IGE Institut für GebäudeEnergetik

Expert system for identification and definition of low investive measures to reduce energy consumption and polluting emissions – EXECO2

Abstract

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1 Introduction

In Germany, the operation of buildings consumes almost 40% of the final energy consumption; the same rate applies to Europe. Therefore, measures are necessary to reduce the energy consumption of existing buildings, such as the 20-20-20 objective agreed at European level. By 2020, the 20-20-20 objectives envisage reducing the greenhouse gas emissions by 20% and increasing both the rate of renewables energies in Europe as well as the energy efficiency by 20%. All measures or legal regulations concerning new build houses and the energetic refurbishment may have only medium-term or long-term impacts, because the annual rate of new build houses and energetic refurbishment is in each case only 1%. For this reason possibilities must be found for reducing the energy consumption in short-term. One possibility is to tap saving potential in optimising operations of technical building services.

The experience from studies carried out so far [1], [2] shows that the energy consumption during the operation of buildings could be cut by 30% in short term by means of measures with low investment costs. These measures taken for improving the operation of buildings affect the heating and ventilation systems, the domestic water heating, the cooling, the lightning and their measuring and control technology.

The aim of this research project is providing instructions for an expert system which allows tapping low investment-related energy saving potentials. This expert system will enable the responsible staff to become familiar with the building and their installations and to identify independently the low investment-related energy saving potentials.

The instructions contain not only technical measures, but also organizing and strategic measures. This is important because the uncovering of the energy saving potentials fails often due to organisational and strategic hurdles. The expert system shall be especially deployed in administration and commercial properties because above all the organisational measures can be transferred only to a limited extend to residential construction.

2 State of scientific research

The studies or the instructions carried out until now in this area have been strongly adapted for each property and limited on individual disciplines or fixed on another phase of the life cycle of a building (e.g. conception and planning) and not on the operation. The expert system worked out is a manual for identification of low investment-related energy saving potentials regarding the phase of the building operation and the different disciplines.

3 Measures catalogue and literature research

In the first step, a catalogue of eventual energy saving potentials based on a literature research is compiled. Both research activities and proceedings by own and third party and manufacturer's documentations, standards and guidelines are regarded. In addition, the energy saving requirements according to the German Energy Saving Ordinance EnEV and the European „Energy Performance of Building Directive" (Richtlinie 2002/91/EG) [7] with all related standards are considered. In the following, the evaluated literature will be outlined.

3.1 Standards and guidelines for inspection

In connection with the directive EPBD, various European standards that deal with the inspection of different disciplines were worked out.
These are the following standards:

- DIN EN 15239 Inspection of ventilation systems [8]
- DIN EN 15240 Inspection of air conditioning systems [9]
- DIN EN 15378 Inspection of boilers and heating systems [10]

These standards contain information about:

- Required documents
- Frequency of inspection
- Contents of inspection
- Evaluation

But just a single disciplines has been treated. The information is mostly vague and for details these standards refer to national guidelines. Concrete instructions of how to identify saving potentials for different installation types are missing.

Beside these standards, there are a few worksheets from the German Machine and Plant Engineering Association (VDMA) for the maintenance of ventilation technology, heating technology, refrigeration engineering and measuring and control technology and several worksheets dealing in more detail with refrigerating machines and plants.

- VDMA 24186-1: 09-2002: Performance programme maintenance ventilation technology
- VDMA 24186-2: 01-2007: Performance programme maintenance heating technology
- VDMA 24186-3: 09-2002: Performance programme maintenance refrigeration engineering
- VDMA 24186-4: 09-2002: Performance programme maintenance measuring and control technology

These work sheets are pure check lists for the maintenance of the installations; the building operation is not included. The measures given from VDMA data sheets are only regarded if they have influence on the energy consumption of the appropriate installation.

3.2 Research reports

In addition to the relevant standardisation, more literature will be analysed. In this field, the following research projects have been executed at the Institute (IGE) and considered for evaluation:

- Schmidt, M. Arold, J.: Untersuchung zur Erschließung niedrig investiver Energieeinsparpotenziale [3]
- Schmidt, F. Stergiaropoulos, K. et. al.: REUSE - Rational Use of Energy at the University of Stuttgart Building Environment [2]
- Grob, R. Schmidt, M. Harter, J., Bach, H.: COURAGE - Computergestützte Überprüfung von bestehenden heiz- und raumlufttechnischen Anlagen
- Grob, R. Kopetzky, R. Schmidt, F.: WIMA - Wissensbasiertes Energiemanagement-eine neue Dienstleistung für mittelständische Unternehmen
- Schmidt, M. Stergiaropoulos, K.: EMSLE - Energie Management System für die Stadt Leinfelden-Echterdingen
- Schmidt, M.; Stergiaropoulos, K.; Schmidt, F.: CAMPUS - Energie- und Gebäudemanagement im Campus Pfaffenwald und seine Auswirkungen auf die Effizienz der Energieerzeugung [1]

Both, own research activities and experiences from other research projects such as the guidelines and reports to the energetic inspection of ventilation systems from the Fachinstitut Gebäude-Klima e.V. (FGK) according to § 12 of the German Energy Saving Ordinance (EnEV) have been included.

The housing company in Mannheim GBG attaches great importance to an energy-efficient operation of their heating installations. An important basis is the hydraulic balance of the heating installation which in practice has been executed insufficiently or mostly not all. The housing company GBG has gained a wealth of experience in this field.

Own experiences and literature sources lead to a collection of measures which are worked in the expert system. The expert system is described detailed in the following chapter.

4 Presentation facilities of the expert system

Based on the methods of Industrial Engineering the options of presenting the expert system have been tested and selected. The organization chart and the flow chart are documentation techniques which are adequate forms. The check list is the most appropriate method for analyse. In the following, the different possibilities are amplified.

4.1 Techniques of documentation

The techniques of documentation are suited for the presentation of procedures, especially of complex cycles. There are 3 types of documentation structures:

- Written description (words)
- Correlograms (connections between elements)
- Process mappings (processes in logical sequences)

In practice, these 3 types are combined.

4.1.1 Organization chart

The organogram displays in hierarchical structures. A hierarchy is typically visualized as a pyramid. The guiding theme is illustrated on the 1st level. Other levels are superordinated or subordinated.

4.1.2 Flow chart

Contrary to the organogram, the flow chart consists of branches, combinations, dependencies and feed backs. Flow charts are suitable for the presentation of logical and temporal process sequences and the dependencies.

4.2 Analysis techniques

Analysis techniques are used for basis for critical consideration on the actual situation. Deviations, weak points and faults are revealed and solution possibilities are shown by including the present situation.

4.2.1 Check list

Check lists are used for organisation and routine problems. Well-targeted questions can initiate thinking processes and the elaborate problem-solving approaches. All different and important aspects of a problem can be presented in the check list. The look of the check lists is not specified. Each check list can be adapted for the individual application.

The check list appears for the expert system as a suitable form. Further elaborations of the expert system refer to it.

5 Structure of the expert system

The expert system is adaptable to buildings with different technical equipment. The partition of the system is the following:

- Building,
- Heating,
- Ventilation,
- Cooling and
- Lightening.

For each part there are

- check lists,
- overview lists and
- an annex

according to the requirements. The annex for the different disciplines is certainly combined to one document, a kind of additional booklet.

5.1 Check lists

In the check lists different questions are posed and provided with instructions. These check lists are used to analyse individual subsystems such as heating circuits, HVAC systems etc. Here, the records of the actual state and the technical equipment as well as the evaluation of the operation are made.
There are different question types with various contents in the check lists. Below are some of the most used question types. If it seems appropriate to diverge from this style in individual instances, the appearance has been thus adapted. Table 5-1 shows an exemplar of the check lists.

Table 5-1: Exemplar of the used check lists

			Yes	No
CL Type 1	Are settings for the hydraulic balance possible?		☐	☐
CL Type 2	**Stairwells** a) ☐ internal b) ☐ external			
CL Type 3	Description of the ventilation zone:			
			Value	
CL Type 4	What is the heating load in the room?		kW	
Instruction 1	**Instruction:**			

Instruction 2	**Instruction for the user:**
instructions 3	**Modification recommendation**:
Instructions 4	**Organizational information:**

- CL Type 1: Here, questions are posed which must be answered with yes or no. Because it was not possible to formulate all questions in the way to put only a checkmark, this type was selected.
- CL Type 2: This type is used if a number of options exist. The additional number system (a) and (b) serves later for addressing. By selecting “external”, later can be referred to “CL Type 2b).
- CL Type 3: This type allows querying questions with extensive responses.
- CL Type 4: Numerical values, real values and set points can be checked by this type.
- Instructions 1: Explanations how the information is to interpret.
- Instructions 2: Information intended for the user of the building.
- Instructions 3: If the investigation shows that the equipment is not state-of-the-art, then recommendations of what should be respected by taking replacement investment are provided at this place.
- Instructions 4: The organizational information includes measures on which the house management and the technical service can react.

5.2 Overview lists

The lists fulfil several tasks. They are used as an overview of the building and installation situation as well as a documentation of the modification. They are only be used when very many details (e.g. in case of the room by room consideration of the benefit transfer) must be investigated. Table 5-2 shows as an example an overview list from the part „building“ of which the parts of the building correspondent with the appropriate systems and supply circuits.

Table 5-2: Example for an overview list of the use in individual use zones (building)

Pos.	Use zone	Type of Utilization	Modification of the utilization?	Change in the building envelope?	Set point /Actual value $\vartheta_{Ra,Heiz}$	Set point /Actual value $\vartheta_{Ra,Kühl}$
1					°C/ °C	°C/ °C
2					°C/ °C	°C/ °C

5.3 Annex

Most extensive information and instructions which may break up the text flow of the check lists appear therefore in the annex. The references to the sources of third parties are also transferred into the annex. These sources include e.g. the German Energy Saving Ordinance (EnEV) [6] and different standards such as DIN EN 15251 [7] and DIN EN 13779 [8]. If

something is changing in those sources, it is sufficient to modify the annex, without having to intervene in the check lists

6 Summary

Within the framework of the project a manual which is overlapping all disciplines was developed to facilitate the discovery of low-invest energy saving potentials: the expert system. The structure of the expert systems is designed so that the potential users can accept it. The expert system is only effective if the user makes use of it and doesn't give up in frustration. For this reason the idea building up the expert system as a flow chart was rejected and a check list was chosen instead. The catalogue with low-invest energy saving measures was based on the experiences gained by the Institute and other bodies. Furthermore, the requirements on the energetic inspection of the EnEV (German Energy Saving Ordinance) and the directive EPBD were respected. A first test run with the operating staff from a real building showed that such test runs were given new impulses from practice which could be used to ameliorate particularly the user-friendly application. Therefore, it seems useful to examine and to further adopt the expert system in a longer testing phase.

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