EINSTEIN – EXPERT SYSTEM FOR AN INTELLIGENT SUPPLY OF THERMAL ENERGY IN INDUSTRY - AUDIT METHODOLOGY AND SOFTWARE TOOL

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Abstract

For optimizing thermal energy supply in industry, a holistic integral approach is required that includes possibilities of demand reduction by heat recovery and process integration, and by an intelligent combination of efficient heat and cold supply technologies.

EINSTEIN is a tool-kit (methodology and software tool) for fast and high quality thermal energy audits in industry, composed by an audit guide describing the methodology and by a software tool that guides the auditor through all the audit steps.

The main features of EINSTEIN software tool are: (1) a basic questionnaire helps for systematic collection of the necessary information with the possibility to acquire data by distance; (2) a fast consistency checking and estimation of missing data, so that already with very few data some first predictions can be made; (3) a standardized model for industrial processes and industrial heat supply systems; (4) semi-automatization: the software tool gives support to decision making for the generation of alternative heat & cold supply proposals, carries out automatically all the necessary calculations, and creates a standard audit report.

Over 150 auditors have been trained in several training courses and the software tool has been tested within 90 audits in 6 European countries. The result of these 90 audits showed a big potential of CO2 savings by energy efficiency and the implementation of renewable energy like solar process heat or CHP.

1. Introduction

The EINSTEIN methodology for thermal energy audit that is described in this paper has been developed in the framework of the European (Intelligent Energy Europe - IEE) project EINSTEIN (www.iee-einstein.org). This project has been the result of the previous collaboration of the project partners Joanneum Research (Austria), Sapienza University of Rome (Italy) and energyXperts.NET (Spain) during the years 2003 – 2007 in the Framework of the IEA (International Energy Agency) Solar Heating and Cooling and SolarPACES Programs, Task 33/IV on Solar Heat for Industrial Processes (www.iea-ship.org). The basic elements and concepts forming this methodology had already been created in the framework of the European (5th Framework Programme) project POSHIP (The Potential of Solar Heat for Industrial Processes) (Schweiger et al., 2001) and of the Austrian national project PROMISE (Müller et al., 2003).

Based on the practical experience of a large number of energy audits in different industrial sectors, the auditing methodologies used by the different partners have been more and more standardized leading to what here is presented as the EINSTEIN audit methodology. For the development of this methodology, also a detailed screening of the available methodologies and tools has been carried out, that is available for the public on the EINSTEIN project web page (Vannoni et al., 2008).

Furthermore several tools have been developed that allow for a fast access to the required information and for a semi-automatization of the required calculations and design decisions (expert system), from simple spreadsheets to software tools addressing specific parts of the problem. Most of these tools are now integrated into the EINSTEIN software tool on which the EINSTEIN audit methodology is based. The implementation of the methodology in form of a complete auditing tool-kit including an expert system software tool makes it easy to use, easily distributable, and helps reducing time (and therefore cost) and increasing standardization (and therefore quality) of energy audits.

The EINSTEIN software tool, together with some of the complementary databases, is being developed as a free and open source software project available in all the project languages1 on the project web page or from any of the consortium members. We hope that this form of distribution will lead to a widespread use in the community of energy auditors, engineers, consultants and researchers, and that the present version can be continuously enriched with new experiences and contributions from the community.

In November 2008 and March 2009, about 250 energy auditors in 7 countries have been trained on EINSTEIN, and some of them elaborated 90 thermal energy audits in industries of the food and beverage, wood processing and metal surface treatment sectors in Austria, Czech Republic, Italy, Poland, Slovenia and Spain.

2. Methodology

1.1 **Areas of application – industrial and non-industrial users**

The EINSTEIN thermal audit methodology focuses on industries with a high thermal energy (heat and cold) demand in low and medium temperature ranges up to 400 ºC, such as food and beverage industry, metal surface treatment, wood processing industry and many other industrial sectors (paper, chemical, pharmaceutical, textile, etc.)

The advantage of EINSTEIN is especially high in small and medium companies, where costs of conventional audits of a comparable deepness and quality are an important barrier for the introduction of energy efficient technologies.

Even if the EINSTEIN methodology is focused on industrial heat and cold demand, a big part of the developed methodology can also be applied to other medium and large scale consumers of heat and cold, such as district heating and cooling networks, buildings in the tertiary sector and other installations consuming thermal energy, such as sea-water desalination, plants for water treatment, etc.

1.2 An integral approach to energy efficiency

In order to optimize thermal energy supply, a holistic integral approach is required that integrates: possibilities of demand reduction by process optimization and by the application of competitive, less energy consuming technologies; energy efficiency measures by heat recovery and process integration; an intelligent combination of the available heat and cold supply technologies (efficient boilers and

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[1] *English, Czech, German, Italian, Polish, Slovenian, Spanish*

burners, cogeneration, heat pumps), including the use of renewable energies (especially relevant for thermal use are biomass and solar thermal energy); and the consideration of the given economic constraints.

1.3 **The EINSTEIN tool-kit**

The EINSTEIN tool kit is based on a software tool with decision aids and guidelines forming a complete expert system for thermal energy auditing. This easy to use expert system software tool, together with the EINSTEIN audit guide forms an energy-auditing tool-kit that leads the consultant through the whole procedure from auditing (preparation of visit and data acquisition), over data processing, to the elaboration, design and quantitative (energetic and economic) evaluation of alternative solutions.

The core of the expert system software tool and the manual is available for free in form of an open source software project (www.sourceforge.net/projects/einstein). This type of software development has shown to be very efficient for dissemination of knowledge and for the continuous maintenance, bug-fix, update, and improvement of the software by user contributions (Ghosh et al., 2002).

1.4 **The advantages of the EINSTEIN audit procedure**

In contrast to many aspects of industrial electricity consumption such as pumps, motors, etc., where often a list of recommendations and standard measures can lead to good results, the task of optimizing thermal energy supply in industry is rather complex from the technical point of view:

In many companies and especially in SME’s only very few and aggregate information on the actual energy consumption is available (fuel bills, technical data of boilers, etc.). Consumption of individual processes and sub-processes therefore has either to be estimated or determined by costly and time-consuming measurements.

The exploitation of existing heat recovery potentials often requires the integration of several processes at different temperature levels and with different operating time schedules (integration of heat exchangers and heat storage).

Different available technologies for heat supply have to be combined in order to obtain optimum solutions.

The technical complexity of the problem to be handled is in contrast with the need for a low-cost and, therefore, necessarily fast assessment methodology. This is one of the main reasons why the energy savings potential for thermal energy is still far less exploited than the electricity savings potential.

1.5 **The standard EINSTEIN audit methodology**

The EINSTEIN thermal energy audit and design of improved energy systems is based on a standard EINSTEIN audit methodology subdivided in 4 phases and 10 audit steps (Figure 1).

The audit begins outside the company with few quick preliminary activities that can be done in the office, the so called “pre-audit”. It allows the auditor to improve his/her knowledge on the status quo (i.e. on the actual energy demand profile, thermal processes in operation, equipments in use, energy bills, etc.) and to get ready before going to the company. Data can be collected already by distance for a first rough evaluation of the energy demand, and of the areas of potential improvements. This preliminary phase is simple, quick but fundamental to save time afterwards: to prepare the company and the auditor for the on-site energy audit.

The second phase (walk-through audit) includes two implementation steps: an on – site walk – through visit to the company and an analysis on-site of the results calculated running the Einstein software tool. The aim of the walk – through audit at the company is mainly to acquire the information still missing, through interviews and direct measurements; to inspect plants and hydraulics schemes, etc.

Back to the office, with the help of EINSTEIN the auditor will be able to check the consistency and completeness of the data acquired; estimate (re-call for) the figures that are still missing; elaborate a detailed breakdown of the heat consumption by process, temperature levels, fuels, etc.; analyze the real operation performance of existing equipments; benchmarking.

Once the auditor has a clear picture of the actual energy flows and inefficiencies of the company, she/he can count on EINSTEIN also for the implementation of the third phase of this auditing procedure: the design and evaluation of energy efficient alternatives: preliminary design of integral energy and cost saving measures, and energy targets definition; calculation of the energetic performance and analysis of the environmental impact of the feasible solutions; analysis of economic and financial aspects.

Finally, there is all the information available required to perform a clear and effective presentation of the results of the audit

The four phases of an EINSTEIN energy audit can be subdivided into 10 EINSTEIN audit steps shown in Figure 1. Each of these audit steps is described in detail the in the EINSTEIN audit guide (Schweiger et al., 2008). For each audit step the different tasks are described of which it is composed, the indications are given how to carry out each of these tasks, and which of the tools from the EINSTEIN tool-kit can be used.

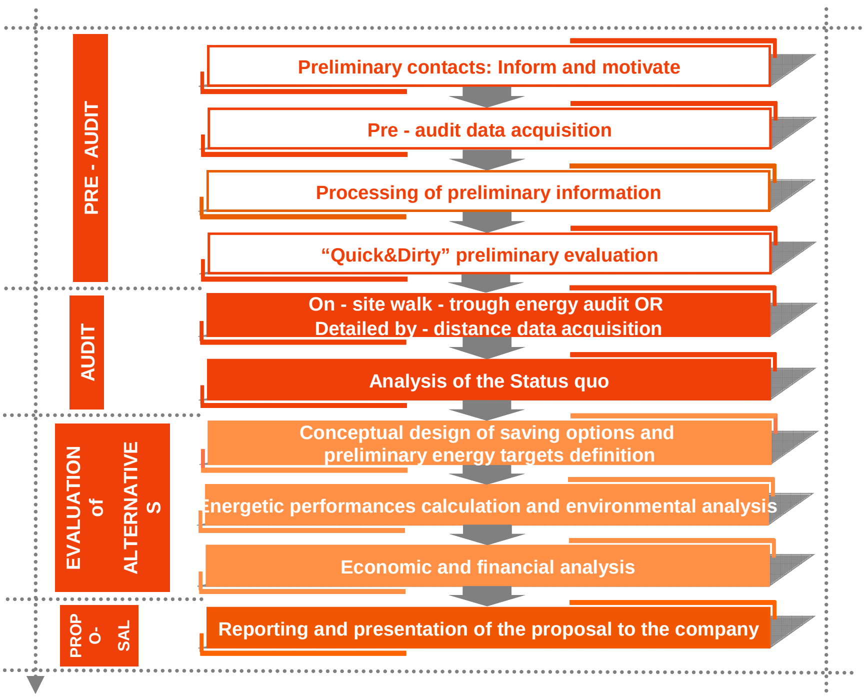

Figure 1: EINSTEIN's ten steps towards energy efficiency

3. Results

1.6 The EINSTEIN software tool

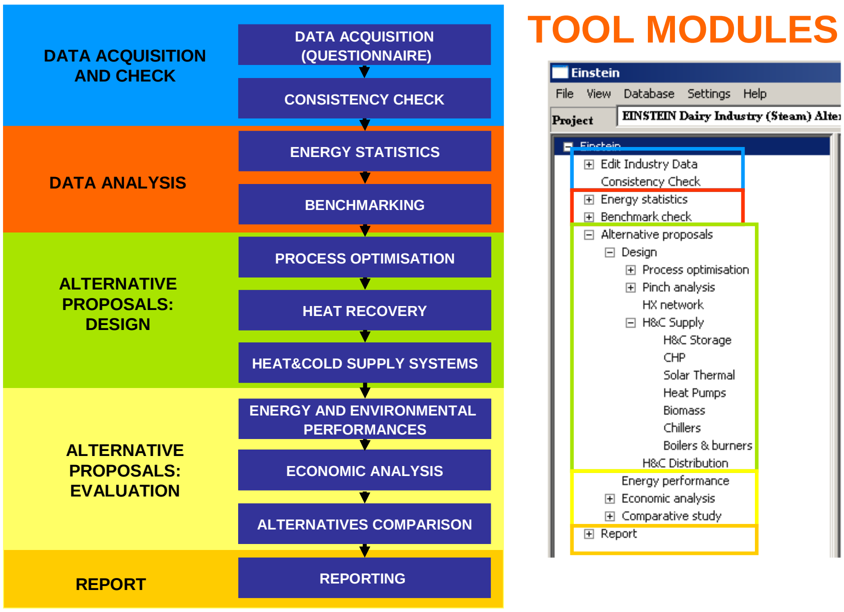

Figure 2. Main functions of the EINSTEIN software tool and their representation in the menu tree.

Very important for both standardisation and automatization of the audit procedure is the use of the EINSTEIN software-tool that includes the following modules:

a) <u>Module for data acquisition and processing:</u> Data acquisition is mainly based on a short questionnaire. An additional module helps the auditor to estimate non-available data. A link to a matrix with information on best practice and benchmarks helps to evaluate the state-of-the-art in the company.

b) <u>Module for the generation of a new proposal:</u> This block is formed by the process optimisation module, the heat recovery module, that helps designing and optimising an appropriate heat exchanger network for heat recovery and process integration; and a heat and cold supply module, that helps to select and to dimension the most appropriate supply equipment and heat or cold distribution systems.

c) <u>Module for the energetic, economic and environmental evaluation of the new proposal:</u> The energetic performance of the system is determined by a simplified system simulation module. Based on the energetic performance, an economic and environmental evaluation is automatically generated by the *total cost analysis* (TCA) module.

d) <u>Module for generation of reports for the presentation of the new proposal to the company:</u> The report contains information on the technical design of the new proposal, the investment cost of the measure, and an economic roadmap for its implementation.

1.7 EINSTEIN audit campaign

The EINSTEIN audit campaign comprises 90 companies from six countries: Austria, Italy, Spain, Czech Republic, Poland and Slovenia.

For each of the 90 companies an EINSTEIN audit summary report (2 to 4 pages) was generated by the auditors, including the following data: description of the participating company, description of the energy supply and distribution system and the thermal processes, current energy demand (PEC, PET…) and useful supply heat (USH), description of the suggested energy-saving concepts, calculated savings (energy, CO2, costs) for each concept, selection of the best alternative and investment costs and pay-back times of the best alternative.

For each audit, several alternative proposals were generated and the best alternative had to be chosen according to saving potential and personal valuation by the auditor.

The results of the EINSTEIN audit campaign were reviewed by consortium members, corrected in some cases and evaluated in a report, which shows the overall results of the audit campaign. The result of these 90 audits showed a potential of 96,000 t/a CO2 savings by energy efficiency and the implementation of renewable energy like solar process heat or CHP.

Acknowledgments

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