION shows in the graph and report the total consumption of certain consumption type in a chosen property. Normally in the Kulu window there are shown the graph and the report of one chosen meter. If in a property there are several meters for some consumption type (eg energy for day and night time), total property consumption shows the sum (total) consumption of those meters (having the same consumption type in meter data). Consumption of sub meters is however excluded. In the demo building (included in the Kulu installation) there are two meters for electricity which can be used to test this report.

COSTS OF THE METER and COSTS OF THE WHOLE PROPERTY show in the graph and report cost information for the chosen property. Costs of meter, shows the costs of consumption for the chosen meter. Costs of the whole property, contains total costs of all consumption types of the property. Costs will be based on so called default tariffs. By choosing 'Updating tariffs' on 'Other' menu you can start Windows Notepad and open the file **kutariff.dat**) containing information on tariffs. In the file there is under heading *default tariff* between quotation marks consumption type of default tariff. You can change default tariffs and add your own ones. Type of consumption joins the default tariff with the consumption type of a meter. When you use default tariff, you do not need to enter tariff code into the meter data. Under heading *tariff* there are on the rows beginning with quotation mark other than default tariffs. You can change them or add new ones following the given examples. If you want to use those tariffs in cost calculations (reports) you must enter the same tariff-code into the meter data. NOTE: **don't use Tab-key when adding new tariffs.**

6. BACKUP OF KULU DATABASES

You can take backup copies of databases by choosing 'Backup' on 'Other' menu. In Kulu application there are three databases: *Kurakulu.foc*, *Kurakiin.foc* and *Kurasaat.foc*. First one contains consumption data, another one some property information, and third one weather data. Backup will copy databases into two diskettes. *Kurakulu.foc* will be copied into the first one and the other databases into the second one. When the size of *Kurakulu.foc* exceeds the capacity of a diskette, use the commands of Windows (or some other software) to make backup copies. If you have a connection to the network the most practical way is to make copies of the Kulu databases (files mentioned before) into some network drive. It's recommended to make backups every time you have added new data into the KULU databases.

7. LANGUAGES

After installing Kulu you can choose the language of Kulu in the drop down menu "Muut/Övrigt/Other /Altro/Andere". Texts in the Kulu window and in menus and reports will change accordingly. You can make corrections or even new language versions by editing with Windows Notepad the file **Kutransl.dat** locating in the same folder where Kulu was installed (usually C:\Kulu). In the file Kutransl.dat you can see in each row words between quotation marks in Finnish, Swedish, English, Italian and German. You can for example replace the Swedish words with your own and after saving the file you will have a new language version. Note: Don't change any other marks in the file Kutransl.dat. At the moment the Help file is however in Finnish only and translation of it will require a bit more work. However the instruction manual in English is available as a separate file.

8. DEMO DATABASES

When installing Kulu you will also get a small demo database containing an example building (school) and some meters for energy, water, etc. You can use the data of this building as an instruction (model) when creating your own properties and meters. Of course you can add new readings for the meters of the demo building too. When you don't need the demo data any more you can delete it by choosing first the demo property and then Delete in the Property menu.

9. ADDITIONAL INSTRUCTIONS

Instructions for using and further information are available from the Kulu web-site: <http://www.vtt.fi/kulu>. Look especially at the section on the standard version. In the future there might be possibilities to upload the consumption data(base) via the internet into Kulu's webserver and to produce benchmarking etc, information based on the data of numerous users. However, at the moment this is just in the planning phase.

At the end of this manual there is a picture describing the main steps needed in the normal use of Kulu. Once you have defined the objects to be monitored (properties and meters) you need only a few steps to keep track of the consumptions and to visualise their yearly, monthly or daily development.

10. COPYRIGHTS

The programme is (c) Copyright VTT Building and Transport. Kulu is **not** a shareware or public domain product. If you want to use it for anything else than for testing or for purposes agreed with VTT please contact us by phone, fax or email. Reproduction under licence.

11. Responsibilities

No warranties are expressed or implied. VTT will not accept any liability for loss or damage possibly caused in using Kulu software.

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FINLAND

The normal use of KULU (choose the language from Other-menu, more information: <http://www.vtt.fi/kulu>)

1. Choose the object of monitoring

(Building, Group of Buildings, Factory etc.)

Open the list of objects by clicking the field. Choose the object from the list. If needed scroll the list of objects.

2. Choose the meter

Open the list of meters and click the meter from the list.

3. Give the date for reading

The **lowest** row in the form is for updating. Click the date field so that the frames will become dark. Give the date in the form dd.mm.yy. or use F12. It brings current date from PC's calendar or the date once given. Tripble clicking gives you the calendar.

4. Give the meter reading

Go by mouse or -key to the next field and give the reading. Separate the decimals by the comma character (,).

You can also give directly the consumption (outputs, amount of users etc.). In this case leave the reading field empty and put into the Sp-field (Special) character **K**.

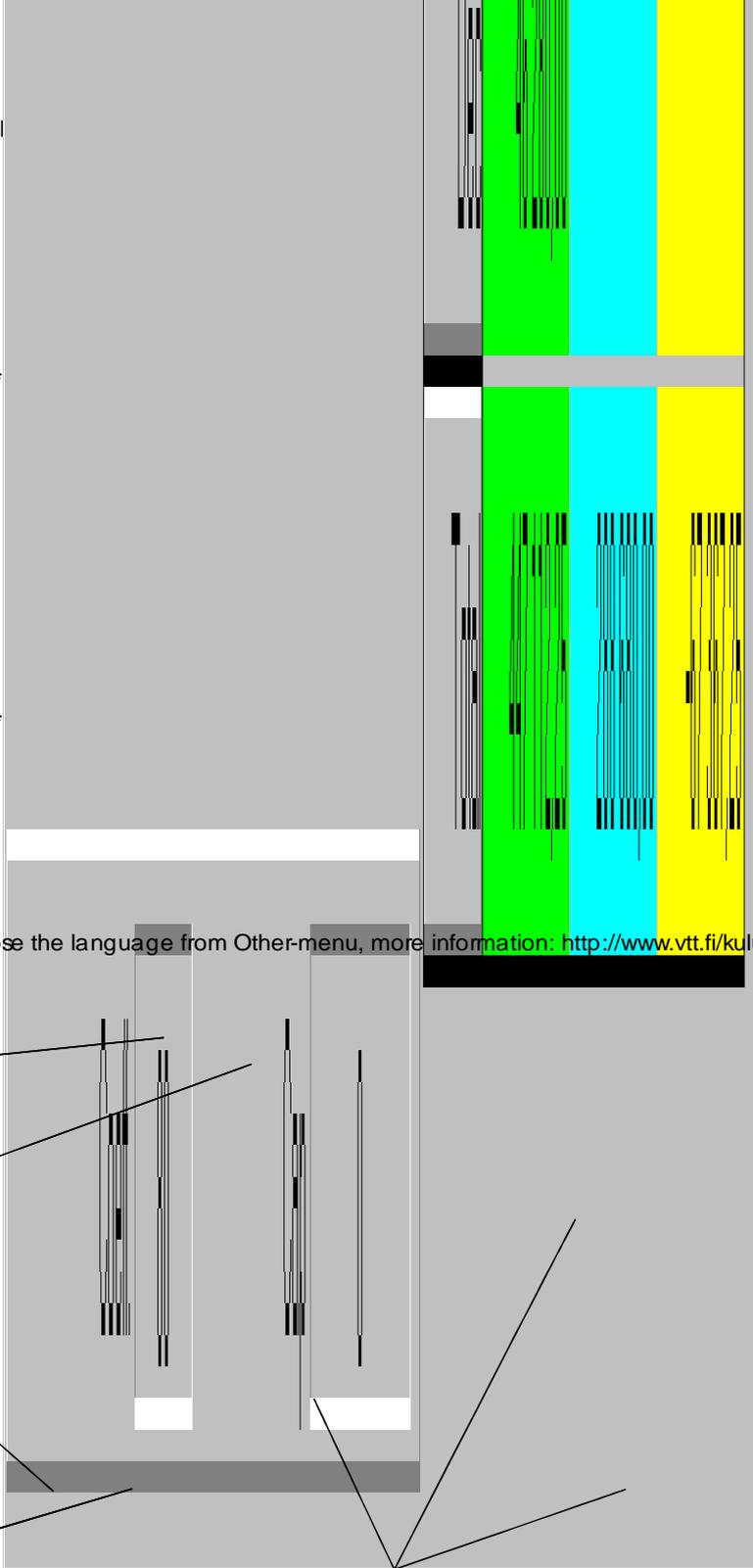
By clicking any date-field (row) in the form and pressing **CTRL+D** you can delete the whole row (wrong values for instance).

5. Look at the results of monitoring (consumptions)

Push **Enter**: The programme puts the given data as a **new row in the form** and calculates the values for **absolute and daily consumption** (columns).

Based on the reading period **consumptions for the calendar months** will be calculated (incl. corrections) and displayed in the **table and graph**.

From the **Graph-menu** choose **yearly/monthly/daily** and **graphtype**. Compare consumptions with respective previous ones and clear the reasons for variations. Click the date in the form to move between years or months (in daily graphs). Copy and paste data to excel if needed.



Appendix C: How to use the ECA calculation models (by Simon Wössner IBP)

Introduction:

The Energy Concept Adviser is a new internet based information tool for decision makers and their technical staff that have to decide about refurbishments in educational buildings.

In front of the description there shall be an introduction, why this was developed.

There is often a high consumption of energy in all types of educational buildings like nursery schools, schools and universities. This is because many were built in times when a low energy consumption was not one of the main criteria while planning an educational building. Now many educational buildings are getting refurbished and so there is the opportunity to think about energy efficient refurbishment.

As the energy consumption is influenced by a lot of parameters like the building itself, the occupation, the heating system, ventilation, lighting,... and all these parameters are influencing the others, it is nearly impossible to estimate the potential of energy savings and investment costs of energy efficient measures without any software tools.

The Energy Concept Adviser (ECA) offers a set of tools that help decision makers through the whole process of thinking about refurbishment. It is easy to use and it can be used at all stages without a detailed knowledge of the actual building.

Structure of the Energy Concept Adviser (ECA)

The Energy Concept Adviser offers tools for every stage of the process of a refurbishment.

If there is an existing problem with the building, a possible solution can be found in the '*Problem Related Recommendations*'. There are over 600 possible solutions for more than 25 problems. The solutions are not restricted to a particular building type. It suggests possible solutions to existing problems.

The next step is a huge information database. It deals on the one hand with the description of some representative refurbishments in the '**Case Study Viewer**' and on the other hand with the technologies for refurbishments in the '**Retrofit Measure Viewer**'. All other elements of the Energy Concept Adviser are linked to this information database, so there is always the possibility to get more background information to the current stage.

Up to this stage, it is quite building independent. If we are now interested in how our building performs in comparison to others, the '**Performance Rating**' gives an answer. The consumption of energy (and for some countries also the consumption of

water) is compared to a national stock of buildings. This results in advice as to whether or not it is worth considering of energy efficient refurbishment .

The '**Energy Concept Development**' is a powerful, but easy to use tool that allows us to develop energy efficient retrofit concepts. The different possibilities for refurbishment can be either explored using a common building or a building that fits an existing building. Finally five different concept can be compared regarding the energy relevant values as well as economic calculations.

The last step is the '**Auditing and Monitoring**' of a refurbishment. To help in this there is the software tool called 'KULU' and several reports available.

Recommendations

Solutions for existing problems
eg IAQ, glare, high energy consumption

Case Study Viewer

Collection of exemplary retrofit of educational buildings sorted by country and building type

Retrofit Measure Viewer

Collection and description of retrofit measures

Benchmarking

Comparison of the consumption of your own building with the typical average consumption figures of your country

Retrofit Concept Development

Starting with a building type you are able to analyse different retrofit measures on your own building. You can create different concepts and look at the energy relevant results as well as on the economic calculations

Auditing & Monitoring

Kulu and Auditing reports

Description of the Energy Concept Adviser (ECA)



REDUCE
Retrofitting in Educational Buildings

INTERNATIONAL ENERGY AGENCY

Energy Conservation in Buildings & Community Systems Programme



ENERGY CONCEPT ADVISER
for Technical Retrofit Measures

country-specific data:



On the first page, the relevant country gets selected. There is no difference in the tools offered only the data behind is country-specific.

By clicking on a country's flag a short introduction into the ECA is shown and the next screen is the main menu of the Energy Concept Adviser.



REDUCE
Retrofitting in Educational Buildings



ENERGY CONCEPT ADVISER
for Technical Retrofit Measures

obtain recommendations for specific problems in your building	Recommendations
study more than 30 retrofitted buildings and retrofit measures	Case Studies & Retrofit Measures
compare your building's consumption to national data	Performance Rating
develop an energy efficient retrofit concept for your building	Retrofit Concept
programs and methods to analyse your building performance	Utilities
any questions	Info & Contact

Problem related recommendations:



Problem Related Recommendation



General Information

This knowledge based list of recommended measures may fit only partly to your building. Select your problem in the left column and in the right column it is possible to group the measures in main groups. Select the useful measures manually and read detailed description in the lower part.

Select the existing problem

General Problems

- Heating energy consumption is high
- Electrical energy consumption is high
- Water consumption is high
- Indoor air quality problems

Specific Problems

- Building envelope not airtight
- Humidity or moisture problems
- Windows need replacement
- Roof covering needs replacing
- Heating controls need upgrading
- Pipework needs replacing
- Boiler or burner needs replacement
- Building fabric insulation is poor
- Pipework needs insulating
- Ventilation uncomfortable due to draughts
- Heating inadequate in winter rooms too cold

Group measures by

No grouping

Possible measures

- Close off open chimneys to prevent ventilation losses an...**
 Payback time: **Very short Term (less than two years)**
- Close off unused air grilles behind radiators.**
 Payback time: **Very short Term (less than two years)**
- Weather strip windows and doors and seal gaps in buildi...**
 Payback time: **Very short Term (less than two years)**
- Install manual swimming pool cover.**
 Payback time: **Very short Term (less than two years)**
- Replace existing gas or oil-fired boilers with condensing...**

The interface to the problem related recommendations' database has on the left hand side the list of available problems. They are sorted by main problems and then more specific problems. The possible solutions are listed on the right hand side. They can also be grouped by energy technologies so that the list offered is more specific. The solutions are sorted by their payback time; first there are the solutions with the lowest payback time and then increasing.

Select the existing problem

General Problems

- Heating energy consumption is high
- Electrical energy consumption is high
- Water consumption is high
- Indoor air quality problems

Specific Problems

- Building envelope not airtight
- Humidity or moisture problems
- Windows need replacement
- Roof covering needs replacing
- Heating controls need upgrading
- Pipework needs replacing
- Boiler or burner needs replacement
- Building fabric insulation is poor
- Pipework needs insulating
- Ventilation uncomfortable due to draughts
- Heating inadequate in winter; rooms too cold

Group measures by

No grouping

No grouping

Building envelope

Heating systems

Ventilation systems

Lighting and electrical appliances

Management

Weather strip windows and doors and seal gaps in buildi...

Payback time: **Very short Term (less than two years)**

Install manual swimming pool cover.

Payback time: **Very short Term (less than two years)**

Replace existing gas or oil-fired boilers with condensing...

Payback time: **Very short Term (less than two years)**

Active management of controls

Payback time: **Very short Term (less than two years)**

Selected Measure

Replace existing gas or oil-fired boilers with condensing boilers

Payback-time:
Very short Term (less than two years)

Low temperature of pool water enables boilers to operate in most efficient condensing mode

Best carried out when plant needs replacing

Below that selection part, a more specific description of the selected solution is shown with the information when it is carried out best.

Selected Measure

Replace existing gas or oil-fired boilers with condensing boilers

Payback-time:
Very short Term (less than two years)

Low temperature of pool water enables boilers to operate in most efficient condensing mode

Best carried out when plant needs replacing

Related Information

Retrofit Measure Viewer



[Heating systems - Heating installations](#)

Case Study Viewer



[Exemplary Retrofitting of a School \(EROS\) in Stuttgart, Germany](#)



[A Retrofitting for Energy Conservation including Atria: The Bertolt-Brecht-School in Dres](#)



[Louise Labe, secondary school Lyon, France](#)

Then at least as already mentioned there is the link to the information database. If this solution is described in the 'Retrofit Measure Viewer' or is applied in a case study, the corresponding link is shown below the detailed description.

Case Studies & Retrofit Measures:

The interface to the information database is organised as a matrix of case studies and retrofit measures.

		Case Studies & Retrofit Measures						
Sorting of: Case Studies by <input type="text" value="country"/>								
Retrofit Measures by <input type="text" value="Energy technologies"/>								
Country	 Retrofit Measures	 Case Studies						
			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
			<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
			<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
			<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

To the right the different retrofit measures are listed and downwards the available case studies. There are different sorting criteria, so that different points of interest are possible. A red tick mark indicates if a retrofit measure is applied in a case study or in which case studies a retrofit measure was applied.



Case Studies & Retrofit Measures

Sorting of:

Case Studies by age

Retrofit Measures by country
age
typology

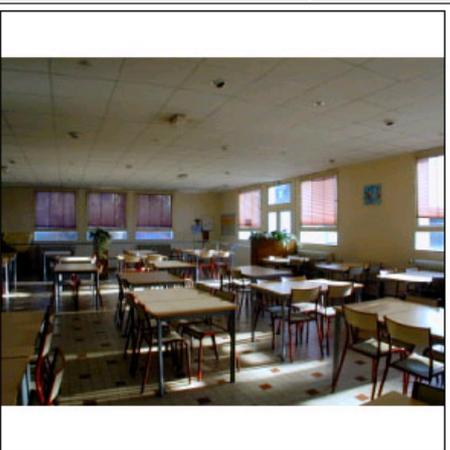
Country	Retrofit Measures ↓ Case Studies	Building Envelope			
		Windows	Insulation materials & systems	Over-cladding systems	Doors
Pre 1930					
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
1930-1950					
		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

The case studies can be sorted by their country, their age or their typology. The different retrofit measure chapters can be sorted by the energy technologies. If an energy technology is selected, the matrix shows, which sub items of this energy technology are described and where they have been applied.

By clicking on a picture the **'Case Study Viewer'** opens in a separate window.

	Case Study Viewer	Gambetta professionnel high school Bourgoin Jallieu, France	Download of REPORT as PDF													
<p>General Data</p> <p>Site, Typology</p> <p>Before Retrofit</p> <p>Retrofit Concept</p> <p>Energy Savings</p> <p>User Evaluation</p> <p>Renovation Costs</p> <p>Lessons Learned</p> <p>Additional Information</p>	<p>General Data</p> <table border="1"> <tr> <td>Address of project</td> <td>Lycée Gambetta 14, avenue Gambetta 38003 Bourgoin Jallieu France</td> </tr> <tr> <td>Year of construction</td> <td>1930</td> </tr> <tr> <td>Year of renovation</td> <td>1993-1995</td> </tr> <tr> <td>Total floor area</td> <td>9213 m²</td> </tr> <tr> <td>Number of pupils</td> <td>520-540</td> </tr> <tr> <td>Numer of classrooms</td> <td></td> </tr> <tr> <td>Typical classroom</td> <td>35-50 m² 26-28 pupils</td> </tr> </table> <p>Project Summary The project aimed to adapt and refurbish the existing building and add an extension in order to give a more functional school building.</p> <p>Retrofit features</p> <ul style="list-style-type: none"> -vertical wall insulation -double-glazed windows -oil boilers converted to gas available on site -renovated electric and lighting systems -mechanical ventilation -building management system 	Address of project	Lycée Gambetta 14, avenue Gambetta 38003 Bourgoin Jallieu France	Year of construction	1930	Year of renovation	1993-1995	Total floor area	9213 m ²	Number of pupils	520-540	Numer of classrooms		Typical classroom	35-50 m ² 26-28 pupils	 <p>View of the building</p>
Address of project	Lycée Gambetta 14, avenue Gambetta 38003 Bourgoin Jallieu France															
Year of construction	1930															
Year of renovation	1993-1995															
Total floor area	9213 m ²															
Number of pupils	520-540															
Numer of classrooms																
Typical classroom	35-50 m ² 26-28 pupils															

All the information on the case studies is organised in the same structure, so that an easy comparison between different case studies is possible. If there is a need for further information the whole chapter of this case study from the Annex 36 report “Subtask B Report” can be downloaded by pushing the button ‘Download of REPORT as PDF’.

	Retrofit Measure Viewer	Solar control and cooling systems	Download of REPORT as PDF
<p>Introduction</p> <p>Shading & glare prot.</p> <p>Cooling systems</p> <p>Air-conditioning</p> <p>Control systems</p>	<p>Shading systems and glare protections</p> <p>To choose a solar control device we need to consider: the site latitude, the orientation of the facade, the orientation of the openings, the aesthetic of the facade, the glazing type of the window, the need for daylight, the solar control devices.</p> <p>The overall thermal and optical performance of a solar control device in respect to solar radiation impinging on it is based on the phenomena: primary transmission, reflected transmission, diffuse transmission, solar absorption.</p> <p>The global shading efficiency of a device is the result of all these direct and indirect transmission processes.</p> <p>Shading devices are also essential to avoid glare situations. If their luminous transmittance is too high, the risk of glare is significant. Several types of shading devices are sufficient to avoid glare from the sky: screens, reflective film, ionised film, sealed blinds.</p> <p>Designers and decision makers must be conscious that the performance of the shading assembly might be different in the actual application conditions</p>	 <p>Shading systems and glare protections</p>	

The ‘Retrofit Measure Viewer’ shows the different energy technologies and their sub items. It is again an abstract from the much more detailed chapter of the Annex36 report “Subtask A Report” and this chapter can be again downloaded by pushing the button ‘Download of REPORT as PDF’.

Performance Rating:

The actual consumption of a building can be compared to a national stock of buildings with the 'Performance Rating'.

		Performance Rating			
Building Information				Reference climate zone: mean climate	
The building is a: educational building(general)		Click here to get further Information about the climate zones			
It has a heated floor area of: 5000,00					
Consumption of electrical energy:			Consumption of heat energy:		
<input type="checkbox"/> Includes heat energy consumption			Energy source: oil		
Unit of the consumption: kWh/m ² a			Unit of the consumption: kWh/m ² a		
Consumption: 56,00			Consumption: 233,00		
Consumption of water:					
Unit of the consumption: l/m ² a			Consumption 174,00		

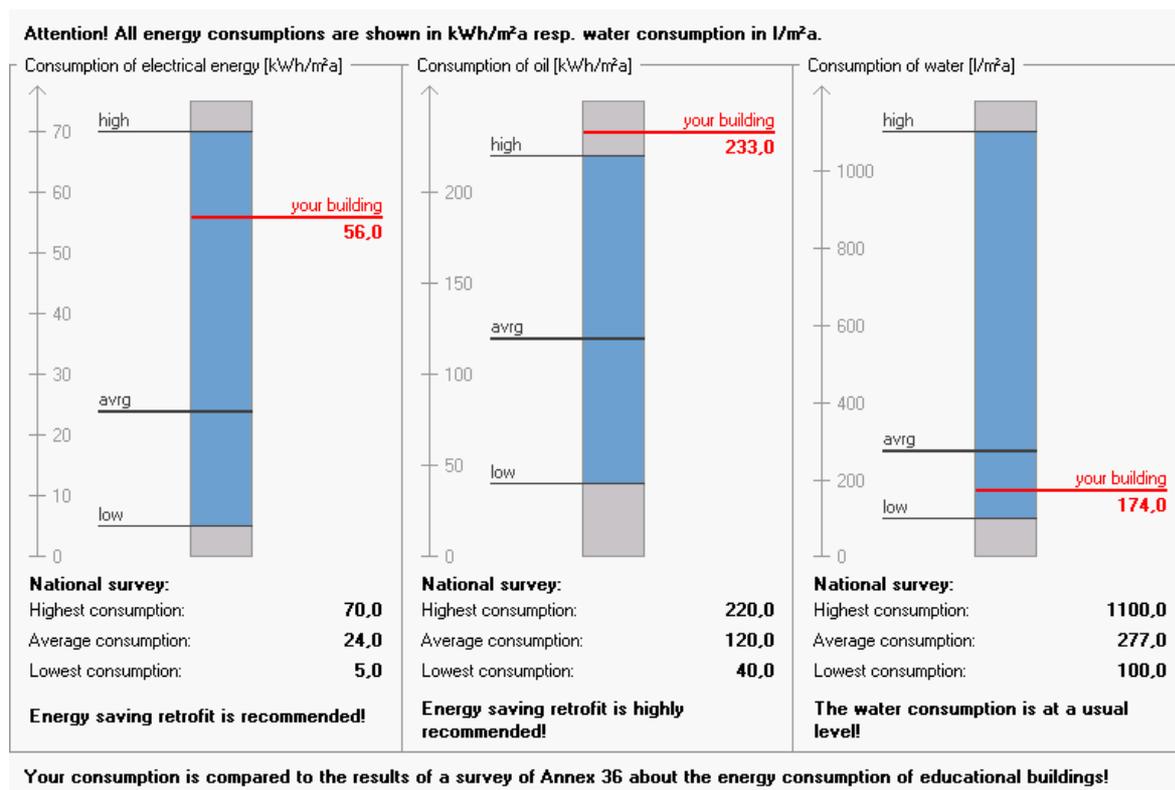
As input are needed:

- the type of building (educational building in general, nursery school, school or university)
- the heated floor area
- the reference climate zone (if more than one available)
- the consumption of electrical energy
- the consumption of heat energy
- if available, the consumption of water

The content might vary from country to country.

Further information on the available climate zones are shown in a separate window by clicking on 'Click here to get further information about the climate zones'.

If the source for the heat energy is electrical energy and there is only one meter available, the option 'Includes heat energy consumption' can be marked. In this case the field for the consumption of heat energy is deactivated and the corresponding diagram disappears. The consumptions can be entered either related to the heated floor area or as absolute values. For the consumption of heat energy this can be entered in unit of the energy source as purchased. The results are always shown as values related to the heated floor area.



The result is shown in diagrams, where the entered consumption is compared to the highest, the average and the lowest consumption of the survey of Annex36 about the energy consumption of educational buildings. There is also information whether energy saving retrofit is (highly) recommended or if it has only a limited potential.

Retrofit Concept:

With this part of the ECA, energy efficient retrofit concepts can be created and compared with each other. The concepts can be created either for a common building or a specific building. The concepts can be compared by energy relevant values as well as economic calculations.

The whole tool is structured in different parts that can be opened and closed by clicking on the '+/-' button or the title bar and specific help relating to each part is available by clicking on the '?' button.

The development part is structured in the sectors listed in the screenshot. A sector can be opened or closed by clicking on its bar. For all information required (values, costs etc) default values from national studies are included, but can be changed individually by the user, so please check the default values for your confidence. If you need help click on ?



General Information	
The development part is structured in the below listed sectors. A sector can be opened or closed by clicking on its bar. For all needed informations (values, costs, etc..) defined values from national studies are deposited, but could be changed individually by the user, so please check the deposited values for your confidence. If you need help, click on ?	
Describe the existing building	? +
Select one retrofit measure for each building element	? +
Create and compare energy saving concept	? +
Summary and Report	? +

The main structure of the ‘Concept Development’ is organised in four parts. First the existing building is described, then a retrofit measure for each part of the building can be defined, then five different retrofit concepts can be created and compared and finally a summary and a report as a PDF-file is available.

Describe the existing building

The building, for which the possibilities for an energy efficient retrofit are to be analysed, is defined in this section. By choosing the basic values a default building is created. This building can be further defied in the lower part of this section

Note: Changes in the ,Further refinement of the building are reset by changing the basic value!

Define key values for a default building

The starting point is the default building. It is defined by a few parameters.

[?](#) -
Describe the existing building

How to use this part

The building, for which the possibilities for a energy efficient should be analysed, is defined in this section.
 By choosing the basic values, a default building is created.
 This building can be further defined in the lower part of this section.
Changes in the 'Further Refinement of the building' are reseted by changing the basic values!

Define key values for a default building

Basic Data

Building Type:

Construction year:

Type of Roof:

Type of basement:

Heated floor area [m²]:

Number of storeys:

Orientation:

Click on diagram to select orientation

Example buildings

Typology:

Click on picture to have a look at the case study!

Primary and Secondary School, Stuttgart-Plieningen, Germany

Consumption of heat energy:

Energy source: **Consumption:**

[?](#) -
Further Refinement of the building

The basic parameters are:

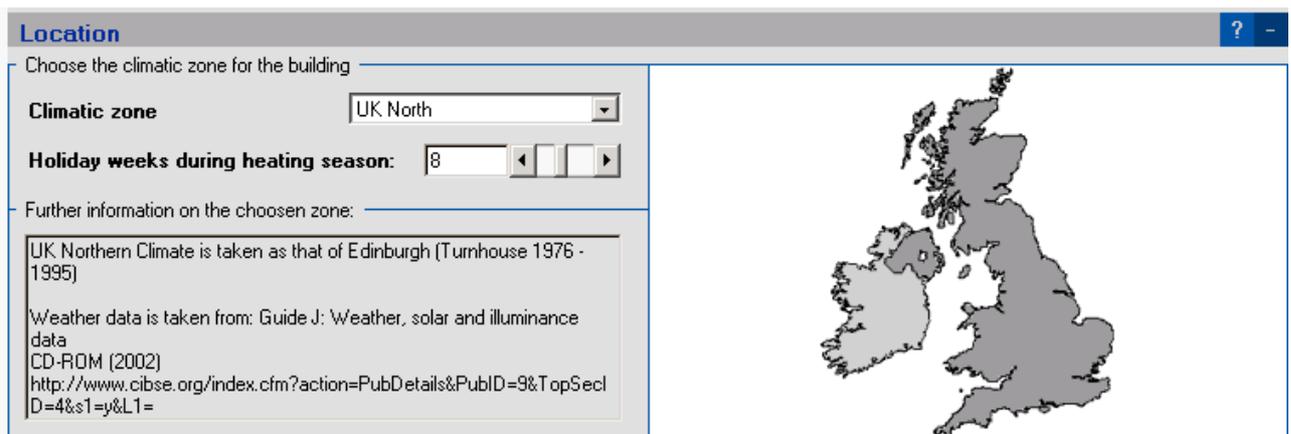
- the building type
- the construction year
- the type of the roof
- the type of the basement
- the heated floor area
- the number of storeys
- and the orientation

Finally the actual consumption should be entered. This information is used for a comparison of the calculated existing building with the real building. If the entered and the calculated consumption are too different, the user is asked to check the input values. On the right hand side, there is again a link to the information database. There are different example buildings available depending on the building typology. The choice 'Typology' is only used for a sorting of the example buildings and has no influence on the default building. By clicking on the picture the '**Case Study Viewer**' is opened with this example building in a separate window.

After the default building is created the development of retrofit concepts can be done. But there is also the possibility to refine the default building to fit it to an existing building.

Further Refinement of the building

Location



Location ? -

Choose the climatic zone for the building

Climatic zone UK North

Holiday weeks during heating season: 8

Further information on the chosen zone:

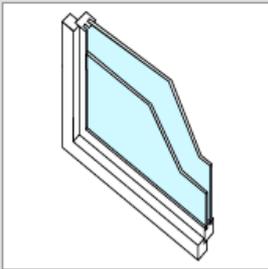
UK Northern Climate is taken as that of Edinburgh (Turnhouse 1976 - 1995)

Weather data is taken from: Guide J: Weather, solar and illuminance data CD-ROM (2002)
<http://www.cibse.org/index.cfm?action=PubDetails&PubID=9&TopSection=4&s1=y&L1=>



If more than one climate zone is available for the selected country, it can be changed in this part. The information on how many holiday weeks are in the heating period between September and March is important if the heating system is operated in the mode 'Holiday setback'.

Geometry and Elements of the Building Envelope

Geometry and Elements of Building Envelope		?	-
Heated volume [m ³]:	33372	Heated floor area [m ²]:	6180
Ratio A/V [m ² /m ³]:	0,32	Area of thermal envelope [m ²]:	10815
Switch through the different envelope elements:			
<input type="button" value=" <"/> <input type="button" value="<<"/> <input type="button" value="external wall"/> <input type="button" value="pitched roof"/> <input type="button" value="ground plate"/> <input type="button" value="window north"/> <input type="button" value="window east"/> <input type="button" value="window south"/> <input type="button" value="window west"/> <input type="button" value=">>"/> <input type="button" value="> "/>			
<input type="button" value="Add element"/> <input type="button" value="Copy this element"/> <input type="button" value="Delete this element"/>			
window			
	Name:	window east	
	Area[m ²]:	194,67	Maintenance Costs: 20,00 €/m ² a
Existing U- / g-Value: 2,4 W/m ² K / 0,78	Structure:	double glazing, wooden or plastic frame, with sealing	
		double glazing, no gas filling, wooden or plastic frame, with sealing	
Shading device:	no shading system		
	Orientation:	east	
	Additional maintenance costs for shading:	0,00 €/m ² a	
<input checked="" type="checkbox"/> This component have to be retrofitted anyway. <input type="radio"/> in a minor refurbishment <input checked="" type="radio"/> in a major refurbishment			

The main geometry is already fixed with the key values, only the gross heated volume can be changed. The gross heated volume is the volume that is enclosed by the heat transfer surface of the building envelope. There are some other geometric values shown, that can't be changed directly. These are heat transferring surface, A/V_e and heated floor area.

In the lower part is the definition of the particular element of the building envelope. These elements are created as default values depending on the building type, the construction year, the type of the roof and the basement, the heated floor area and the orientation of the building. They represent typical constructions and sizes for the building described in the basic input part.

There is an index card for each element. By clicking on the name of an element, it is shown in the lower part. There is the possibility to add new elements and to remove existing elements.

The data are slightly different for transparent and opaque elements as there is for example no shading definition for opaque elements. Everything except the type (external wall, pitched roof, flat roof,...) of the building element can be changed.

The default maintenance costs are country-dependent mean values, that have to be checked carefully to get proper results from the economic calculations.

At the bottom, there is the question if an element of the building envelope has to be retrofitted anyway in a minor or a major refurbishment.

A major refurbishment means a refurbishment, where national regulations eg, for the maximum heat transmission have to be considered. The specific definitions for being a major refurbishment are given in national regulations.

As an example the German definitions for a major refurbishment of an external wall are shown here:

A maximum limit on the heat transmission coefficient of the external wall has to be complied with if:

- a) an external wall is replaced or built for the first time
if it is renewed, the maximum limit has to be complied with if
- b) linings? as boards or board-like elements as well as a curtain wall are applied
- c) on the inner side, linings or boarding is applied
- d) the wall is thermally insulated
- e) the rendering of an existing wall with a heat transmission coefficient of more than $0,9 \text{ W}/(\text{m}^2\text{K})$ is renewed
- f) the infills of half timber framings are replaced

If any of these conditions applies to the refurbishment, the thermal transmission coefficient of the particular external wall must be lower than $0,45 \text{ W}/(\text{m}^2\text{K})$ in cases a), c), f) and $0,35 \text{ W}/(\text{m}^2\text{K})$ in cases b), d), e) for buildings with a normal inside temperature and $0,75 \text{ W}/(\text{m}^2\text{K})$ for buildings with a lower than normal inside temperature.

If there is to be a major refurbishment of an element, the investment costs of all possible retrofit measures for this element are set as marginal costs relative to the defined anyway measure. Anyway measure means a retrofit measure that has to be applied anyway. So there is the possibility to spend some little extra money for a measure with a better energy efficiency, but the additional savings of energy might be worth it.

Heating and ventilation plant

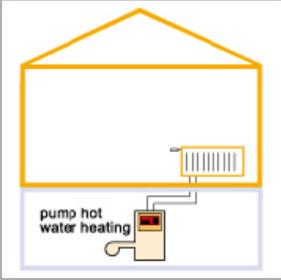
Heating and Ventilation system ? -

Choose the existing plant

The heat energy is generated by:

The type of ventilation is:

Details of selected plant



Detailed description of the chosen plant:

pump hot water heating 90/70 °C, high temperature boiler, thermostatic room regulation, natural ventilation

Maintenance Costs €/m²a

Adjusted setback modes:

Used energy source

This component have to be retrofitted anyway.

The existing heating and ventilation plant can be chosen here. The plant is set as a default depending on the key value '*Construction year*'. There are some plants available and also the energy source for the heating plant can be changed. There is the possibility to choose which type of ventilation there is in the existing building. The default maintenance costs are country dependent mean values, that have to be checked carefully to get proper results from the economic calculations.

The adjusted setback mode of the plant has four possibilities:

no setback	the average temperature is the same as the set-point temperature
night setback	the average temperature is reduced for 7 hours a day to a given temperature, that can differ from country to country. As a default value, it is reduced by 3K to 16°C.
weekend setback	this mode includes the night setback over the weekend. It reduces the temperature on 2 days a week to a given temperature that can differ from country to country. As a default value, it is reduced by 5K to 14°C. The other 5 days a week, the temperature is reduced like the night setback mode.
holiday setback	the temperature is reduced in holiday weeks during the heating season to the value of the weekend setback. In other weeks the weekend-setback mode is applied.

On the bottom line, there is the question whether an element of the building envelope has to be retrofitted anyway in a minor or a major refurbishment. Major retrofit means a refurbishment, where national regulations eg for the maximal heat transmission are given. See also the paragraph 'Geometry and Elements of the Building Envelope' for a further description of a major refurbishment. If there is to be a major refurbishment of an element, the investment costs of all possible retrofit measures for this element are set as marginal costs to a defined anyway measure. Anyway measure means a retrofit measure that has to be applied anyway. So there is the possibility to spend a little extra money for a measure with better energy efficiency, for which the additional savings in energy might be worthwhile.

Lighting

Lighting			
Classrooms			
Fraction of total floor area:	<input type="text" value="75,0"/>	<input type="text" value=""/>	%
Fraction Area window/facade:	<input type="text" value="50,0"/>	<input type="text" value=""/>	%
Mean room depth:	<input type="text" value="7,50"/>	<input type="text" value=""/>	m
Installed System:	<input type="text" value="Incandescent"/>		
Lighting control:	<input type="text" value="Switch with manual control"/>		
Maintenance Costs:	<input type="text" value="2,60"/>	<input type="text" value=""/>	€/m ² a
<input type="checkbox"/> This component have to be retrofitted anyway.			

The electrical energy for lighting is calculated for the classroom-area and the remaining area. Only the lighting installations for the classroom-area can be changed. It is assumed that the remaining area is lighted with half of the power of the classrooms with the same controls installed.

At first the geometric attributes, fraction of classroom-area to heated floor area, the fraction of the window area to the façade area and the mean room depth, have to be defined. Then the installed lighting system and lighting control have to be chosen. Finally the maintenance costs for the existing system have to be entered.

The default maintenance costs are country dependent mean values, that have to be checked carefully to get proper results of the economic calculations.

Cost data

Cost data			
General values			
Inflation rate:	<input type="text" value="2,00"/>	<input type="text" value=""/>	%
Interest rate:	<input type="text" value="5,00"/>	<input type="text" value=""/>	%
Period of analysis:		<input type="text" value="20"/>	years
Energy prices			
Electrical energy	Meter price:	<input type="text" value="95,00"/>	€/a
	Consumption price:	<input type="text" value="11,00"/>	Ct/kWh
Oil	<input type="text" value="0,00"/>	€/a	<input type="text" value="3,00"/>
			Ct/l
Gas	<input type="text" value="15,00"/>	€/a	<input type="text" value="5,00"/>
			Ct/m ³

The values needed for the economic calculation can be adjusted here. First the inflation rate, the interest rate and the period of analysis are defined. They are needed for the calculation of the net- present value and the present value for investment and maintenance.

The energy prices have to be defined for electrical energy and all possible energy sources for the heating plant.

These cost data are country dependent mean values. To get a proper result from the economic calculations, these values have to be checked carefully.

Select one retrofit measure for each building element

Select one retrofit measure for each building element ? -

How to use this part -

This part is for the selection of retrofit measures for each building element, which are going to be retrofitted. The measure with the best cost benefit value is automatically selected. This selection can be changed.

Select a Component: Choose a component and an element, which are going to be retrofitted.

Select a Retrofit Measure: Shows all retrofit measures. Change the chosen measure here by clicking on the checkbox 'Select this measure'.

Overview: Shows the results of the retrofit measures for this element. Each of the measures are calculated related to the unretrofitted building

Select a component +

Select a retrofit measure +

Overview +

This part is for the selection of retrofit measures for each building element. There are various possible retrofit measures for each element of the building. The measure with the best cost benefit value is automatically selected, but of course the selected retrofit measure can be changed. The overview in the lower part shows the effects for each measure, as if only this measure would be applied in comparison to the unretrofitted existing building.

Select a component

Select a component -

Main Group **Element**

Existing Structure

Existing U-Value: **Existing g-Value:**

The lower part of this section shows all the possible measures for a single element. All the elements can be chosen in this part. If another element is selected, the two lower parts show this element.

Select a retrofit measure

Select a retrofit measure			
0	low-e-coated double glazing, plastic frame, with sealing		
improved U-Value:	<input type="text" value="1,70 W/m²K"/>	Investment costs:	<input type="text" value="300,00"/> €/m²
improved g-Value:	<input type="text" value="0,65"/>	Maintenance costs:	<input type="text" value="10,00"/> €/m²a
This is the anyway measure! The costs of the other RM are set to marginal costs to this measure.			
<input checked="" type="radio"/> Select this measure as chosen retrofit measure for this element			
1	exchange of glazing while keeping the old frame, low e-coated double glazing, new sealing		
improved U-Value:	<input type="text" value="1,30 W/m²K"/>	Investment costs:	<input type="text" value="220,00"/> €/m²
improved g-Value:	<input type="text" value="0,65"/>	Maintenance costs:	<input type="text" value="20,00"/> €/m²a
<input type="radio"/> Select this measure as chosen retrofit measure for this element			
2	low-e-coated double glazing, plastic frame, with sealing		
improved U-Value:	<input type="text" value="1,30 W/m²K"/>	Investment costs:	<input type="text" value="320,00"/> €/m²

This part shows the available retrofit measures for the selected element. At first the attributes of the existing element are listed, so that there is the possibility to see the improvements of the retrofit measures. Then all the available measures are listed. By default the measure with the best cost-benefit ratio is selected. Another measure can be selected by pushing the button 'Select this measure as chosen retrofit measure for this element'.

If the element has to be retrofitted in a major refurbishment, the first measure is set as an 'anyway-measure'. That means this measure will be applied anyway. The investment- costs of the other measures are only calculated as marginal costs to the investment costs of this measure.

The investment and maintenance costs can also be changed for every measure. The given costs are recommendations based on national knowledge. To get a proper result from the economic calculations, these costs have to be checked carefully.

A change of the selected measure as well as changes in the cost-values are calculated immediately and the results of the changed values are shown in all parts of the ECA.

Overview

Overview			
Retrofit Measures:	Heat Energy demand:	Extra investment costs:	Cost Benefit Value:
Existing Building	437.0 kWh/m²a		
0 low-e-coated double glazing, plastic frame, with sealing	436.0 kWh/m²a <small>This Measure will be applied anyway. Its investment-costs are 58400 €.</small>	0 €	0,00 €/(kWh/a)
1 exchange of glazing while keeping the old frame, low e-coated double	434.0 kWh/m²a	-15000 €	-1,00 €/(kWh/a)
2 low-e-coated double glazing, plastic frame, with sealing	434.0 kWh/m²a	+3890 €	0,20 €/(kWh/a)
3 low-e-coated double glazing, plastic frame, with sealing	435.0 kWh/m²a	+5840 €	0,50 €/(kWh/a)
4 low-e-coated double glazing,			

The possible energy savings of single measures only applied to the existing building, the total investment costs and the cost benefit ratio (except for shading) are listed in the 'Overview'. This overview helps you to select the best measure.

Create and compare energy saving concepts

Create and compare energy saving concept ? -

How to use this part -

This part is for the creation and comparison of different concepts for an energy efficient retrofitting. There are possibilities for creating five different concepts. After having selected elements for a concept, the different concepts can be compared in the lower part 'Overview'.

Select elements for the different concepts Choose here, which elements shall be retrofitted within a concept

Overview: Look at the results of the different concepts. Different energy and economic values can be displayed.

Select elements for the different concepts +

Overview +

Five different retrofit concepts can be created and compared in this part. There is the possibility to mark elements that should be retrofitted in the refurbishment.

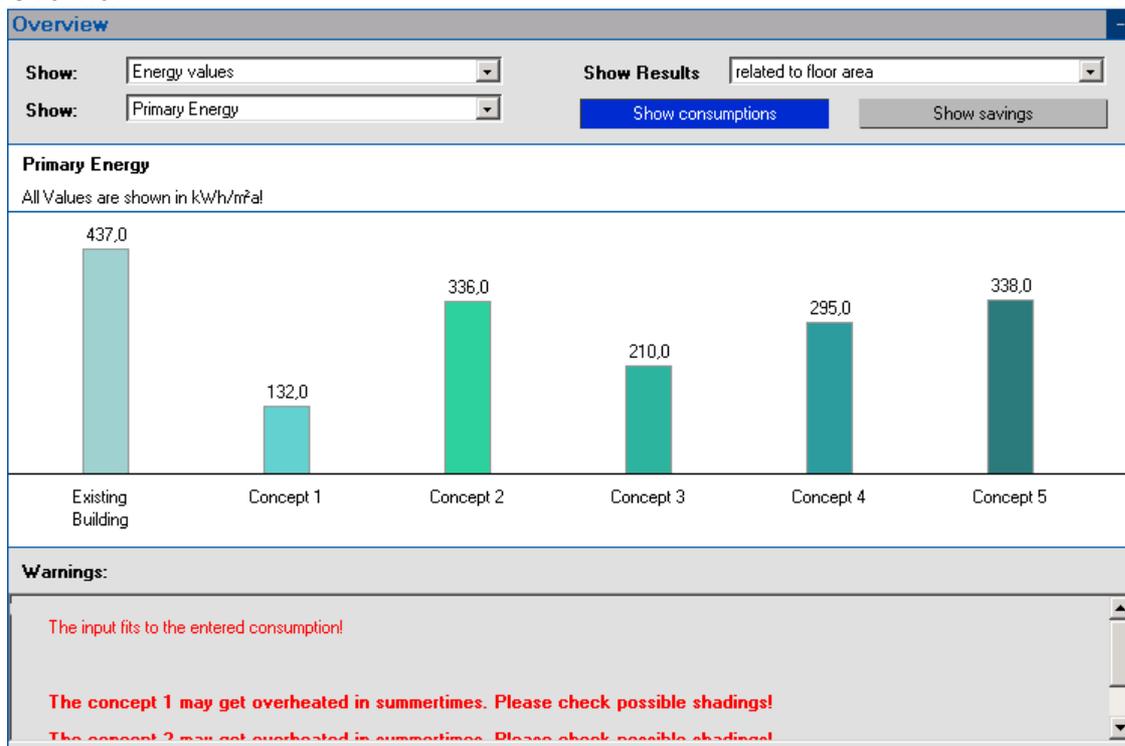
For the selected elements the retrofit measures chosen in the part 'Select one retrofit measure for each building element' are applied, the other elements are calculated with their existing attributes.

Select elements for the different concepts

Element: Chosen retrofit measure:	Concept				
	1	2	3	4	5
pump hot water heating 90/70 °C Add ventilation system (80% recovery)	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
ground plate 4 cm mineral wool, screed/floor	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
lighting source Compact Fluorescent	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
external wall internal insulation with 6 cm polystyrene, vapour barrier and gypsum board	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
lighting control Occupancy sensor	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>
window west The measures are sorted by benefit-cost-value					

In this list all elements are listed. They are sorted by their cost-benefit value, best on top. There is an entry for each element with the name of the element and the name of the selected retrofit measure. There are five check boxes on the right hand side of each entry, one for each retrofit concept. If a check box is marked, the element will be calculated as retrofitted with the selected retrofit measure. If a selection is changed, the calculation is performed immediately and the results are shown in the part 'Overview'.

Overview



This part shows the current results of the calculation of the five different concepts. As soon as something is changed, the calculation is executed and the results are updated. There are various results that can be displayed:

- Energy relevant values
 - o Primary Energy
 - o Final Energy
 - o CO₂- Level
- Economic relevant values
 - o Net present value
 - o Present value – Investment
 - o Present value - Operating costs
 - o Simple payback

The corresponding result for the existing building is also shown for the energy relevant values. Additionally there are some options for how the results are presented. There is the possibility to show consumptions or savings and the values can be displayed as total values, related to the heated volume or related to the heated floor area.

Summary and Report

As a last step there is the possibility to get a summary or a report of the calculation. The summary is a listing of all input values, the selected retrofit measures and the main calculation results. It is intended for a quick check of the calculation and it is shown in a pop-up window. There is no possibility to save or print this summary, as Java (the programming language) doesn't offer this possibility. The report is intended for a handout report of the different concepts. It is sent as a PDF-File via email.

Summary and Report ? -

How to use this part

Two different output will be created in this part.

Summary This is a short summary of the input values and the selected retrofit measures. It is shown in a pop-up window.

Report The report is a comprehensive list of the whole concept including input values and results. It is also possible to include the diagrams into the report. The report can include all concepts or just one selected.
The report will be delivered by e-mail as a pdf document.

Options

Summary

Select a concept:

Report

Show: **show Diagramms**

Enter your Email-address:

Options

A summary of the selected concept is shown by pushing the Button 'Show Summary'.

A report is sent after input of an email-address by pushing the Button 'Show Report'. There is the possibility to choose whether the report shall include all concepts or just one and if there shall be diagrams in it or not.

Utilities:

This part of the Energy Concept Adviser offers a program called KULU (see Appendix B for a description) and all the reports of Annex36 as downloads. These reports are:

- Subtask A report
- Subtask B report
- ...

Info and Contact:

If there are any questions regarding the Energy Concept Adviser or the work of Annex36, a list of all members and their contact information is contained within Appendix F.

Appendix D: Default Values (by Heike Kluttig, IBP)

1. General

The user interface of the Retrofit Concept Development part of the ECA is based on default values. Figure 1 shows an overview on the different steps of the input data and their influence on the default data. The first step into the ECA is a choice for the flag of one of the 10 participating countries at the front page. By that the user decides for a country specific climate and after the finalisation of the working group work following the Annex phase additionally for country specific default values of geometry, constructions, heating systems, costs, etc. Right now most data besides the climate data is based on German default values. So even if you enter the ECA with another country's flag, so far you will get the geometric, the component construction and the cost default data of Germany.

The next step is the base input (Retrofit Concept Development part). Seven different input data for; building type, heated (net) floor area, number of storeys, orientation, type of roof, type of basement and construction year are asked for. The first 4 data will influence the geometric default data of the building. Fraunhofer IBP has prepared a study on characteristic geometric values of 26 German schools. Values like heated (gross) volume, wall area, window area, basement and roof area as well as the whole area of the thermal envelope and therefore the A/V-ratio are defined depending on the building type school, the heated floor area and the number of storeys. So by using only three definitions, the other values are calculated as default values, but can be changed by the user. The orientation input defines the distribution of the window area. The values that are used by the tool, if nothing is changed by the user, are given in blue in figure 1. The user should refine the values according to their own case study, may also add additional building elements, but may also start calculating with the default values if no specific information is available.

The last 3 data (type of roof, type of basement and construction year) have influence on the default construction types for each envelope element. The programme proposes a construction type for the wall, windows, roof and basement that fits to the type and the age of the building. Here the user has again to decide if he wants to adapt the original values to his defined building (if he has the necessary information), by using one of the additionally offered construction types. All construction types, their U-values and maintenance costs are based on the database of Fraunhofer-IBP.

The construction year also defines the default value for the heating and ventilation system. The data is divided into heating system (like eg pumped hot water heating with 90/70°C temperature split), ventilation system (naturally or mechanically ventilated), the setback mode of the system and the energy source used. The typology and efficiency values were developed by IKE, the costs are based on a database from IBP, confirmed by IKE. The user may again overwrite all values.

In case of the lighting system, all data refer only to the classrooms. So besides default data on the currently installed lighting systems additional geometrical default data like the ratio of classroom floor area to total floor area and window area to total façade area and the mean room depth for all classrooms is used. This data was provided by ENTPE.

For all constructions, heating and ventilation systems and lighting systems maintenance costs are given as a default value, too, but can be updated by the user. The database for the maintenance cost was made available by IBP for the constructions and the heating and ventilation systems and by ENTPE for the lighting systems. Both institutions have a long experience with the realisation of such constructions and systems. The values for the fuel costs were provided by IKE, the economy factors like the interest rates, the inflation factor, etc. are based on the knowledge of the University of Poznan.

The final step of the default value usage is the retrofit measure input. Different improvement possibilities for the building envelope constructions, the heating and ventilation systems and the lighting systems are available including default values for maintenance and investment costs. The programme calculates for each retrofit measure the energy savings and the costs. If the user wants to use his own cost data he may of course do so. Again the retrofit measures were provided by Fraunhofer-IBP (building elements), IKE (heating and ventilation system) and ENTPE (lighting systems) with the cost data from experiences at IBP and ENTPE (lighting). Figure 2 gives an overview on the investment cost data for component constructions gained at many realised projects during the last 10 years.

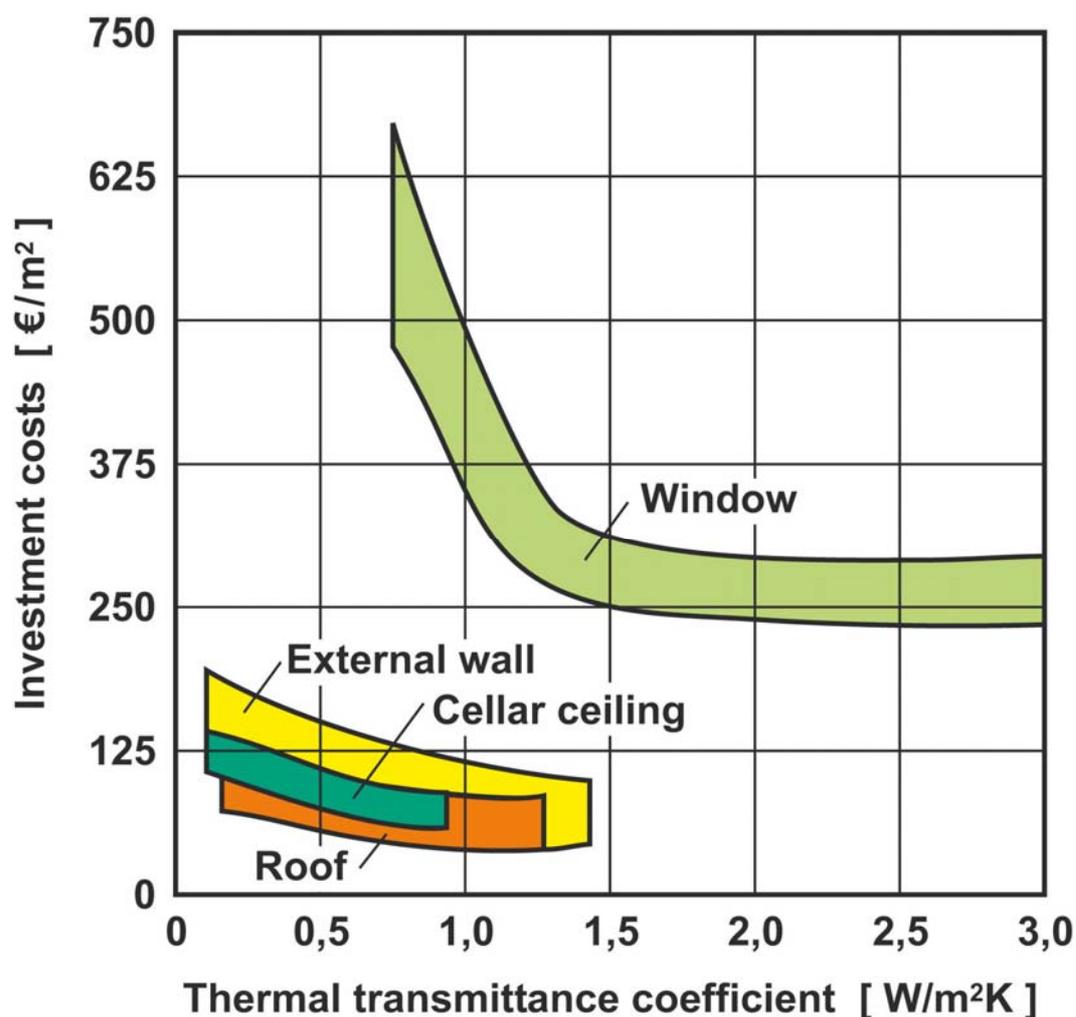


Figure 2: Experienced building investment costs gained over the last 10 years in project with collaboration with IBP, cost base date is 2003.

2. Study on characteristic geometric values of 26 German schools

Based on a diploma thesis [1], IBP has made a study to find out what characteristic values represent the geometrical data of schools. Table 1 contains the base data like gross and net floor area, amount of storeys, the wall, window, roof and cellar ceiling areas, etc. These numbers are the background of the geometric default data, starting with the average heated net floor area of 5802 m². Contrary to the study, the group has decided to use the net floor area as the starting value, not the gross floor area, since that is a value the decision makers at administrations should know, because the invoices of the cleaning companies, etc are related to that.

That meant that in the ECA all default data has to be factored with the ratio of net floor area to gross floor area, which averaged to 0,86. All evaluations in the study were related to the gross floor area. The first evaluation dealt with the average ratio of the gross volume to the gross floor area. The result is shown in figure 3. The average gross storey height of the 26 schools is exactly 4,0 m. The Annex group decided also to use only 3 instead of the average 4 storeys of the study for the default value because most countries felt more comfortable with that number.

Gross storey height

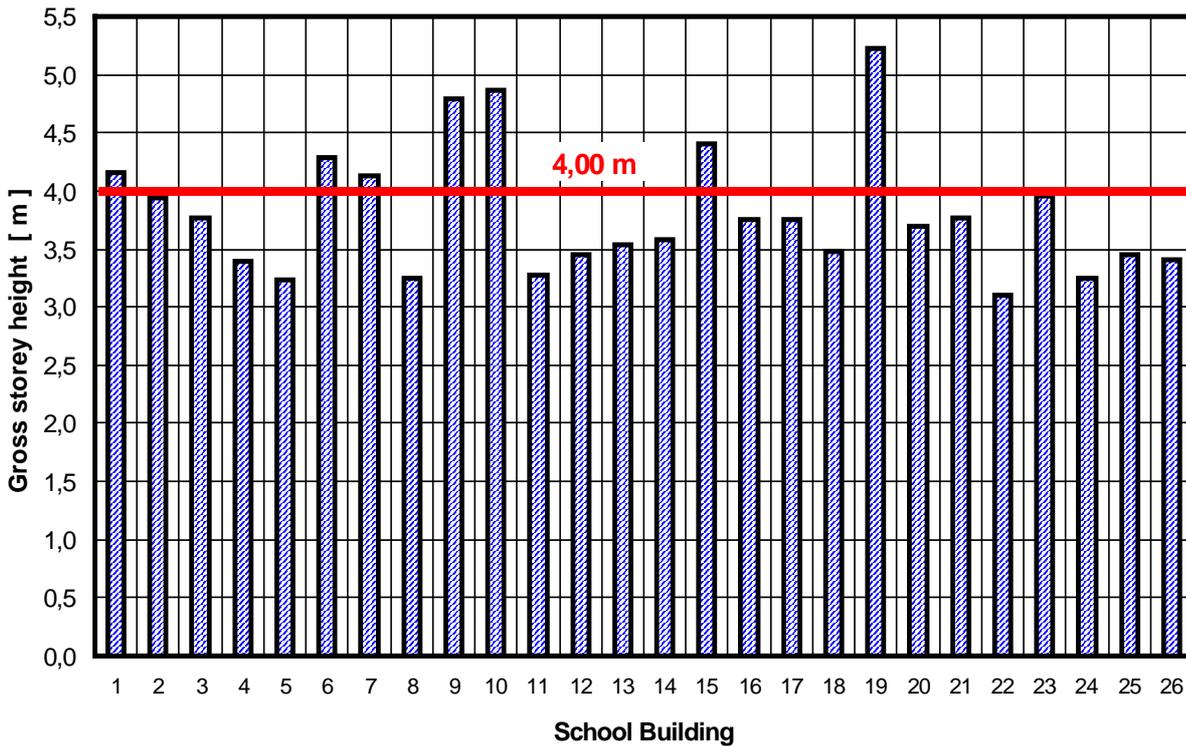


Figure 3: Average gross storey height of the 26 German schools.

For the default data in the Retrofit Concept Development part of the ECA, characteristic values for the envelope area types were needed. It was found out that for the walls and windows there was a rather good correlation with the gross floor area (see figures 4 and 5). The average ratio of the external wall area to the gross floor area is 0,52 m²/m² and of the window area to the gross floor area is 0,23 m²/m².

The ratios of the roof and cellar ceiling area to the gross floor areas are a lot more diverse. Therefore it was decided to group them according to the number of storeys as shown in table 2. As expected the ratio of the roof area to the gross floor area is decreasing with higher numbers of storeys. For two and three-storey buildings the average ratio amounts to 0,41 m²/m², for four and five-storey buildings to 0,26 m²/m² and for six-storey buildings to 0,15 m²/m². The same is true for the cellar ceiling or basement slab with values of 0,38 m²/m² (2-3 storey buildings), 0,24 m²/m² (4-5 storey buildings) and 0,15 m²/m² (6 storey buildings).

External wall through gross floor area

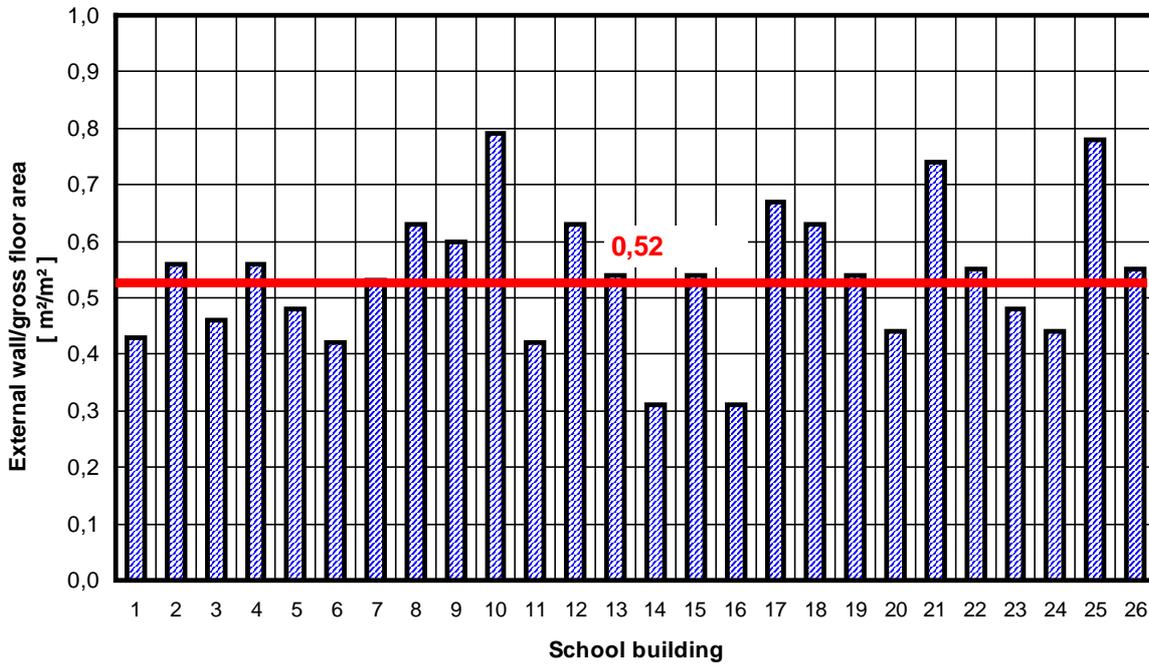


Figure 4: Average ratio of external wall area to the gross floor area of the 26 German schools.

Window area through gross floor area

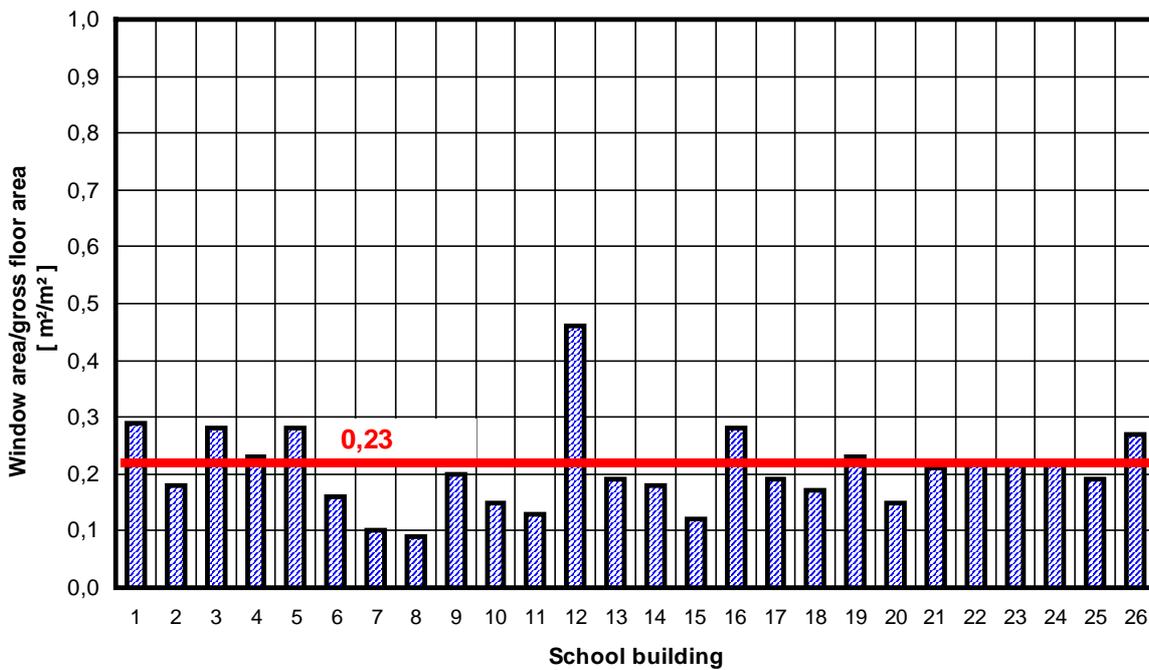


Figure 5: Average ratio of window area to the gross floor area of the 26 German schools.

Table 2: Roof and cellar ceiling area depending on a factor of the gross floor area for the 26 German school buildings.

School building	Gross floor area	External wall area	Window area	Roof/ top floor area	Cellar ceiling area	Number of storeys	Roof area/gross floor area		Cellar ceiling area/gross floor area			
	m ²						m ²	2 and 3 storey buildings	6 storey buildings	2 and 3 storey buildings	6 storey buildings	
1	5259	2254	1505	1225	1624	4		0,23			0,31	
2	6180	3445	1087	2538	2404	3	0,41		0,39			
3	8025	3699	2214	2917	2917	3	0,36		0,36			
4	4325	2425	979	967	967	5		0,22			0,22	
5	4326	2064	1215	865	865	5		0,20			0,20	
6	2899	1220	467	1185	1185	3	0,41		0,41			
7	4373	2308	451	860	864	4		0,20			0,20	
8	2310	1452	210	745	565	4		0,32			0,24	
9	6152	3705	1227	1600	1503	5		0,26			0,24	
10	4536	3603	673	1207	1210	4		0,27			0,27	
11	4412	1835	555	1090	811	5		0,25			0,18	
12	19201	12077	8814	9627	6326	2	0,50		0,33			
13	3259	1766	625	1000	901	3	0,31		0,28			
14	5936	1844	1059	804	806	6				0,14		
15	11900	6457	1441	4321	4308	3	0,36		0,36			
16	24694	7756	6954	3901	3901	6				0,16		
17	5430	3613	1015	2722	2490	3	0,50		0,46			
18	7877	4968	1304	3273	3117	3	0,42		0,40			
19	5131	2776	1168	2116	2117	2	0,41		0,41			
20	8548	3795	1240	3193	3041	2	0,37		0,36			
21	7126	5241	1523	3100	2866	3	0,44		0,40			
22	6900	3795	1510	2355	1920	5		0,34			0,28	
23	1930	921	431	643	460	4		0,33			0,24	
24	5005	2200	1100	1120	1290	5		0,22			0,26	
25	5464	4265	1028	1535	1136	4		0,28			0,21	
26	4283	2362	1159	971	956	5		0,23			0,22	
Average	6749	3533	1575	2149	1944	4	0,41	0,26	0,38	0,15	0,24	0,15

The study showed that it is possible to define rough default values by simply using the floor area and the number of storeys. The computer calculates the default volume and the default thermal envelope areas with the help of the analysed ratios.

A second analysis was carried out to try to find specific values for the different school types defined in the case study report of Annex 36 [2]. However, the amount of school buildings that could be divided into the different types is rather small, so that for some types no cases could be found and for others only a few. Most of the case study school buildings represent the side corridor or central corridor schools. A relation between the school type and the different ratios could not be found.

Reference

- [1] Blaha, A.: Analyse vorhandener Gebäude-, Energie- und Kostendaten sanierter Schulen als Grundlage typologischer Kosten-/Potentialabschätzungen für Schulsanierungen mit Handlungsempfehlungen. Diplomthesis at the Fraunhofer Institute of Building Physics, Stuttgart, Germany (2001).

- [2] Mørck, O. (editor): IEA ECBCS Annex 36: Retrofitting of Educational Buildings – REDUCE. Energy Concept Adviser for Technical Retrofit Measures: Case Study Reports. ECBCS Bookshop, Birmingham, United Kingdom (September 2003).

Appendix E: Description of Buildings in MOSES Project (by Fritz Schmidt IKE)

Building 1					
General Values:		<i>Type</i>	Side corridor	<i>Constr. year</i>	1936
		<i>roof</i>	unheated	<i>basement</i>	Cellar ceiling
A_n	2090	<i>orientation</i>	NW	<i>window</i>	Double glaz.
heated vol	9621			<i>Year boiler</i>	1969/1992
Number of storeys	3				
Building Envelope					
name	area	U before retrofit	g before retrofit	U after retrofit	g after retrofit
external wall	1138	1.5	-	0.25	-
roof	1338	2	-	0.18	-
groundplate	1301	2.1	-	2.1	-
window north	111	3.2	0.78	1.1	0.58
window east	48	3.2	0.78	1.1	0.58
windows south	111	3.2	0.78	1.1	0.58
window west	48	3.2	0.78	1.1	0.58
A_{surface}	4095				
		Before retrofit		After retrofit	
Plant	Steam Heating HVRM 2				
Demand		1.64			
ECA Demand		145			
Efficiency Nr.		1.53		1.41	
ECA Efficiency Nr.		1.7			
Consumption		250		36 - 43	
ECA Consumption		247			

Building 2					
General Values:		<i>Type</i>	Side corridor	<i>Constr. year</i>	1957
		<i>roof</i>	unheated	<i>basement</i>	Cellar ceiling
A_n	1110	<i>orientation</i>	NW	<i>window</i>	Double glaz.
heated vol	4532			<i>Year boiler</i>	1969/1992
Number of storeys	2				
Building Envelope					
name	area	U before retrofit	g before retrofit	U after retrofit	g after retrofit
external wall	714	1.73	-	0.25	-
roof	493	0.9	-	0.18	-
groundplate	390	2.35	-	2.35	-
window north	80	3.5	0.78	1.4	0.58
window east	42	3.5	0.78	1.4	0.58
windows south	80	3.5	0.78	1.4	0.58
window west	42	3.5	0.78	1.4	0.58
A_{surface}	1981				
		Before retrofit		After retrofit	
Plant	Steam Heating HVRM 1				
Demand		137		35	
ECA Demand					
Efficiency Nr.		1.53		1.22	
ECA Efficiency Nr.					
Consumption		210		40-45	
ECA Consumption					

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