Good practice thermal energy audits

First EINSTEIN draft version of the CEN Workshop Agreement

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Foreword

This CEN Workshop Agreement has been drafted and approved by a Workshop of representatives of interested parties on 2012-xx-xx, the constitution of which was supported by CEN following the public call for participation made on 2012-yy-yy.

A list of the individuals and organisations which supported the technical consensus represented by the CEN Workshop Agreement is available to purchasers from the CEN-CENELEC Management Centre.

The formal process followed by the Workshop in the development of the CEN Workshop Agreement has been endorsed by the National Members of CEN but neither the National Members of CEN nor the CEN-CENELEC Management Centre can be held accountable for the technical content of the CEN Workshop Agreement or possible conflict with standards or legislation. This CEN Workshop Agreement can in no way be held as being an official standard developed by CEN and its members.

The final review/endorsement round for this CWA was started on 201y-bb-bb and was successfully closed on 201y-vv-ww. The final text of this CWA was submitted to CEN for publication on 201y-gg-bb.

Below is a list of companies and persons that endorsed this CWA:

- Austrian Energy Agency, Konstantin Kulterer
- AEE - Institut für Nachhaltige Technologie, Jürgen Fluch, Chistoph Brunner
- Cardiff University, Ian Knight
- CCMC, Maitane Olabarria Uzquiano, Catherine Moutet
- CETIAT Villeurbanne, Romain Casaliggi
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- Energyxperts, Dr. Hans Schweiger
- Public Research Centre Henri Tudor, Alex Bertrand
- Standart BM Trada Belgelendirme A.S., Neşe Güneş

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The Workshop was supported by the European Commission through its Intelligent Energy Europe program (IEE).

Introduction

This CEN Workshop Agreement is based on the results of work and on documents realized within the framework of the European IEE projects EINSTEIN and EINSTEIN II.[1] These projects implemented a large number of thermal energy audits in different industrial sectors and other large scale applications and led over time to a specific approach to thermal energy audits, called the EINSTEIN Audit Methodolody.

Point of departure for developing the specific EINSTEIN approach was the lack of appropriate audit tools for thermal energy supply in industry and beyond, due among others to

— requiring a broad knowledge of process technology, process integration, heat recovery techniques and of different energy efficient technologies for heat and cold supply, including renewabl nergies, to be able to execute thermal audits in industry,

— lack of time available for implementing even quick audits or initial rough feasibility studies,

— lack of allocation of financial resources for audits in companies.

The EINSTEIN Audit Methodology takes into account these facts and incorporates several tools that allow for a fast access to the required information and for a semi-automatisation of the required calculations and design decisions (expert system), from simple spreadsheets to software tools addressing specific parts of the problem. The implementation of the methodology in form of a complete auditing tool-kit including an expert system software tool makes it easy to use, easy to distribute, and helps to reduce time and thus costs while increasing the level of quality of energy audits due to the systematics of the approach.

Looking at the methods for calculations used by the software they were developed focussing on

— Quality…

— Quantity…

— Type …

This lead to specific considerations for the calculation schemes, focussinfg on thermal energy demand (heating, cooling), temperature levels, clear definitions of system and of sub-system boundaries, and the evaluation of the present state energy consumption with respect to Best Available Technologies to assess the savings potentials.

Specifically small and medium companies may benefit from applying the EINSTEIN Audit methodology, where costs of comparable conventional audits are often considered a barrier to introduce more energy efficient technologies.

1 Scope

This CEN Workshop Agreement … describes a methodology for thermal energy audits that incorporates a guide to thermal energy audits, an expert system to support decision making, and software tools addressing specific parts of thermal energy audits.

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[1] Refer to http://www.einstein-energy.net/, last query 2012-11-12, for a description of the projects.

It gives examples how prEN 16247-1 may be implemented for auditing

- thermal energy demands in industry and
- non-industrial large-scale applications.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 16247-1:2012-10, *Energy Audits – Part 1: General requirements.*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply / the terms and definitions given in EN 16247-1 and in preen 16247-3 and the following apply.

3.1
thermal process
any operation *[-> part3: "production process": all the steps necessary to manufacture a product or delivery of a service*] (or sequence of operations) requiring heat or cooling. Process may include also space heating or cooling requirements in buildings

3.2
process medium
medium (liquid, solid, gas or mixtures) that has to be cooled or heated

NOTE the process medium may be different from and has to be distinguished from the supply medium

3.3
supply medium
medium (liquid, solid, gas or mixtures) used for heat transport (e.g. hot water, steam, chilled water, thermal oil, etc.)

3.4
conversion equipment
equipment converting final energy (that may include energy in form of heat or cooling as input) into heat, cooling and/or electricity (e.g. a boiler, burner, chiller)

4 Symbols and abbreviations

4.1 Abbreviations

BAT	best available technology
BCR	benefit cost ratio
BREF	
CC	consistency check
CHP	combined heat and power
CST	central supply temperature

CSTmin	minimum required central supply temperature
EI	energy intensity
EINSTEIN	Expert-system for an Intelligent Supply of Thermal Energy in Industry and other Large Scale Applications
FEC	total final energy consumption
FET	final energy consumption for thermal uses
HR	heat recovery
HX	heat exchanger
IRR	internal rate of return
LCV	lower calorific value
MIRR	modified internal rate of return
NPV	net present value
PT	process temperature
PST	process supply temperature
PSTmin	minimum required process supply temperature
QCX	recovered waste cold
QHX	recovered waste heat; heat flow over heat exchangers
QWC	available waste cooling
QWH	available waste heat
RES	
SEC	specific energy consumption
UPC	useful process cooling
UPH	useful process heat
USC	useful supply cooling
USH	useful supply heat

5 An integral approach to energy efficiency

5.1 Challenges for thermal energy audits

In contrast to many aspects of electricity consumption in industry and other large-scale applications, where often a list of recommendations and standard measures based on an audit can lead to good results, the task of optimising thermal energy supply in industry is rather complex from the technical point of view:

— In many companies and especially in small and medium enterprises 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, contrasts 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.

5.2 The EINSTEIN holistic approach

In order to overcome the constraints (refer to 5.1) and to optimize thermal energy supply, a holistic integral approach (Figure 1) was developed by the EINSTEIN project[2] integrating

— Possibilities of demand reduction by process optimisation 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 burners, co-generation, heat pumps), including the use of renewable energies (especially relevant for thermal use are biomass and solar thermal energy).

— Consideration of the given economic constraints.

2 Refer to www.einstein-energy.net

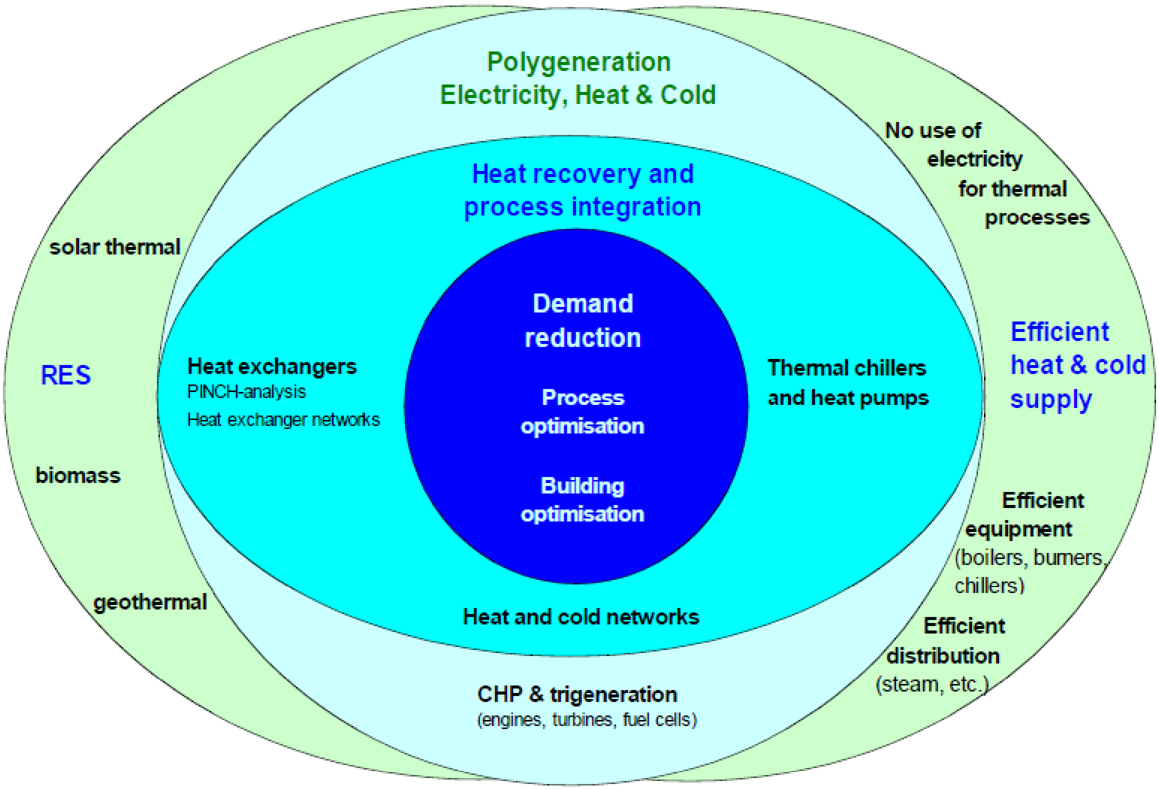

Figure 1 — EINSTEIN´s holistic approach, combining demand reduction, heat recovery and process integration, and an intelligent combination of supply technologies

5.3 Benefits of the EINSTEIN audit procedure

EINSTEIN focuses on industries and other large scale consumers with a high thermal energy (heat and cold) demand and based on the holistic approach set up a tool-kit.

EXAMPLE industrial sectors such as food industry; chemical industry; paper industry; construction of machinery, equipment and automobile; plastic processingwood processing industry; metal surface treatment; textile industry. Large-scale non-industrial applications such as district heating and cooling networks, including also the integration of demands in form of centralized generation of power and heat for industry groupings or networks that integrate industrial companies with other sectors; buildings in the tertiary sector, such as large office buildings, malls, commercial centres, hotels, hospitals, convention centres, schools, spas; other installations consuming thermal energy, such as sea-water desalination, plants for water treatment.

The tool-kit uses the concepts described below and allows to process data and to generate proposals for typical small and medium enterprises.

The main advantages of the EINSTEIN tool-kit are (refer also to Figure 2)

— standardisation of the problem and the possible solutions: both the data acquisition and the proposal generation are carried out using standardized models for unit operations (processes) representing a generic industrial process applicable to the industrial branches and types of buildings addressed by the project; and standardized modules for the heat and cold supply subsystems.

— fast estimates: aids for estimation and calculation of non-available, but necessary data on heat demand. In many cases, at least approximate figures on the heat demand of the different processes can be obtained by combining several different – often incomplete, fragmented, and sometimes only qualitative –

information collected in the visits and interviews with the technical staff in a company. These often lengthy and time-consuming calculations necessary for processing these data can be substantially shortened using a limited data set as input to the standardized procedure. By this way less than one hour of calculation effort can often be a substitute for on-site measurements, with sufficient accuracy also thanks to an internal data cross-check, at least in the pre-design stage.

— semi-automatization of the auditing procedure and proposal generation: the EINSTEIN software tool incorporates data bases, e.g. including the technical parameters of standard components, and aids for decision making so that also not specially skilled technicians will be able to use the tool for dealing with rather complex problems. Benchmarks will help the user to evaluate the state both before and after the proposed interventions. Lists for quick-check and standard measures are also incorporated. Audit reports are generated automatically from the tool, in a format so that they directly can be delivered by an external auditor to a customer or by the technical staff to the manager of the company itself.

— data submission by distance using a checklist or a short questionnaire; taking into account that in many cases for a first fast assessment it is sufficient to process few data, a short questionnaire has been created. It allows data collection in situ and, if the case, it can be easily completed by means of telephone calls.

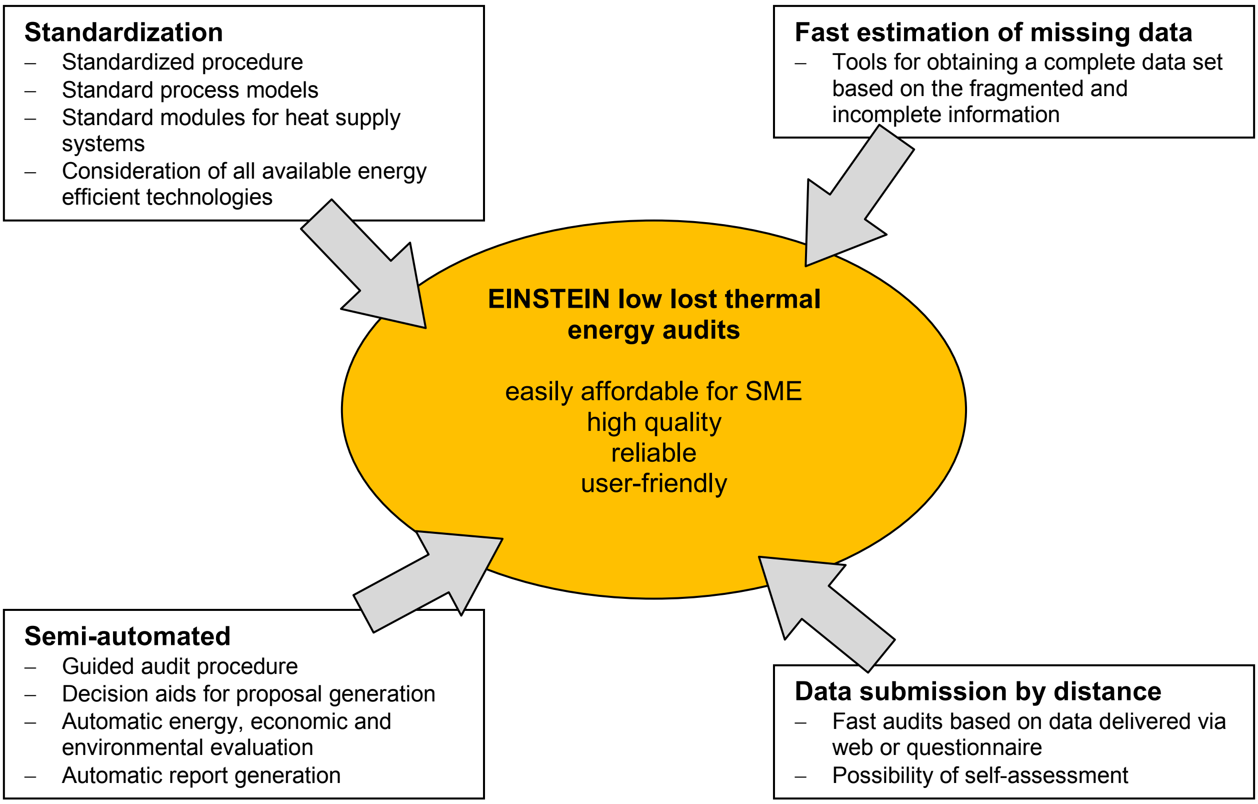

Figure 2 — Overview of the EINSTEIN thermal auditing functions

5.4 EINSTEIN levels of analysis and related methodology on quantity and accuracy of data

The EINSTEIN methodology distinguishes between three levels of analysis with increasing level of detail and accuracy:

— Level 1: EINSTEIN fast analysis

For a fast analysis it is sufficient to know with a certain minimum accuracy the energy consumption and the main temperature level (process temperature) of the most energy consuming processes in the company.

NOTE EINSTEIN considers an error margin of less than +/- 30 % as minimum accuracy.

- Level 2: EINSTEIN standard level of analysis

  For the EINSTEIN standard level of analysis at least the following parameters should be known with the minimum level of accuracy:

  - energy consumption of the main energy consuming processes and its decomposition in heat and cold demand for circulation, maintenance and start-up

  - all temperature levels (inlet, process, outlet) and hours of operation of those processes and the corresponding heat and cold supply equipment

  - waste heat streams from the main energy consuming processes

- Level 3: EINSTEIN detailed analysis

  For a detailed level of analysis at least the full set of information as given by the EINSTEIN basic questionnaire should be available with the required accuracy.

The accuracy of the available data, both in the qualitative sense of level of reliability and in the quantitative sense of the margin of error, depends on several factors:

- source of information

  Sometimes in big companies the figures on energy consumption are directly measured by accurate metering equipments and stored in sophisticated energy management systems, while small companies often know only the average operating conditions of the plants and global energy consumption from energy bills. One year or even single month data may not be very representative for the average consumption in the future.

- procedure for data acquisition

  Mistakes can easily result when filling in a data sheet or when copying figures while entering data in a calculation tool

  EXAMPLE properly entering the data into the questionnaire, confusion of measurement units, assistance used to fill in the questionnaire.

- level of detail

  The deeper the level of the analysis, the more detailed and specific are the data required, resulting in a risk to acquire less accurate figures.

  NOTE there might be a drift to collect less accurate data, the more figures are requested.

5.5 Characteristics of the EINSTEIN tool-kit

The EINSTEIN audit methodology 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 theelaboration, 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[3]. 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 [FLOSS 2002].

The EINSTEIN tool-kit allows to produce solutions for thermal energy and economic savings on behalf of an expert system software tool with a user friendly and easy-to handle interface.

The EINSTEIN expert system software tool includes six modules:

- Data acquisition and analysis module
- Process optimization module
- Heat recovery module
- Energy supply and renewables module
- Simulation and evaluation module
- Reporting module

NOTE further information on the modules can be found in annex C.

The expert system guides the auditor on any decision to be taken, by help menus, suggestions for best options to be selected, etc. This support, together with the guide for thermal energy auditing with recommendations and best practices, make the tool-kit accessible also for non-expert users in a company.

6 EINSTEIN energy accountancy: definition of subsystem boundaries, energy flows and temperature levels

6.1 General

In order to quantify energy flows (demand and supply) in general, and under the specific consideration of the associated temperature level (associated quality), it is necessary to recur to a clear definition of the terms used, and specially the sub-system boundaries, to the reference temperatures used for assigning energy quantities to real flows of heat transport media, and to the definition of which temperature is used as quality attribute for which energy flow.

Based on the experiences gained in the development of the EINSTEIN approach, EINSTEIN developed conventions of energy flows, sub-system boundaries, definition of temperature levels in view of quantity and quality, and temperature levels as quality attributes of energy flows.

Such a consistent and unique system of definitions (or accountancy scheme) is particularly important when it comes to exchange and compare results.

6.2 Energy flows and sub-system boundaries

NOTE The information and formulas and contained in 6.2 present general engineering knowledge; it is included here to better described the concept of EINSTEIN concerning energy flows and boundaries

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3 www.sourceforge.net/projects/einstein

6.2.1 Energy flows – quantity definitions

For the analysis of the thermal energy demand within the EINSTEIN methodology, the following basic quantities are used.

— FEC and FET: LCV of the fuel consumption, heat and electricity consumption (for thermal use).

— USH and USC: heat or cooling generated in the heat or cold supply system (e.g. boilers, burners, and chillers) and that is distributed to the different heat or cold consuming processes in form of steam, hot air, hot water, chilled water, etc.

— UPH and UPC: heat or cooling delivered to a process (measured at the entrance of the process heat exchanger).

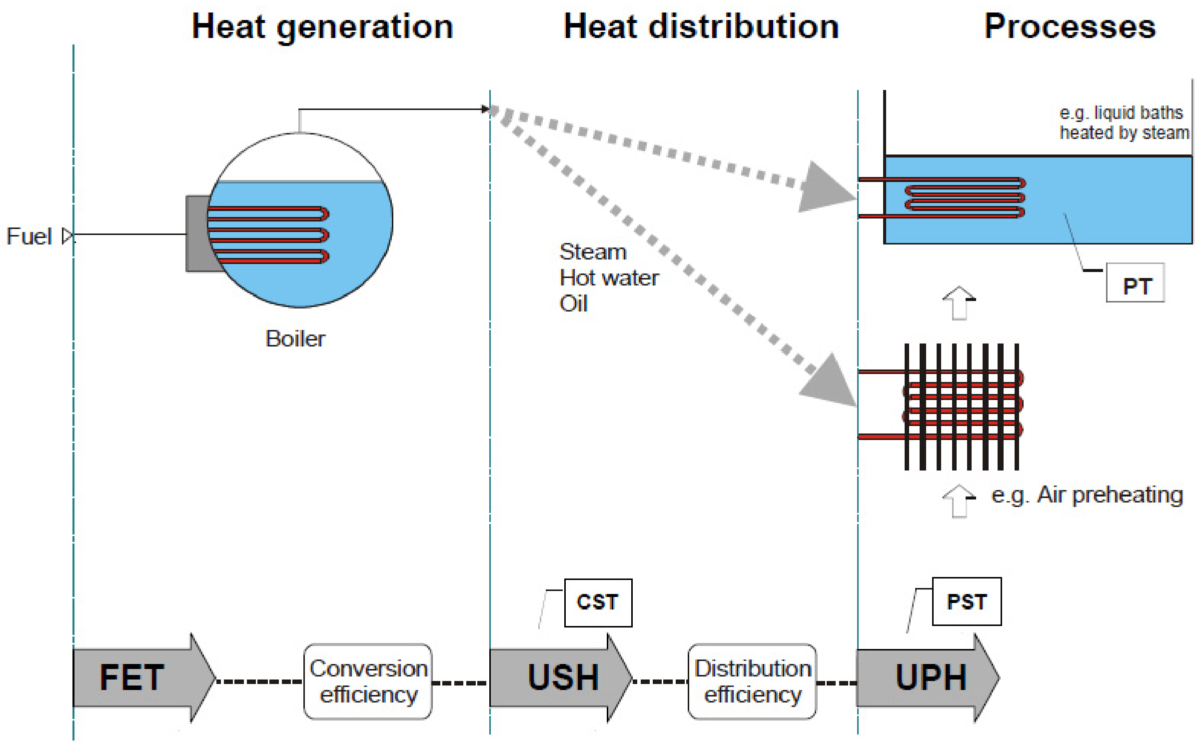

Figure 3 — EINSTEIN definitions of energy flows in a heat supply system

The ratios of USH/FET or of USC/FET and of UPH/USH or of UPC/USC define the conversion efficiency and the distribution efficiency of the system (Figure 4).

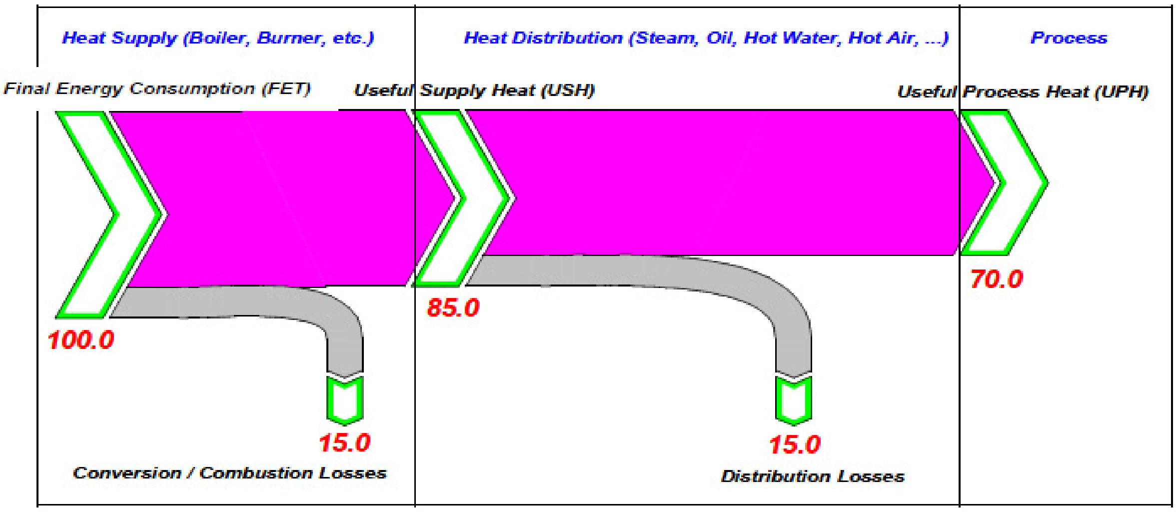

Figure 4 — Sankey diagram of energy flows with typical conversion and distribution efficiencies

If in addition the different flows of waste heat or waste cold are also considered, the scheme of energy flows is becoming more complex (Figure 6). An example of an industrial process with different types of waste heat recovery is shown in Figure 5.

QWH is an energy flow produced by any of the subsystems (supply, distribution, processes, others) that is not the main output of that system, or in other words, whose associated energy is not accounted for within the concept of USH/USC.

EXAMPLE Heat contained in the exhaust gas of a boiler or in the heat rejection cycle of a cooling machine; condensate recovered from a steam piping; heat contained in the waste water of a washing process

Analogously, there can be QWC, e. g. cold exhaust air from an air conditioned space.

QHX or QCX is an energy flow used as input for any of the subsystems (supply, distribution, processes) that originates from the waste heat recovery system (including ambient air and ground).

EXAMPLE Preheating of combustion air and/or of feed-up water in a boiler; preheating of water at the inlet of a washing process; preheating of return in a hot water distribution circuit; precooling of air at the inlet of a germination process in malt production

NOTE mathematical definitions of the quantities used in EINSTEIN energy balances are included in the EINSTEIN Audit Guide.

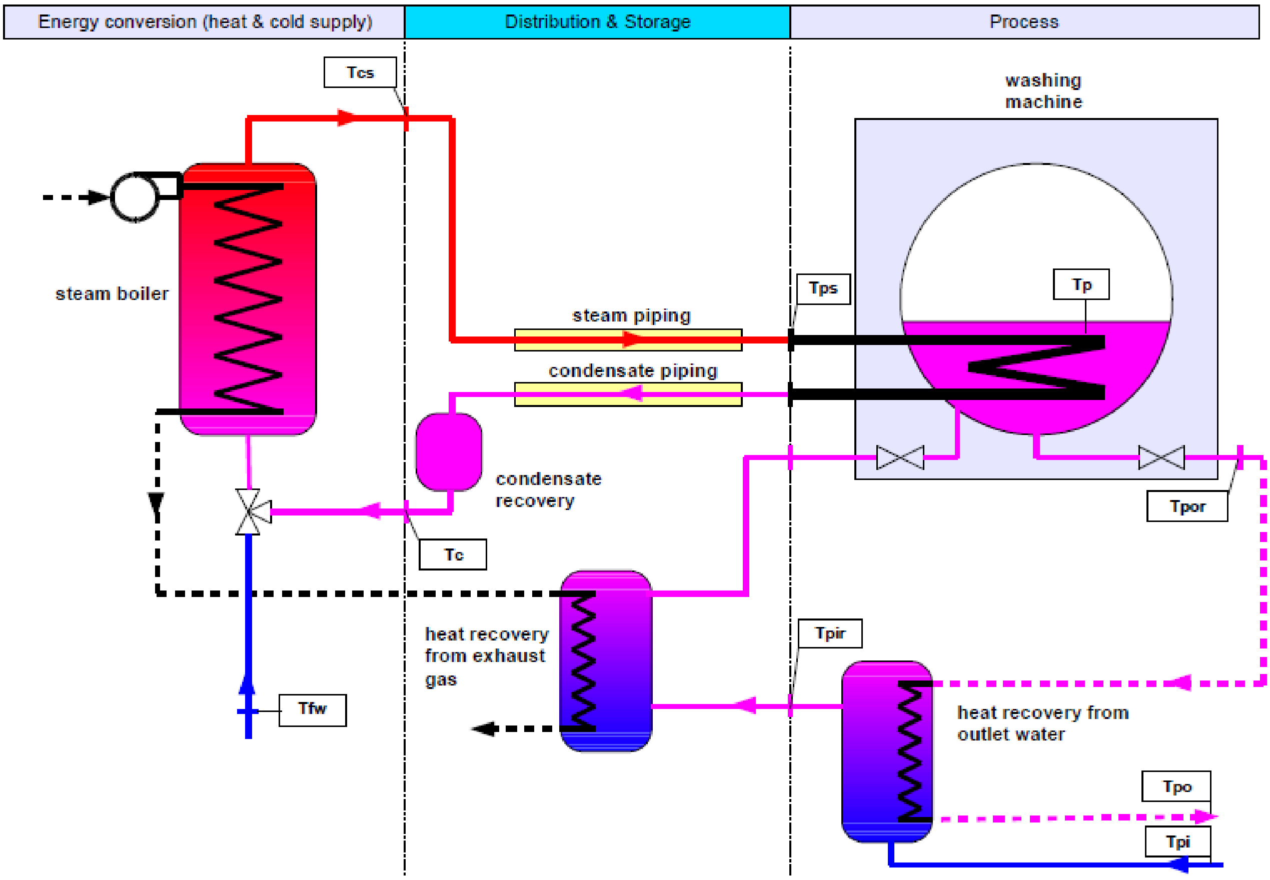

Figure 5 — Example of an industrial washing process represented according the EINSTEIN model, with different types of heat recovery: heat recovery from boiler exhaust gas for water preheating; heat recovery from waste water for water preheating; condensate recovery for preheating of boiler feed-up water

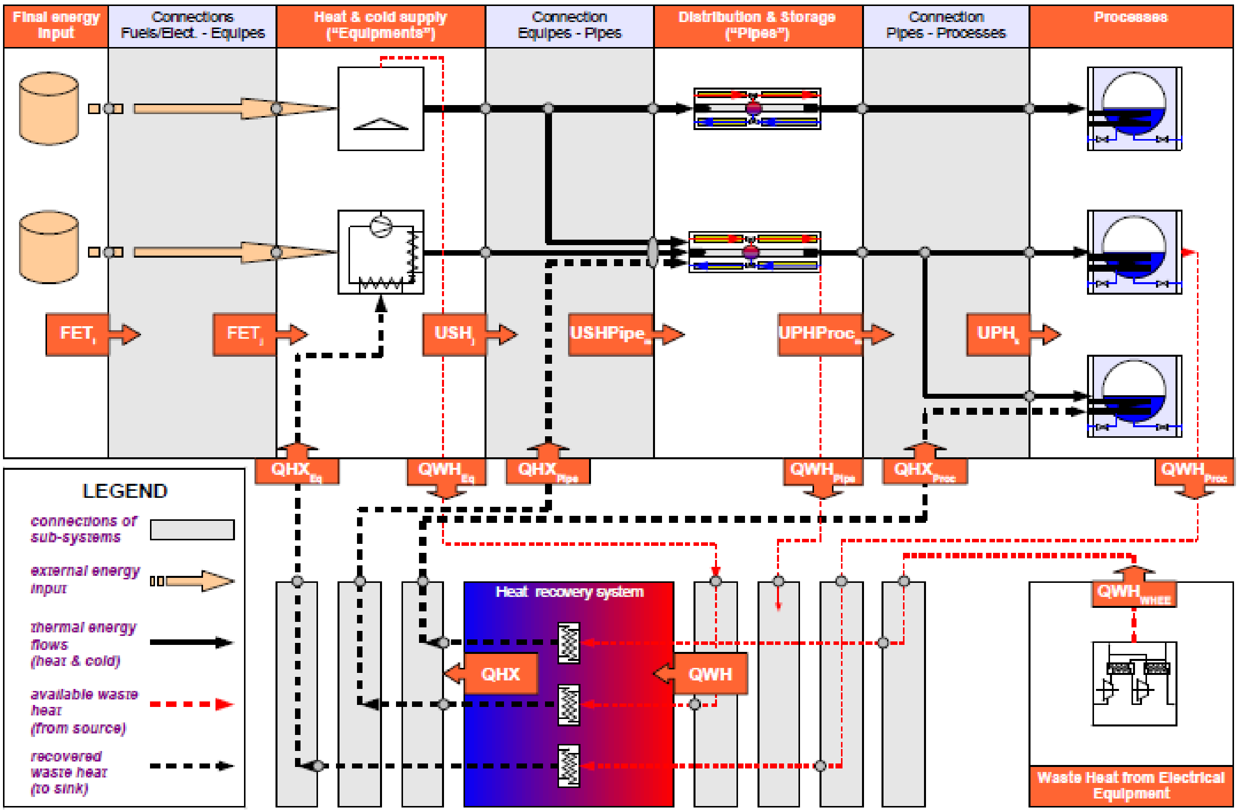

Figure 6 — EINSTEIN definitions in a heat supply system with heat recovery (analogous for cooling supply system)

6.2.2 Final and primary energy consumption

6.2.2.1 Breakdown by energy carriers

FEC is used to account for the total final energy that enters the company in the form of fuels (expressed in terms of LCV), electricity and district heat or cooling.

$$E_{FEC} = E_{FEC} + \sum_{i=1}^{N_{fuels}} E_{FEC,fuel(i)} + E_{FEC,heat} \qquad ((2.1))$$

PEC is obtained from this applying the different conversion factors for each of the energy types.

$$E_{FEC} = f_{PE,el} E_{FEC,el} + \sum_{i=1}^{N_{fuels}} f_{PE,i} E_{FEC,fuel(i)} + f_{PE,heat} + E_{FEC,heat} \qquad (2.2)$$

where

$f_{PE,el}$ is the primary energy conversion factor for electricity

$f_{PE,i}$ is the primary energy conversion factor for the different fuel types.

6.2.2.2 Breakdown by type of use: definition of thermal and non-thermal uses

Energy is consumed for thermal (heating or cooling) and non-thermal uses (e. g. lighting, motor drives). Electricity used in chillers for air conditioning and cooling, and in electrical heating equipment is accounted for as energy for thermal use. Also, electricity or other energy sources used as auxiliary energy for thermal equipment and/or that can be directly associated to the thermal supply and distribution system is considered as energy for thermal uses.

EXAMPLE electricity of pumps and fans for distribution of heat / cooling; electricity for control and auxiliary consumption of thermal equipment (e.g. electricity for control and/or feed-water pumps in boilers); electricity or other energy sources for internal transport and handling of energy carriers (e.g. transport belt for solid biomass)

The corresponding amounts of energy are denominated as:

- PET: Primary energy for thermal uses
- FET: Final energy for thermal uses
- FEO: Primary energy for other (non-thermal) uses
- PEO: Final energy for other (non-thermal) uses

The following equation holds (and in an analogous way for primary energy).

$$E_{FEC} = E_{FET} + E_{FEO} \tag{2.3}$$

6.2.2.3 Breakdown by equipment

6.2.2.3.1 Total final energy

The total final energy for thermal uses is the sum of the energy consumed by the heating and cooling equipment in the company.

$$E_{FET} = \sum_{j=1}^{N_{eq}} E_{FET,j} \tag{2.4}$$

where

N_{eq} is the number of thermal equipment units in the company (boilers, chillers, CHP engines, etc.)

6.2.2.3.2 Special case CHP

From the perspective of EINSTEIN, CHP is treated as heat supply equipment. The final energy consumption of CHP equipment is considered as the net consumption composed by the fuel consumption and the negative consumption in form of self-generated electricity.

Self-generated electricity in CHP is accounted for as a negative consumption of (final or primary) energy, this is as a negative input and not as an output. The (net) primary energy consumption of CHP equipment, therefore, is considered as the net consumption composed by the fuel consumption and the negative consumption in form of self-generated electricity.

$$E_{FET,j} = E_{FET,fuel(j)} - E_{FET,e\lg en,j} \tag{2.5}$$

NOTE if the electrical conversion efficiency of a CHP equipment is higher than the reference value of the reference electricity grid, the net energy consumption in a CHP equipment in terms of primary energy may be negative.

6.2.3 Useful supply heat and cold

USH or USC is the energy delivered by the conversion equipment (boilers, burners, etc.), measured at the outlet of the equipment (machine room). The energy balance is obtained as

$$\dot{Q}_{USH,j} = \dot{Q}_{USH,eq,j} + \dot{Q}_{QHX,j} \tag{2.6}$$

where

$\dot{Q}_{USH,eq,j}$ is the additional heat generated in this equipment by conversion from final energy

$\dot{Q}_{Qhx,j}$ is the recovered waste heat used in this equipment (e. g. preheating of combustion air or feed-up water)

The net equipment conversion efficiency is defined as

$$\eta_{conv,j} = \frac{\dot{Q}_{USH,eq,j}}{\dot{E}_{FET,j}} \quad 2.7$$

The total heat entering the different distribution lines is given by

$$\dot{Q}_{USH,pipe,m} = \dot{Q}_{USH,m} + \dot{Q}_{QHX,m} \quad 2.8$$

where

$\dot{Q}_{USH,m}$ is the useful supply heat from the conversion equipment to pipe m

$\dot{Q}_{QHX,m}$ is the recovered waste heat fed directly into pipe m (e. g. preheating of return line).

The heat content in heat supplies that are not closed loops (e.g. steam w/o condensate recovery, direct hot water preparation and distribution) is defined based on some default (external) reference temperature (cold water inlet, air inlet):

$$\dot{Q}_{USH,pipe,m} = q_{m,o}h_o - q_{m,ret}h_{ret} - q_{m,i}h_i \quad 2.9$$

where

o is outlet

ret is return

i is inlet being the external reference for open loops.

For closed loops with

$$q_m = q_{m,o} = q_{m,ret}$$

equation (2.9) simplifies to:

$$\dot{Q}_{USH,pipe,m} = q_m \left(h_o - h_{ret}\right) \quad 2.9a$$

Analogous equations apply for USC.

6.2.4 Useful process heat and cold

The net UPH demand is defined as the difference between the total (gross) heat demand of the process (UPH_{gross}, see chapter below) and the internally recovered waste heat.

$$Q_{UPH} = Q_{UPH,gross} - Q_{HX,\text{int}ernal} \quad 2.10$$

On the other hand, the useful (net) process heat is also obtained as the total external heat supplied to the process, either by the heat supply system (Q_(UPH,proc)), or by externally recovered waste heat fed directly into the process (Q_(HX,proc)):

$$Q_{UPH} = Q_{UPH,proc} + Q_{HX,proc} \quad 2.11$$

Here again, similar equations apply UPC and QCX.

6.2.5 Recoverable waste heat, recoverabale cooling, recovered waste heat and recovered cooling

For the calculation of the heat recovery potential it is important to distinguish between the total amount of waste heat and those waste heat streams that can technically be used. For flows which are used as input to another process, the recoverable waste heat is furthermore limited by the final temperature to which the flow can be cooled down, determining the minimum enthalpy hmin. The recoverable waste heat from a specific process ($Q_{QWH,proc}$) is given by:

$$Q_{QWH,proc} = m_o \left(h_{po} - h_{\min}\right) \quad 2.12a$$

The amount of available waste heat from equipments

$$Q_{QWH,Eq}$$

(e. g. exhaust gas) or from pipings

$$Q_{QWH,pipe}$$

(e. g. condensates) is calculated in an analogous way, based on the inlet temperature of feed-up in open circuits as a reference temperature.

Apart from waste heat flows, waste heat can be also contained (stored) in the thermal mass of process equipment or process media that remain within the process. The total amount of waste heat can be calculated as follows,

$$Q_{QWH,\Pr oc} = m_o \left(h_{po} - h_{\min}\right) + mc_p \left(T_p - T_{\min}\right) N_s \quad 2.12b$$

where

N_s is the total number of start-ups – and correspondingly of breaks – of the process

Analogous equations apply for waste cooling.

In a complex heat recovery system with both heating and cooling demands, there may be the possibility of direct heat exchange between cooling demands at high temperature and heating demands at low temperature. Therefore, the cooling demands of all subsystems (processes, pipes, equipments), $Q_{D,cooling}$, have to be added as potential heat source for waste heat recovery, and vice versa, the heating demands of all susbsystems, $Q_{D,heating}$, have to be added as potential cold source.

The really recovered waste heat Q_{QHX} depends on the configuration of the heat recovery system and is always less or equal than the total available heat and cold sources

$$\sum_{h=1}^{N_{HX}} Q_{QHX,h} \leq \sum_{source} Q_{QWH,source} + \sum Q_{D,cooling} \qquad 2.12c$$

and the total available heat sinks

$$\sum_{h=1}^{N_{HX}} Q_{QHX,h} \leq \sum_{source} Q_{QWH,source} + \sum Q_{D,heating} \qquad 2.12c$$

6.3 Quantity and quality: definition of temperature levels

6.3.1 General

In the EINSTEIN analysis, not only the amount (quantity) of energy in each of the subsystems is considered, but special attention is given to analyse the temperature level (quality) of the energy (demand and supply).

Although this makes the analysis of heat demand much more complex, it is absolutely necessary for the design of energy efficient solutions:

- The potential of heat recovery and heat integration depends strongly on the temperature levels of demand and supply (available waste heat or waste cooling)
- Many of the energy efficient conversion technologies such as CHP and heat pumps, and renewable energy sources (solar thermal energy) are (practically) limited to low and medium temperatures. The design of a supply system that makes maximum use of low temperature sources is therefore a necessary precondition for the utilisation of these technologies.
- Conversion efficiency of conventional heat supply equipment improves, and heat losses of distribution, storage and process equipment are lowered, if temperature levels are decreased.
- Cold generation is the more efficient, the higher the temperatures at which cooling energy has to be delivered, and the lower the heat rejection temperatures.

The temperatures in the processes and the heat supply systems must be distinguished as to their allocation in the system.

6.3.2 Process temperature

The temperature of the working fluid (process medium) in a process is the process temperature.

EXAMPLE temperature of the water in washing processes, temperature of air in drying processes, required indoor temperature for space heating or cooling, chamber (air) temperature in cooling chambers

6.3.3 Process supply temperature

PST is the temperature of the (heat or cooling) supply medium used for heating or cooling of the process at the boundary of the process (process heat exchanger or direct connection without heat exchanger).

EXAMPLE steam temperature of a water bath that is indirectly heated with steam (via heat exchanger), chilled water temperature in a cooling chamber that is indirectly cooled via fan-coil, hot air introduced into a drying chamber

PST can be distinguished into PST in the current system and a required minimum PST.

6.3.3.1 Process supply temperature – current system

The temperature in the current system is the one used in the currently running operation of the system.

6.3.3.2 Process supply temperature – minimum required

The PSTmin is the temperature needed in case of applying state-of-the-art good practice.

In the case that a direct supply of the (heated or cooled) process medium is possible, PSTmin is identical to the process temperature.

If indirect heating via heat exchangers is required, good practice is defined as

$$PST_{\mathrm{min}} = PT +/- \Delta T_{\mathrm{min}}$$

where

+	applies to heating
–	applies to cooling.

ΔT_{min} depends on the type of heat exchange.

Higher values of ΔT_{min} can be applied in case of specific process requirements:

- Requirements due to process kinetics (fast heating or cooling required),
- Requirements due to limited space for heat exchangers.

6.3.4 Central supply temperature

CST is the temperature of the (heat or cooling) supply medium used for heating or cooling of the process at the boundary of the conversion equipment (e.g. boiler or chiller house).

EXAMPLE steam temperature measured at the steam boiler, chilled water temperature at the chiller

Like in the case of PST, CST can be distinguished into CSTcurrent and the minimum required value CST_{min} .

In the case of decentralized heat or cooling generation (e. g. direct combustion in ovens, electrical resistance heaters in water tanks) CST is considered identical to PST.

6.4 Temperature levels as quality attributes of energy flows

6.4.1 Characteristic temperature level, temperature range, temperature dependent distribution of energy

Temperature levels such PT, PST and CST are relevant for the EINSTEIN methodology as an attribute (quality) of energy (heat or cooling) flows.

The following functions are relevant for a detailed temperature dependent analysis:

- UPH as a function of PT
- UPH as a function of both PST and PSTmin
- USH as a function of both CST and CSTmin

Depending on the required detail of information required, the following parameters are given for a heat flow Q at temperature T,

Where

Q is used for UPH or USH

T is used for PT, PSTmin or CSTmin.

6.4.2 Cumulative function and derived differential function

These functions represent the total amount of energy requirement (heat or cooling) in a cumulative and differential way as a function of the required temperature level. Q(T) gives the total amount of energy (heat or cooling) required at a temperature below or equal the temperature T.

EXAMPLE for the special case of heating of a fluid with constant heat capacity cp from an inlet temperature Ti to a targe (or process) temperature Tp, Q(T) is given by

0 for T < Ti

Q(T) = mcp (T – Tin) for Ti <= T <=Tp

Q(T) = mcp(Tp – Ti) for T > Tp

The temperature distribution of the heat demand is given by the derivative of the function Q(T) by temperature T:

Q'T = (dQ/dT)(T).

Alternatively to the representation by the temperature derivative Q' the temperature distribution may also be given as the incremental value

ΔQ(T,T+ΔT) = Q(T+ΔT) – Q(T)

over a discrete number of temperature intervals of size □T, with □T <= 10 K for heating and <=5 K for cooling.

6.4.3 Temperature range

The temperature range of the heat or cooling flow is given by the minimum and maximum temperature [Tmin, Tmax] for which there is a heat (or cooling) demand Q'(T) > 0.

6.4.4 Characteristic temperature

In order to give an orientative (descriptive) detail of information, the characteristic temperature is defined as the maximum temperature Tmax (in the case of heating processes) or the minimum temperature Tmin (in the case of cooling processes).

6.5 Environmental analysis

6.5.1 General

The environmental impact of energy use is due to a several factors such as:

- Emissions of different substances due to energy conversion (e. g. CO_2, other greenhouse gas (GHG) emissions, NO_x, CO, radioactive emissions, nuclear waste)
- Consumption of finite and non-renewable resources (fossil fuels, raw materials)
- Risk associated with the energy supply and conversion system (e. g. nuclear accidents, transport of fuels)
- Water consumption (e. g. cooling towers)
- Land use (e. g. use of land for biofuels or biomass competing with land use for agricultural production)

It would be beyond the scope of this document to make an exhaustive assessment of the environmental impact taking into account all the above mentioned factors. The parameters listed in the following section are used for a basic environmental assessment with EINSTEIN.

6.5.2 Main indicator: Primary energy consumption – definitions

The primary energy consumption should be used as the main indicator for environmental assessment.

The conversion factors used for electricity should correspond – by default – to the corresponding national electricity grid.

If other values are used (e. g. values of regional grids, values of a specific electricity supplier), this should be clearly highlighted.

All conversion factors used should be documented in the audit report.

Primary energy consumption should be split up into:

- NPE: fossile fuels and nuclear energy
- RPE: primary energy from sources with limited availability and potential alternative uses: e.g. biomass, waste, etc. In this case the specific type(s) of energy sources should be spedified and disclosed.

Physical energy that can be associated with unlimited renewable primary energy sources, such as solar radiation or wind energy, should not be accounted as primary energy consumption.

6.5.3 Multi-dimensional detail environmental assessment

6.5.3.1 General

If alternatively or as complement to primary energy consumption, other parameters on environmental impact are given, at least the following three parameters should be given. Additional parameters such as NO_x emissions, land use, etc. may be added.

6.5.3.2 Water consumption associated with thermal equipment

Water consumption by thermal equipment includes:

- Cooling water used in cooling towers
- Cooling water used for direct water cooling
- Feed-water for steam generation

6.6 Economic analysis: parameter definitions used in EINSTEIN

6.6.1 General

In energy auditing, economical analyses generally compare the costs of the existing system (existing heat and cold supply) with the expected investment and other costs of the proposed alternative energy supply system. Usually, the time horizon of the economic calculation is set to the life time of the project (life time of the equipments of the energy supply system), can however be changed to any value.

6.6.2 Basic cost-analysis

The economic calculation of EINSTEIN is based on the costs of the existing heat and cold supply system to be replaced and those of the proposed alternative(s). The main cost categories include investment, energy costs, operating and maintenance costs, contingencies and other non-re-occurring costs.

Contingencies are possibly occurring costs or revenues that have an effect on the economic analysis, such as increase in market shares, expected tax benefits etc. Other non-re-occurring costs include costs that arise once throughout the lifetime of a project, such as costs from legal allowance for the investment realisation.

For each proposal of a new heat and cold supply system, the cash flow shall be calculated year by year during the project lifetime, and then the net present value of the project during the project lifetime shall be calculated.

For each proposal, the internal rate of return (IRR) is also calculated for each year of the project lifetime after the payback period:

The modified internal rate of return (MIRR) is used in order to determine the efficiency of various alternative choices. For each alternative, the MIRR is calculated for each year of the project lifetime after the payback period:

The payback period refers to the period of time required for the return on an investment to "repay" the sum of the original investment. As an alternative approach, the total (yearly) energy system cost can calculated as the sum of the energy cost for fuels and electricity, the operation and maintenance (O&M) costs and the annuity of investment.

NOTE the EINSTEIN Audit Guide supports the auditor in theses calculations by indicating the formulas to be used.

6.6.3 Comparison of different points of view concerning economic and societal perspectives

One of the main differences between the macro-economic or social point of view and the micro-economic or company point of view is the consideration (or not) of subsidies[4] and externalities in the economic calculations:

- Whereas for the company's cost-benefit analysis, the net investment is the relevant investment cost parameter, from a social point of view the total (gross) investment cost should be considered, as subsidies are an effective cost for society. In the case of not realising the proposed investment, the amount of subsidies could be dedicated to another alternative energy saving or environmental protection measure.

- On the other hand, the cost of externalities (e. g. environmental hazards, see above) does not appear in a company's balance, but has to be considered in a social balance.

The second important distinctive feature is in the selection of the reference real interest rate for calculation of the annuity of investment, or – in other terms – the expectation (critical value) on return of investment.

Whereas the company point of view might request rather high rates of return (typically 10 %/year or more) comparable with the (expected) return of possible alternative investments, from society point of view rather low return rates comparable with average economic growth rates (2 – 3 %/year) are acceptable.

See table 2 and table 3 for an EINSTEIN comparison of the different points of view for optimization.

Table 1 — Most relevant cost parameters in micro and macro economic analysis

	Micro-economic analysis (company's point of view)	**Macro-economic analysis (society point of view)**
Investment	Net investment (gross investment minus subsidies/fundings)	Gross investment (money for funding otherwise could be used for other environmental protection measures)
Energy costs	Energy costs including expected rise of energy costs	
Other operation and maintenance costs	Utilities, maintenance, labour, legal compliance etc.	
Contigencies	e. g. positive impact on market share, saving of CO_2 emission certificate fees	e. g. external costs due to environmetal hazards, public health
Non-reoccurring costs	Saving repair costs that would occur without changing the energy supply systems; costs for authorization (construction permits)	

Table 2 — Most relevant indicators and objective function subject to optimization in micro- and macro-economic analysis

	Micro-economic analysis (company's point of view)	**Macro-economic analysis (public administration point of view)**

[4] In an analogous way the same reasoning applies also to other public support mechanisms such as tax reductions, feed-in tariffs, etc.

Main objective	Energy cost reduction (yearly costs and annuity of own/net investment)	Saving of primary energy consumption
Relevant indicators	IRR / MIRR Pay-back period NPV BCR	Additional yearly energy system cost per unit of primary energy saved. (Minimum required IRR as input)
Impact of economic constraints on optimisation criteria	Maximum absolute saving vs. maximum IRR/MIRR	Maximum absolute primary energy saving vs. minimum additional cost per unit of primary energy saved

7 Implementation of an energy audit using the EINSTEIN methodology

7.1 General

Energy audits have been developed and implemented by many parties[5] and yet present a challenge due to reasons among others as set out in 5.1. As energy consumption and its aftereffects are significant economic and environmental issues, where standardization can suggest solutions for having valuable and comparable results and outcomes of audit, standards for energy audits are being developed.

EN 16247-1 defines the attributes of good quality audits and presents the energy audit process as as a simple chronological sequence. This chapter presents the phases of a thermal energy audit based of the experiences gained by implementing such audits based on the methodology and tool-kit developed in course of EINSTEIN and EINSTEIN II.

Figure 7 illustrates the four phases of an EINSTEIN energy audit.

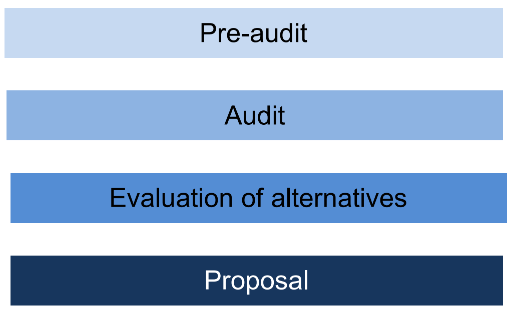

Figure 7 — Phases of an EINSTEIN energy audit

Figure 8 illustrates the then steps in an EINSTEIN audit within the four audit phases.

5 For an overview and evaluation of a series of … refer to ((EINSTEIN review??))

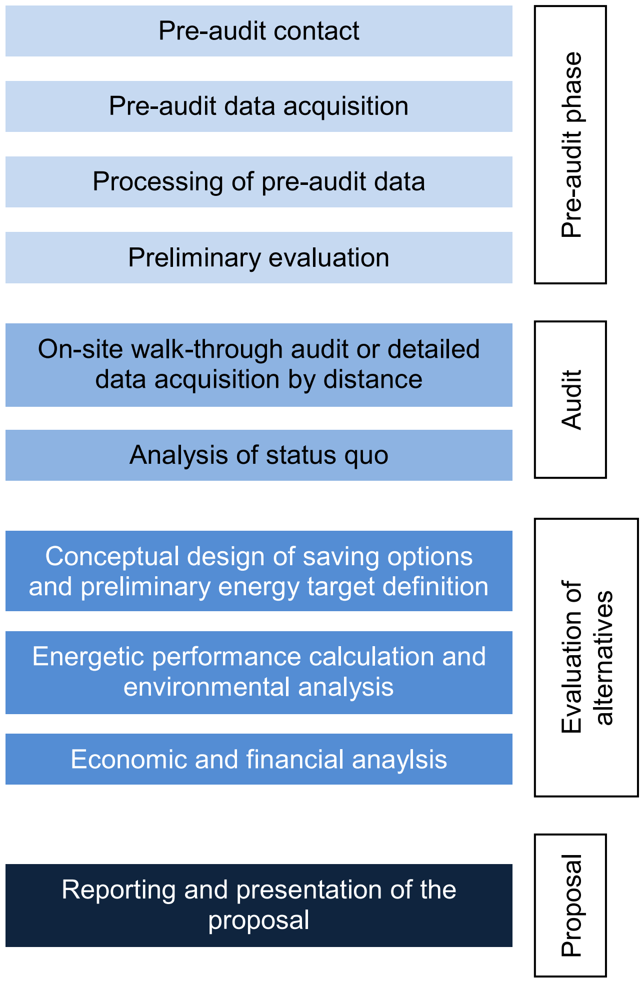

Figure 8 — The phases and steps of an EINSTEIN audit

Figure 9 establishes a reference of the EINSTEIN steps to the processes defined in EN 16247-1.

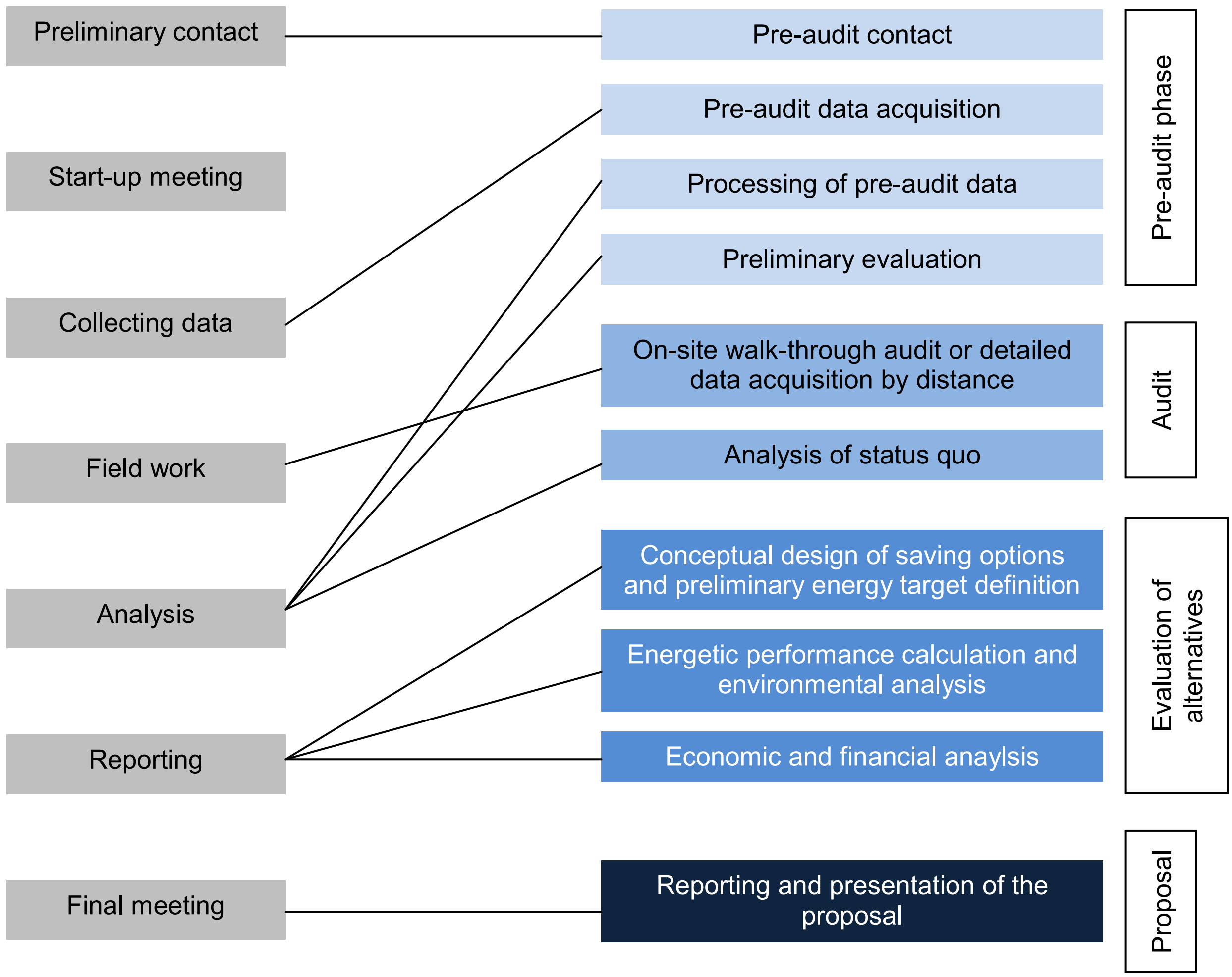

Figure 9 — Comparison of processes of EN 16247-1 and of the EINSTEIN methodology

7.2 Phases of an EINSTEIN audit

7.2.1 Phase 1: Pre-audit phase

The pre-audit phase is a preliminary activity realized outside the company to be audited. It consists of four steps:

— Initial contact with the company to be audited

— research of the status-quo of the company (i. e. actual energy demand profile, thermal processes in operation, equipments in use, energy bills), using an electronic standardized questionnaire for data acquisition to be filled in by the company.

— Processing the data obtained in form of preliminary information.

— first rough evaluation of the energy demand and of the areas of potential improvements.

A well-planned and diligently implemented pre-audit phase allows for time savings both in the company to be audited as well as on the auditor´s side.

7.2.2 Phase 2: Audit phase

Phase 2 consists of two implementation steps:

- an on-site walk-through visit to the company
- analysis of the results calculated by the software tool

The goal of the walk-through audit at the company is used e. g. to acquire missing information, through interviews and direct measurements; to inspect plants and hydraulics schemes.

If the pre-audit phase was implemented diligently, the resources needed for the on-site visit are less than compared to an audit with a less diligent pre-audit phase.

The data and information collected so far are used as input into the calculation tool provided by the methodology to evaluate the information gathered and to estimate the energy and economic savings. The tool used allows to

- check the consistency and completeness of the data acquired
- estimate (re-call for) the figures still missing
- elaborate a detailed breakdown of the heat consumption by process, temperature levels, fuels, etc.
- analyse the real operation performance of existing equipments
- compare with available benchmarks
- render the actual energy flows and inefficiencies of the thermal energy processes implemented by the company.

7.2.3 Phase 3: Evaluation of alternatives

Phase 3 looks after the design and evaluation of energy efficient alternate solutions and results in a comparison of different options through the following steps:

- 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.

7.2.4 Phase 4: Proposal

Reporting and presentation of proposals derived from the audit are supported by software tools, decision-supporting instruments and other features of an audit methodology to reduce time for analysis of data and to develop recommendations of measures to be taken to increase energy efficiency. The results, e. g. in form of reports, are easily understood also by non-experts, being descriptive and illustrated with graphs and tables.

7.3 Steps in the audit

7.3.1 General

The four phases of the EINSTEIN audit are divided into 10 steps (Figure 8). The following chapters explain the steps in detail and describe the related tasks, recommendations how to implement them and which tools should be available for support. The specific tools of the EINSTEIN tool-kit are indicated as well.

7.3.2 Step 1: Pre-audit contact

The contact with a company before the audit is used to assess the interest on the costumer´s side, to get access to preliminary information. Information should be provided on the overall procedure of the audit methodology and the type of results to be expected.

EINSTEIN Recommendations:

— collect information on the company and on the contact person before the initial contact;

  EXAMPLE who is the client, what might be expected from the audit (e. g. solution of technical problems, reduction of energy costs, fulfilling legal requirements, distinguishing the company from competitors)

  NOTE sources can be the internet, website of the company, company flyers, association registers, etc.

— verify who the right person with the authority to provide information and data and potentially to take decisions is;

— Use open questions to gain as much information as possible.

  EXAMPLE Open questions can be such as: Did the energy costs increase, and why? Are there any technical or organisational problems with the thermal system, e.g. with the public authority or neighbours, or the utilities? Who is responsible for the maintenance? How old is the boiler? Is there a shortage of time, budget, know how? Are there any plans for the future? Who will be responsible for a possible project?

— Presentation of the tool to be used to the company

— Inform client of data needed for the audit, including explanation of which data they could provide themselves and how to obtain them.

  NOTE Informing the client early about which data will be requested helps saving time both for the client and for the auditor. In addition, proceeding this way it is more likely to get a rather complete and detailed set of data.

EINSTEIN tool/support:

— EINSTEIN checklist

— EINSTEIN road show, EINSTEIN promotional brochure, EINSTEIN technical brochure.

7.3.3 Step 2: Pre-audit data acquisition

7.3.3.1 General

This step in the auditis related to acquiring data and to the preparation of the auditor, such as acquiring knowledge about the technical processes and about best available technologies in a typical company of the specific industrial sector.

7.3.3.2 Data acquisition

Acquisition of data before any actual audit on site may allow for first fast assessment and generate some preliminary ideas of possible energy saving measures at a very early point. A support feature indicating further information needed enhances the quality of the methodology.

Recommendations:

— use of a well structured questionnaire for the company to fill in

NOTE The EINSTEIN questionnaire is an example for a questionnaire that can be sent to the company to be audited after the initial contact (refer to Annex XX).

EINSTEIN tool/support:

— EINSTEIN questionnaire or checklist or both

NOTE refer also to the description of the menu “consistency check” in the user manual

7.3.3.3 Preparation of the auditor

Thermal industrial processes can be complex and are different for all industrial sectors; for an auditor it is important to gain a basic insight about sector specific problems, at best as soon as getting in touch with the client, and no later than visiting for the first time.

A large amount of information is available for most industrial sectors and subsectors, but in many cases access to the right information is difficult and time-consuming.

Recommendations:

— Gain insight of what are the most relevant processes in terms of energy consumption in a typical company of the specific industrial sector or type of building

— Understand what are the existing options for process technologies (best available technologies – BAT) and their main advantages and disadvantages

EINSTEIN tool/support:

— EINSTEIN tool-kit feature, supporting easy and fast access with indicating links to basic information in most sectors; additionally a large amount of web-links and bibliographic references is given in the additional documentation.

7.3.4 Step 3: Processing of pre-audit data

7.3.4.1 General

This step deals with the acquisition of consistent data necessary to implement the audit, completeness of data, including suggestions for prioritizing further inquiries.

It is a specific feature of EINSTEIN at this point to support the auditor to gain more technical knowledge and to prepare benchmarking. The EINSTEIN tool-kit also allows identifying possible measures already in step 3.

7.3.4.2 Consistency check: Pre-checking of data

At this stage, a pre-checking of the data delivered by the client should be carried out that results in a statistic of energy demand and supply and that checks the consistency of data.

EINSTEIN defines consistency as data set of a given company being consistent with respect to mathematical and physical relationships and with respect to practical limit values given by engineering knowledge.

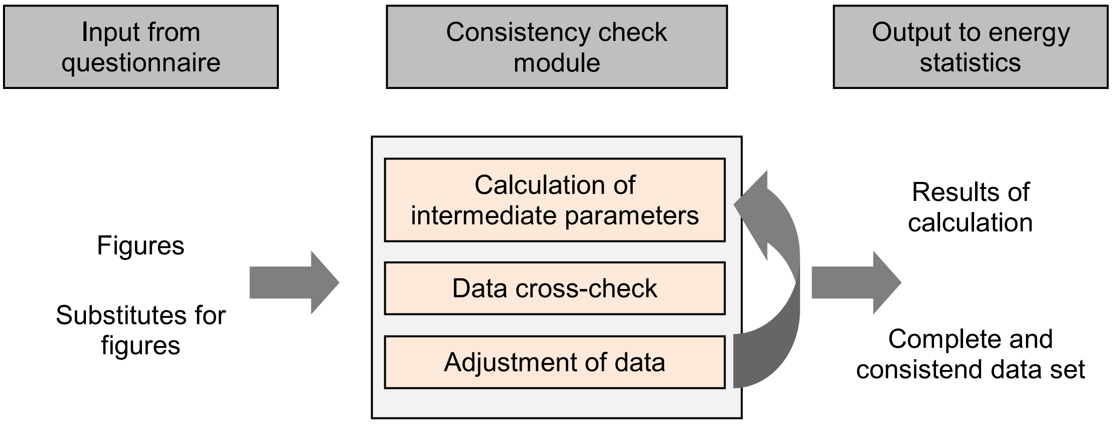

Figure 10 — Scheme of the consistency check procedure in the EINSTEIN software tool

Recommendations:

- Results of processing pre-audit data should provide information such as
  - a list of severe inconsistencies within the data (e. g. consumption of a fuel type is specified that is not used in any equipment)
  - a list of necessary data that are missing and can neither be computed nor estimated from other available information

EINSTEIN tool/support:

- EINSTEIN Audit Guide containing information on how to establish mathematical and physical relationships and how to recur to engineering knowledge on typical values or practical limits for certain quantities
- EINSTEIN guidance on resolving uncertainties for values obtained
- consistency check tool, delivering information on conflicts between the data set introduced and the given limits, automatic correction of the data production of a list of error messages
- automatic completion of all data that could not be directly taken from the questionnaire, but could be calculated from correlations and constraints.
- generation of a checklist with the most relevant additional data that should be obtained by the auditor.

NOTE refer also to the description of the menu “consistency check” in the user manual

7.3.4.3 Completing the set of information

If during the processing of the pre-audit data (refer to 7.3.4), serious inconsistencies or a lack of very basic data have been detected that are indispensable even for a first rough assessment, contacting the company e. g. by telephone or e-mail may help to acquire additional data or for clarifying doubts.

Having received the additional information, the consistency checking (see 7.3.4.2) should be repeated.

Recommendations:

- the following information should be available after requesting more data and clarifications:
  - the main products in the production process of the company and the quantities
  - the amount of total energy consumption in the company for thermal uses
  - the major heat and cold consuming processes should be identified, and at least a rough estimate of the energy consumption of each one
  - the main heat and cold supply equipment and nominal powers; a rough layout of the heat and cold distribution system; e. g. which boiler supplies heat to which process
  - temperature levels in the heat supply and in the main heat consuming processes

EINSTEIN tool/support:

- refer to 7.3.4.2

NOTE consistency of data can be assessed using the EINSTEIN consistency check as often as needed.

7.3.4.4 Acquisition of benchmark data

If at this stage some detailed information on the industry, on the applied processes and on the products is available, reference values from other similar industries can be used as benchmarks for energy performance.

Recommendations:

- search and collect benchmark information
- use data bases containing reference values

EINSTEIN tool/support:

- benchmark data base of the EINSTEIN tool allowing to search for reference values for many industrial sectors.

7.3.4.5 Acquisition of additional knowledge on the specific industrial sector or type of company

Based on the recommendations in 7.3.3.3, the auditor should enlarge the knowledge on the specific industrial sector or type of company using the knowledge obtained from company data on the specific types of processes and machinery.

Recommendations:

- Get information on and possible technological alternatives for the specific machinery used
- Get information on possible technological alternatives for the specific supply equipments and systems used

EINSTEIN tool/support:

- EINSTEIN documentation summarizing information available in the database (refer also to 7.3.3.4)

7.3.4.6 Identification of possible measures

Using the information on the company available by this time, a complete auditing cycle from data acquisition to proposal generation can be carried out. The results cannot be expected to be very precise, but can help to generate ideas, e. g. about the magnitude of possible savings, and approximate dimensions of possibly necessary investment, to be discussed with the client.

Recommendations:

- consult documentation on BAT for specific sectors and problems to generate ideas

EINSTEIN tool/support:

- EINSTEIN tool-kit automated function

7.3.4.7 List of priorities for further inquiry and data acquisition

Depending on the type of audit scheme (e. g. level of deepness of analysis or resources available for doing the audit) proposed to and agreed with the company, prioritization of further input needed supports the audit process.

A priority list of which information should be looked first for during the audit, and where the auditor must insist to obtain it, even if access to the information might be difficult, should be set up. This will result in a colleation of information after the audit that allows assessing the feasibility of the technologies and solutions that might be proposed or excluded.

Recommendations:

- Collect all data essential for the type of audit to be implemented;
- avoid collecting unnecessary data, especially if access is difficult.

EINSTEIN tool/support:

- n/a

7.3.5 Step 4: Preliminary evaluation

7.3.5.1 Quick pre-evaluation

As a result of processing of preliminary information collect to this point, a first quick pre-evaluation report should be generated. This first sketch of “what possibly might be done” in the client´s company can help both the auditor and the client company to focus from then on on the specific information required for assessing the most promising technological options.

Recommendations:

- A first report should give information on
    - identification of the most relevant heat and cold consuming processes and approximate quantification of the energy consumption
    - first quantitative analysis of heat and cold demand by temperature levels and time schedules; cumulative heat demand curves
    - based on this analysis of the heat and cold demands the report should

- identy of possible technological options for efficient heat and cold supply
- indicate the order of magnitude of dimensioning of required equipment
- estimate of energetic and economic performance to be expected

EINSTEIN tool/support:

- Report function of EINSTEIN processing the preliminary information, resulting in a first fast pre-evaluation report.

7.3.5.2 Interpretation of data towards the client

The presentation of a first pre-evaluation report to the company can be very useful in order to inform them about possible options and the necessary future steps to to go through. Estimative figures from pre-evaluation may help the company to take decisions on how to proceed concerning the audit.

EXAMPLE the company direction could want to deepen the analysis or apply for funding from public resources.

Care should be taken not to present too much detail that does not have a solid basis.

Recommendations:

- Information of the client that the presented figures are only first order-of-magnitude estimates that can change considerably in a more detailed analysis.

  NOTE Interpretation of economic estimates for proposed system designs are only as good as the data on equipment and sub-system costs that previously have been fed into the corresponding data bases. These data can vary strongly depending on local and national conditions, and the given default values should be interpreted only as rough and orientative figures.

EINSTEIN tool/support:

- n/a

7.3.6 Step 5: On-site walk-through audit or detailed data acquisition by distance

7.3.6.1 General

The information to be gathered at this stage of the audit should be collected on site; it can alternately be collected by distance, e. g. email or a phone call.

NOTE The success of an audit by distance depends largely on the knowledge and expertise of the auditor and on the degree of insight/expertise/personnel of the company and degree of contribution/involvement of the company.

NOTE Audits by distance might be implemented more frequently in the future due to lower costs and legal requirements to prove the implementation of an audit.

Step 5 also suggests applying the EINSTEIN consistency, to take measures on site and to inform the client about preliminary conclusions obtained so far.

7.3.6.2 Interviews and visit of site to gather detailed data

7.3.6.2.1 Data collection in the client´s office

Data collection in the client´s office should lead to completion of the set of data needed.

The same structure as used for collecting pre-audit data should be used (see 7.3.3); information should be requested on:

- general information on the company
- fuel and electricity bills and energy tariffs
  - information over several years, and, if available, detailed information on which share of consumption corresponds to which equipment, process and production line.
- data on the processes

Furthermore, additional information about the different components that contribute to the process heat demand should be gathered:

- fluid inflow and outflow
  - volume or mass and temperature levels (inlet/outlet)
- mass or volume to be heated (or cooled) at start-up of a process, number of operation cycles or breaks, and initial temperature from which the equipment has to be heated up (cooled down)
- thermal losses of the process equipment in operation
  - the power required to maintain the process at a given temperature.
- data on the heat and cold supply equipment
  - inventory of the existing equipment and the most relevant technical data, incl. age and state of conservation, in order to decide whether it makes sense to suggest a substitution; collect at least indicative information not only on the nominal power, but also on the energy (heat or cold) produced by this equipment (operating hours, part load factor), block diagram of which equipment supplies heat or cold to which process.
- data on the heat and cold distribution and storage
  - length and diameters of pipes and ducts; temperature and pressure levels and flow rates; this information can help to obtain a more precise picture of the consumption in the factory; heat storage wherever existing (volume, temperature and pressure levels, insulation).
- existing heat recovery systems
  - identification of existing heat exchangers for heat recovery, including technical data and the typical real operation conditions (flow rates and temperatures at hot and cold side).
- renewable energies
  - identification of available area (roof and ground surfaces) for a possible use of solar thermal energy (size, orientation, static capacity of roof, distance from the machine room and/or the processes); assessment of availability of biomass or biogas (either residual biomass from the production process itself, or from other nearby suppliers); motivation for the use of renewables besides the possibility of economic saving (e. g. contribution to protection of environment, marketing aspects)
- building heat and cooling demand

- inventory of heat and cooling demand of the existing buildings, the heating and air conditioning system used; temperature levels and schedules of use, etc.; sketches of the buildings whenever available.

— economic and financial parameters

  - O&M costs in the company (in addition to the energy bills); financial schemes (externally, internally) for investments in the energy supply system; requirements regarding pay-back or return rates.

NOTE the EINSTEIN Audit Guide includes many examples of data to be collected in the company´s office to orient the auditor.

Recommendations:

— If possible, technical staff of the company should be present in a visit on site, or any other personnel familiar with the technical details of the processes and equipment in the company.

— Organize the questions to ask and the information to gather into thematic blocks

— Take notes during the visit in the same structured format, grouped by the blocks. This helps to keep track and to be able to rapidly check if all necessary data was collected, or if and what is still missing

EINSTEIN tool/support:

— Support to calculate thermal losses of the process equipment in operation in some of the most frequent cases

7.3.6.2.2 Walk-through of the site

The walk-through should be used to deepening the insight into the different processes, to ask about details and to put questions that did not come up during the visit so far.

The walk-through should be used to see at least the relevant process and heat supply equipment.

Recommendations:

— take a camera to take pictures of equipment and of details

— get in touch with the maintenance staff of the company that can give valuable information on everyday practice.

— anticipate possible problems that might have to be solved for the modifications of the systems could be suggested as alternatives already in mind

  - possible points of connections for new heat and cold distribution lines or equipments

  - available space for new equipments or storage

EINSTEIN tool/support:

— Examples of guiding questions

7.3.6.3 Fast on-site completeness check and consistency check

The EINSTEIN support tool allowing easy data entry and rapid assessment during the on-site visit, another consistency check should be executedon site. The missing information can then be immediately and explicitly requested.

Recommendations:

- The consistency check should result in information indicating
  - if the data are consistent
  - if there are contradictions in the informations (e. g. confusion of units)
  - if there are relevant data missing and if so
  - which data are missing.

EINSTEIN tool/support:

- consistency check option of the EINSTEIN software tool
- automatic proposal generation tool, if information is sufficient, giving an idea of orders of magnitude of possible alternative supply systems

7.3.6.4 Measurements during visit

In many production processes the total yearly and often even monthly energy demand is known based on the utility bills of the company, but the demand cannot be allocated to the specific equipments and processes. This knowledge, at least for some crucial processes and for the main heat and cooling supply equipment, is essential for auditing purposes

It is also essential for applying the EINSTEIN methodology.

Recommendations:

- check together with the company which data are already monitored and which combination of data sets can be used for analysing the energy flow.
- measurements during a visit at the company might be necessary to overcome the existing lack of data.
- on-site measurements done by the company itself can help to analyse detailed energy profiles including energy demand and waste heat availability schedules

EINSTEIN tool/support:

- Information on different methods, instruments and procedures are given in the EINSTEIN Audit Guide

7.3.6.5 Involving the client in measurement programs

If there is information missing that cannot be obtained instantaneously by metering on-site, the company should be requested to collect the data.

EXAMPLE Register of temperatures, pressures or counters of already existing sensors in some periodic intervals

Recommendations:

— Supply the client with the measurement device needed instruct the client to register and how to register the measured values during a specified period

— define some simple experiments that can be carried out by the client (e. g. determine heat-up or cool-down curves of some equipment) to support data collection

EINSTEIN tool/support:

— n/a

7.3.6.6 Discussion of insights from the visit

After the visit, initial information should be given to the audited company.

Recommendations:

— Include information on how the auditing process will proceed;

— Define and decide together with the company which of the possible measures should be analyzed in detail and which should be excluded a priori.

— Fix a schedule for the future steps: deadline for the delivery of additional information by the company; deadline for the delivery of the audit report.

EINSTEIN tool/support:

— n/a

7.3.7 Step 6: Analysis of status-quo

7.3.7.1 General

This step includes another checking of consistency and of completeness of data, suggests how substitutes for missing parameter information can be set up, how to breakdown consumption, how to do an analysis of real operation of existing equipment. It also includes information on benchmarking.

7.3.7.2 Checking of consistency and completeness of data

A systematic analysis of the status-quo is the starting point for further identification of energy saving opportunities for the client. Breaking down the total energy consumption into different components and defining the main energy streams, sources and sinks usually requires the acquisition of a rather large number of data; accuracy and consistency of the available data affect significantly the reliability of the alternative solutions envisaged.

NOTE the EINSTEIN Audit Guide includes many examples of how this can be done to orient the auditor.

Gathering data on the status-quo (e. g. present state energy demand) can confront the auditor one or both of the following problems:

— Redundancy of information and possible conflicts between data

  — If different ways are used to determine or to calculate the same parameter, this might lead to different results. It might be difficult to select one, resulting in uncertainty about correctness of the information.

— Lack of information

EXAMPLE the total heat demand (calculated from the fuel consumption) might be known as well as the demand of the most heat consuming process, but there is no information on how the remaining demand is shared by two other small processes.

Checking both redundancy and completeness in a complex system can be difficult and time-consuming. Mathematical functions and physical laws and engineering knowledge can be used for the checking.

Whereas mathematics give a sharp and clearly defined result on the validity of some parameter value (in the context of the whole data set), the limits from engineering knowledge are diffuse to a certain degree.

Recommendations:

- solve redundancy and lack of information applying
  - mathematical and physical knowledge
  - engineering knowledge

EINSTEIN tool/support:

- EINSTEIN consistency check

7.3.7.3 Substitutes for missing parameter information

Depending on the thoroughness of the energy audit, the quantity of information and the level of accuracy necessary can be different. For the purpose of preliminary evaluations the amount of information needed is less, while for a detailed analysis a large number of parameters have to be taken into account.

However, in many cases, not all the figures which are theoretically required are easily available. Sometimes, especially in small companies, even very basic data are difficult to acquire, and therefore after basic consistency checking and data completing, there still may be gaps in the data set or data can be determined only with a very low degree of accuracy.

These unknown parameters can be substituted by typical values derived from engineering knowledge.

If collection of data, calculation, estimation or assumption does not deliver usable data, some hypothesis or scenarios on the missing information could be developed to propose figures that at least seem reasonable. Alternate scenarios can be developed to define boundaries: one scenario that is very good (for the system to be proposed), one very bad, and one in between.

Recommendations:

- If estimates or ssumptions have to be made or if scenarios are developed to simulate a set-up, this has to be clearly indicated and labelled. A follow-up should be done when data become available at a later point.
- If no such procedure leads to feasible results, the client should be informed that no reasonable proposal can be generated due to lack of input data.

EINSTEIN tool/support:

- n/a

7.3.7.4 Detailed breakdown of consumption

The breakdown of the energy consumption by processes, equipment, and fuel and temperature level is very important in order to have in view all the aspects related to the energy usage in the analysed industry. The resulting statistical information for the present state is a starting point for decisions on application of energy saving measures and technologies.

The overall energy consumption permits the auditor to rapidly assess the rate of the energy consumption and the a priori possibilities for energy savings, when compared with available reference data for the industrial sector (benchmarks).

When different alternative proposals for energy efficiency improvements are considered, the information on energy demand and its composition can be used as reference for analysing the effect of the proposed measures for improvement.

- Recommendations:
  - Generate useful energy statistics
    - Breakdown of the energy by processes, equipment and fuel type: used for identification of the principal energy consuming processes, equipment, and the fuel types responsible for the highest energy bill.
    - Analysis of the energy consumption by temperature level: permits to evaluate the potential for waste heat recovery and for the application of efficient low-temperature technologies, e. g. solar thermal, heat pumps, cooling water from CHP engines.
    - Analysis of the impact of the energy consumption in terms of primary energy consumption, CO_2 and other emissions: permits the evaluation of the environmental impact of the company.
    - Breakdown by specific energy consumption ratios, EI and specific energy consumption SEC: permits the comparison with reference benchmark data and fixing realistic energy consumption targets.
  - Generate statistics breakdowns for different temporal scales
    - Annual data show the main energy consuming processes, equipments and energy types, and give general indications where the energy efficiency measures should be aiming first.
    - Monthly data are necessary for considering seasonal or ambient temperature-dependent variations in demand (e. g. space heating, drying processes, seasonal variations of production in the beverage industry) and in supply (e. g. solar thermal systems) and are required for assessing the feasibility of specific technologies.
    - Hourly data scale of heat demand and supply is important for determining peak power consumption, analysing possibilities for waste heat recovery, and especially for determining the requirements of accumulation of heat and cold.

EINSTEIN tool/support:

- EINSTEIN software tool supporting the auropmatic generation of breakdowns of a company´s energy demand both for the present state of the industry and for any future scenarios given the different alternative proposals

7.3.7.5 Analysis of real operation of existing equipment

Technical data of equipments are very important for assessing the energy system performance. The most relevant performance parameters are energetic conversion efficiencies and heating and cooling capacities.

In most cases, the only accessible information on these data is the nominal value indicated in the technical data sheets of the equipment manufacturers or on the label of the equipments.

Actual performance of equipment can be quite different from nominal data, due to fouling and malfunctions, to extreme operation conditions in specific applications, and to a series of other factors. Therefore it can be interesting to compare actual performance of the equipments with nominal performance data.

One possibility of assessing actual performance is measuring of input and output.

Recommendations:

— compare actual performance of the equipments with nominal performance data

EINSTEIN tool/support:

— EINSTEIN tool automatically carrying out the calculations, if measurement data are available, and in case of significant differences between nominal and actual equipment performance warning messages will be generated to the attention of the auditor.

7.3.7.6 EINSTEIN benchmarking

7.3.7.6.1 General

EINSTEIN has developed a concept for benchmarking as part of its methodology.

Data for benchmarks used in EINSTEIN have been selected from BAT reference documents, other literature and sources in order to form a basis for defining indicators and benchmarks and targets.

NOTE BAT Reference Documents (BREFs) for different industrial sectors are published by the European Union on http://eippcb.jrc.es/pages/FActivities.htm

EINSTEIN also indicates additional sources such as literature for industrial sectors and sub-sectors, for products or for unit operations. This information is available in the default data base of the EINSTEIN software tool. For each benchmark in this database the reference of origin is specified. Classification by industrial sector and sub-sector is based on the NACE code.

NOTE the EINSTEIN Audit Guide fully explains the current EINSTEIN benchmarking procedure.

Classification used in EINSTEIN benchmarking is based on reference quantities and on types of energy.

7.3.7.6.2 Classification of indicators by reference quantity used in EINSTEIN benchmarking

For benchmarking in EINSTEIN three types of reference ratios are systematically used depending on the quantity used as a reference. This feature is integrated into the EINSTEIN software.

— Energy intensity;

— Specific energy consumption per product unit;

— Specific energy consumption per intermediate products in a unit operation.

7.3.7.6.3 Classification by types of energy used in EINSTEIN benchmarking

For benchmarking in EINSTEIN three classifications types of energy are used as a reference.

— Electricity vs. fuels;

— Total final energy consumption;

— Total primary energy consumption.

7.3.8 Step 7: Conceptual design of saving options and preliminary energy target definition

7.3.8.1 General

EINSTEIN uses a concept at step 7 that looks at potential energy savings from several perspectives; demand reduction is one aspect, another is the pre-design of heat exchange and storage. Then alternative supply system options are analyzed.

Figure 11 illustrates the sequence of the steps used in the EINSTEIN methodology. After technical and technological performance assessment, energetic and economic performances are considered. These are part of EINSTEIN step 8 and step 9. These three steps of phase 3, evaluation of alternatives, enable the auditor to compare the options and to select the best one.

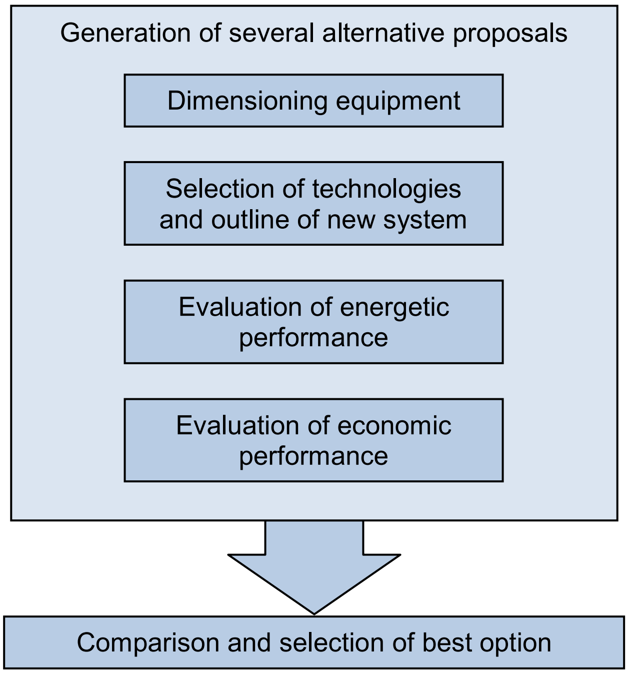

Figure 11 — Steps for generation and evaluation of alternative proposals

7.3.8.2 Demand reduction related to maintenance, repair and behavior

Activities related to maintenance, repair and behavior can lead to demand side savings and contribute to energetically improve the production process.

NOTE Many energy efficiency manuals and reports of case studies exist that show the possibilities of different measures for demand side savings. An extensive list of relevant documents has been put together in the EINSTEIN report on Energy Auditing Practices and Tools [Vannoni et al. 2008]. In the report measures have been listed by sectors, as well as by heat and cold supply technologies to give a structured overview of saving potentials.

Recommendations:

— Foresee housekeeping measures to be regularly implemented

EINSTEIN tool/support:

— List of suggestion for measures included in the EINSTEIN Audit Guide

7.3.8.3 Demand reduction based on process optimization in industry

Process optimisation can lead to demand side savings; the analysis of the possibilities is based on a deeper analysis of data and information; each process should be evaluated on its effectiveness and efficiency.

Recommendations:

- assess measures to improve the processes, such as change of the technology in place and improvement of the process by improved regulating

EINSTEIN tool/support:

- EINSTEIN tool for process optimization in industry including a database of BAT and process optimisation measrues for different unit operations and an identification tool for optimization possibilities for the technology and equipment used for the processes

- EINSTEIN database to browse for general energy saving measures and specific saving measures documented for the unit operations applied in the production system

  NOTE The builds on existing information sources, which were partly collected within the EINSTEIN project. The EINSTEIN database consolidates information on best available technologies and process optimization possibilities for different unit operations from different sectors. This allows learning from other solutions applied in other industry sectors for similar process engineering problems.

7.3.8.4 Demand reduction based on measures for buildings

EINSTEIN includes a concept of how to reduce thermal energy demand in buildings, main energy improvement measures in buildings being distinguished into basic and active measures (see Figure 13).

Recommendations:

- Measures for buildings should be included in an audit to reduce energy demand in buildings

EINSTEIN tool/support:

- The EINSTEIN Audit Guide provides information on measures, including measures on
  - exterior insulation
  - Thermally optimized windows and doors
  - Airtightness
  - External shading
  - Natural cooling
  - User‘s briefing/ behaviour
  - Solar space heating of factory buildings

NOTE Specifications on building design and construction and space heating to reduce energy demand are not a part of this CWA.

7.3.8.5 Pre-design of heat exchanger and storage network

7.3.8.5.1 General

A structured analysis of the potential of further energy savings by heat recovery is highly important as the application of any energy efficiency measures prior to the change of an energy supply system ensures an efficient overall concept for a sustainable supply of energy in the future and avoids over-dimensioning of supply equipment.

7.3.8.5.2 Stream assessment

In EINSTEIN, by using the pinch analysis[6)] the potential of heat recovery is shown within a system of energy streams. Based on the acquired data of processes and supply equipment of the company and based on the energy balance, enthalpy streams can be defined that show the energy demand or the energy availability of a process, respectively.

Such streams can be defined for any process and equipment; hot and cold composite curves can easily be drawn and show the theoretical maximal potential for heat recovery for a defined ΔT_{min} over the heat exchangers.

NOTE details on the principles and on how to evaluate streams can be found in the EINSTEIN Audit Guide.

Based on the theoretical potential, a technical and economical sensible heat exchanger network can be identified.

NOTE the EINSTEIN Audit Guide contains a list of general criteria to be taken into account.

Recommendations:

— Use the pinch theory to assess heat flows

— use algorithms for an automatic proposal of heat exchanger networks developed by research to facilitate calculation.

  NOTE time schedules and storage design has hardly been integrated into existing algorithms. Addittionally, giving internal heat recovery higher priority and aiming in general at highest energy savings of the overall network are not usually considered.

EINSTEIN tool/support:

— Automatic design of a heat exchanger network based on the strategy of the maximum energy recovery network [Kemp, 2007].

  NOTE within the heat exchange network simulation, the heat exchanger performance is simulated with the varying enthalpies and temperatures over time. In this simulation, also the size of an approximate storage tank is calculated

7.3.8.5.3 Storage conception

EINSTEIN Storage concepts and batch processes are important factors for the development of heat recovery networks in industry. General operation schedules of the different processes within a typical week, including start and end time of a shift, number of batches done, the duration of one batch, etc. indicate the real operation schedule. This leads to conclusions related to the need for storage. Operation management and

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6) SOURCE/REFERENCE

intelligent planning of heat demand cannot only reduce peak loads but as well increase the continuity of streams to influence the need for storage.

EXAMPLE full continuity of a process cannot be reached, as there are breaks in the production schedule that cannot be coverd by management decisions. Assuming a desired exchange heat between two processes, heat exchange cannot be assured without storage.

Recommendations:

- Apply a time slice model, with each time slice being defined by start and end times of processes.
- For each time slice calculate the difference in energy demand and energy availability. The energy surplus or the energy demand form the basis for the storage design
- Design storage in a simulation that takes into account cumulation, appropriate size of the storage, current volume of the storage and respective losses in each time period.

EINSTEIN tool/support:

- EINSTEIN methodology that first selects two streams for a heat exchanger, then calculates their storage capacity over the principle time slice model and finally calculates the total transferable energy between the two streams. This is done for many combinations of streams and finally the best one (highest energy savings with one heat exchanger) is selected.

7.3.8.5.4 Proposal of heat exchangers and their design

As EINSTEIN aims at the highest possible energy transfer, for the heat exchangers proposed in EINSTEIN step 7 it suggest them all to be counter-current heat exchangers.

EINSTEIN offers a method how for a first estimate on the investment costs of heat exchangers, the area of the heat exchanger and the heat transfer coefficient have to be defined as well as overall heat transfer coefficients.

It also distinguishes between values to be used for a first estimate which should be recalculated taking into account subsequently available information on real flow characteristics.

Heat demand and availability cuves are suggested as auxiliary to design suitable supply equipments according to the heat demand that exists at different temperature levels.

It might be important in some cases to re-design the heat exchanger network after the energy supply systems have been changed.

EXAMPLE This might be the case, when a heat exchanger uses an off-gas of the existing boiler which is later substituted by a combination of a biomass boiler and a solar plant.

Recommendations:

- check the heat exchanger network proposed after any change in the energy supply system

EINSTEIN tool/support:

- re-use of the EINSTEIN heat exchanger network calculation based on the future energy balance with new supply equipments

7.3.8.6 Pre-design of alternative supply system options (including changes in fuels and changes in the distribution system)

7.3.8.6.1 General

Once the possibilities for heat recovery and process temperature modifications have been examined and applied the next essential part of the EINSTEIN audit methodology is the generation and pre-design of alternative supply options aiming at a further reduction of the energy consumption.

An alternative supply option or proposal is an alternative set of heat and cooling supply equipment and distribution system that can substitute the existing one, offering energy savings, environmental and economic benefits with respect to it.

The pre-design of such alternative system involves the selection of the appropriate equipment, and the evaluation of its energy performance considering the heat and cooling demand and availability of the processes and its temporal distribution.

Starting point for the design of the heat and cold supply system therefore is the analysis of the aggregate energy demand after process optimisation, heat recovery and storage pre-design, taking into account the following aspects:

- temperature level of the remaining heat demand (after heat recovery)
- quantity of heat demand and waste heat availability
- temporal distribution of heat demand and waste heat availability
- availability of space
- availability of alternative energy sources and their cost (e. g. biomass)

7.3.8.6.2 Methodological approach of EINSTEIN on the pre-design of alternative supply system options

The optimisation of the overall system of heat and cold supply in EINSTEIN is based on the assumption of a heat supply cascade for the aggregate heat and cold demand:

- the most efficient equipments supply heat at base load (large number of operating hours) and at relatively low temperature levels.
- the remaining peak load and/or the remaining demand at high temperatures is then covered by less efficient equipment, appropriate for this purpose.

The approach of the heat supply cascade does not lead necessarily to the optimum, and also does not take into account the peculiarities of a specific heat distribution system, but it gives a good first approximation, that then can be manually optimised and adapted to the specific case, depending on the experience of the auditor.

The design process of the overall supply system is carried out in the following steps:

- Selection of the type of equipment to be used in the heat supply cascade, and order in the cascade. This step has to be carried out manually by the auditor, although the EINSTEIN software tool by default proposes some recommended ordering of the equipment.
- Dimensioning of the equipment individually for each type of equipment in the cascade. For this purpose, the EINSTEIN software tool offers so-called design assistants for several technologies. This automatic or semi-automatic pre-design can then be manually fine-tuned if desired.

— Selection of the optimum combination of the “whole”. This step has to be done essentially a posteriori by a “trial and error” strategy: different alternative combinations of technologies can be consecutively designed and finally compared with respect to their energetic, environmental and economic performance.

— In many cases, the optimisation of the sequence heat recovery – heat and cold supply has to be carried out iteratively (repeating the same sequence several times), as a change in the supply system may lead to changes in the available waste heat, and therefore may affect also the waste heat recovery potential.

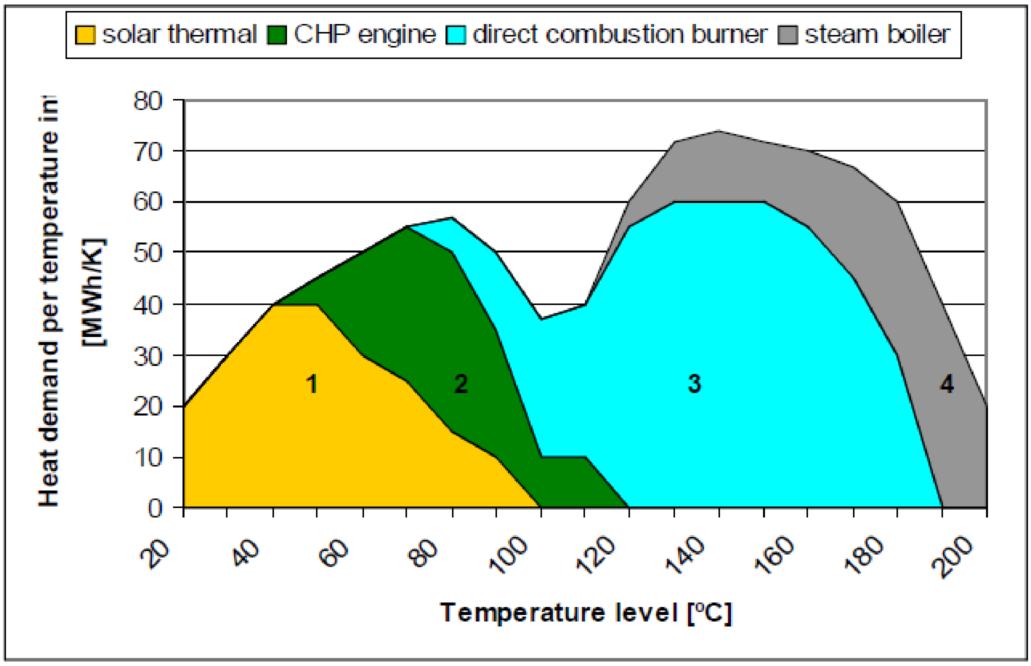

Figure 12 — Example of the contribution to the aggregate heat demand at different temperature levels by a heat supply cascade formed by different types of equipment.

7.3.8.6.3 Pre-design of heat and cold storage

EINSTEIN suggests which criteria to apply for selecting a storage technology and to look at such technology as an integral part of all energy efficient heat and cooling supply options.

7.3.8.6.4 Pre-design of energy efficient heat and cold distribution

EINSTEIN suggests several alternatives.

Recommendations:

— Analyse various possibilities, e. g. reduction of the temperature level and direct combustion:

EINSTEIN tool/support:

— n/a

7.3.8.6.5 Pre-design of combined heat, cooling and power

As EINSTEIN suggests the design of a cogeneration installation to supply the heat load of the industrial site where it is located.

This includes advice on the excess electricity produced and on the calculation of the primary energy savings achieved by combined heat and power installations.

As EINSTEIN is concerned mainly thermal energy supply, the specific net primary energy consumption per unit of heat produced with CHP, is a prime concern..

Recommendations:

- The selection of the appropriate technology for CHP depends on the size, continuity and on the temperature level of the heat demand. CHP should be designed for base load and/or in combination with a heat or cold storage.

EINSTEIN tool/support:

- n/a

7.3.8.6.6 Pre-design of heat pumps

EINSTEIN focusses on heat pumps used typical industrial applications, such as process water heating and cooling, drying processes, space heating, evaporation and distillation processes, and waste heat recovery.

Recommendations:

- List of.aspects to be considered

EINSTEIN tool/support:

- Description of context to be considered when heat pumps application is planned.

NOTE details explaining the suggestions can be found in the EINSTEIN Audit Guide.

7.3.8.6.7 Pre-design of solar thermal energy applications

EINSTEIN suggests to couple solar thermal energy with an existing conventional heat supply system.

Recommendations:

- Assess viability of coupling
- Find the techno-economic optimum
- Consider load profile and solar heat storage

EINSTEIN tool/support:

- Suggestions for feasibility assessment of a solar process heat plant

7.3.8.6.8 Pre-design of energy efficient boilers and burners

EINSTEIN suggests several measures for the pre-design to reduce the energy consumption of a new or existing heat generation system, such as boilers, steam boilers and condensing boiler, including the evaluation of the overall performance of an existing boiler, the year of installation; the technical data (manufacturer, nominal power, etc.), the state of insulation, possible leakages and the control strategy of the boiler.

Recommendations:

- Follow a list of items to be considered.

EINSTEIN tool/support:

- The EINSTEIN Audit Guide gives detailed information on the various items to be considered.

7.3.8.6.9 Pre-design of energy efficient cold generation

EINSTEIN suggest several issues to consider for chiller application and design.

Recommendations:

- Follow a list of items to be considered.

EINSTEIN tool/support:

- Support for assessment of chiller application and design

NOTE the EINSTEIN Audit Guide provides explanations to all assessment aspects.

7.3.9 Step 8: Energy performance calculation and environmental analysis

In order to assess the energy consumption of a proposed heat and cooling supply system, a model calculation (simulation) of the system has to be carried out. It should allow dynamic simulations.

For this purpose, within the EINSTEIN software tool, a system simulation module is available for all technologies, so that dynamic simulations can be carried out.

For a detailed description refer to annex C.

7.3.10 Step 9: Economic and financial analysis

7.3.10.1 General

EINSTEIN explains to the auditor which costs and cost categories should be considered. Different from conventional cost assessments with focus on investment costs and operating costs, EINSTEIN looks also at contingencies and non-reoccurring costs for a consideration of the overall true costs.

Specifically, for a TCA that looks at a longer time period and takes into account macro-economic parameters as well, contingencies and non-reoccurring cost are the categories to be considered.

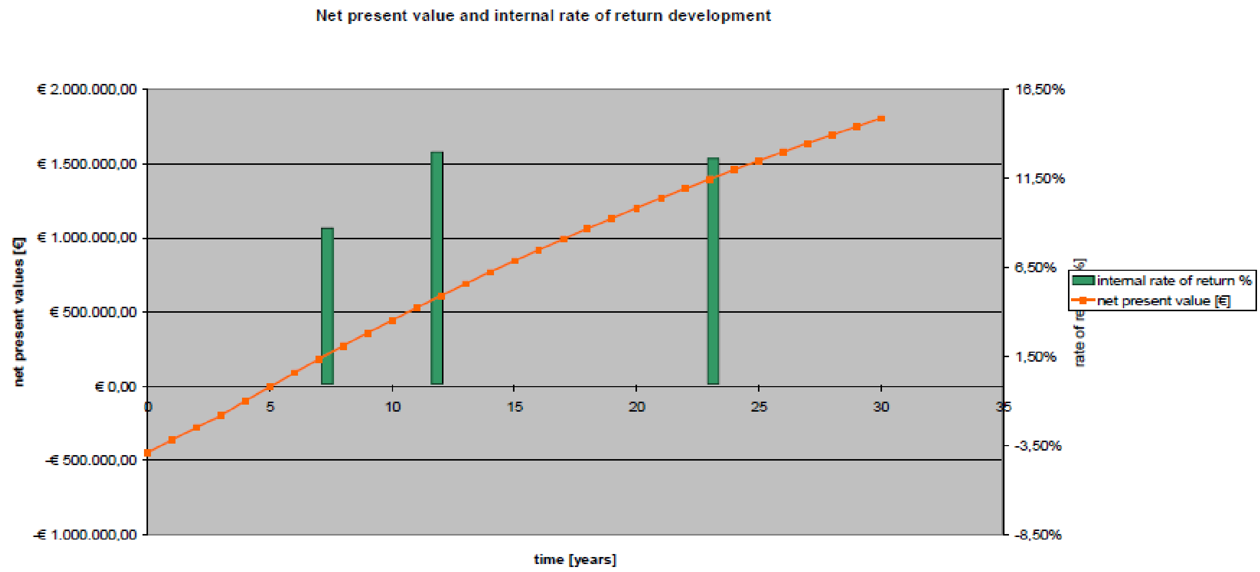

Figure 13 — Example of the result of an economic analysis in EINSTEIN

Recommendations:

— put emphasis on the economic analysis of the proposed energy supply

— The cost analysis should be suitable for detection of all parameters that influence the economic performance of energy efficiency and the installation of an energy supply systems in industrial processes, besides the energy costs.

— result of the economic analysis should the investment, the payback period and the benefit cost ratio, economic parameters that show the economic performance over a longer period of time.

EINSTEIN tool/support:

— List of cost categories to be considered, e. g. investment costs, operating costs, contingencies and non re-occurring costs

— List of parameters to be considered for TCA:

NOTE the EINSTEIN Audit Guide includes details on calculation of internal reate of return, development of net values, etc.

7.3.10.2 Minimum requirements for the specification of economic analysis

EINSTEIN has set minimum requirements for the results of an economic analysis, including qualitative economic assessments:

— Basic project parameters: investment, energy and O&M costs; other costs, if included in the analysis. It should be clearly specified whether the total or the own investment cost is used in the analysis.

— Rates of increase of prices used in the analysis (general inflation rate, expected rates of increase of energy tariffs)

— Economic depreciation period (used for calculation of annuity) and expected lifetime of equipment supposed

  - Interest rate used for the calculation of the annuity of investment. It should be clearly specified whether the nominal or real interest rate is given.

  - For qualitative assessment, such as feasible/not feasible, the parameter used for assessment and the corresponding thresholds should be specified (e.g. maximum pay-back period, minimum internal rate of return).

7.3.11 Step 10: Reporting and presentation of the proposal

7.3.11.1 Content of the report

EINSTEIN suggests a report from consisting of the description of the alternative proposals and schematic drawings (e. g. block diagrams and or hydraulic schemes) that clearly illustrate the position of the new equipment in the existing system.

A minimum contents is suggested as well as what should be included in the description of alternatives.

Recommendations:

- Minimum contents of the audit report:
  - executive summary
  - data collected and/or estimated during the auditing process and used as a starting point for the analysis.
  - breakdown of present state energy consumption comparison with benchmark reference data.
  - description of the different alternative proposals analysed, highlighting the necessary modifications with respect to the present state, and the differential features of each of the alternative proposals.
- alternative proposals description including
  - Comparative tables and figures with the main results (energetic, environmental, economical) of the different alternatives studied
  - Presentation of a detailed financial analysis of the finally proposed solution or solutions,
  - Mention of possibility of third-party financing of necessary investments, possible sources of funding and other types of incentives, if available.
  - Statement and identification of the necessary uncertainties that exist after concluding a fast audit, especially if these may have a critical impact on the feasibility of the proposed systems.
  - Highlighting the aspects that should be analysed in more detail before taking a decision on a change in the system.

EINSTEIN tool/support:

- EINSTEIN software tool automatically generating a standard audit report containing all information, produced as spreadsheet that can be edited and modified, adding manually additional content, etc.

NOTE the EINSTEIN Audit Guide contains a detailed description of the report details.

7.3.11.2 Presentation to the company

EINSTEIN suggests presenting the report to the company in person to explain the proposals, to avoid misunderstandings and to highlight the advantages of the proposal to the decision makers in the company.

Recommendations:

- An audit report clear enough to be sent by mail or e-mail, in case a personal presentation is not possible (e. g. large distance to the company, no budget for another second visit)

EINSTEIN tool/support:

- EINSTEIN audit report in a format that can be edited and adjusted to client´s capacity to understand such a report.

7.3.12 Follow-up actions

The follow-up of the audit is not part of the phases and steps of EINSTEIN; it is recommended though by EINSTEIN to have the auditor do a follow-up to learn from the audit and add to expertise and knowledge.

The main objective of the follow-up is to check if the audited company realized the the proposed investment and installed the new energy efficient systems.

If the company did not follow the suggestions that the auditor considered energetically and economically feasible, it is worthwhile to know the reasons for further usage.

If the company installed the system proposed, keeping track and making use of the actual performance of the new system, will also add to the expertise and can serve as reference.

Annex A
(informative)

Topics of a typical checklist for thermal energy audits

General situation of the company:

- economic situation (past and present)
- future prospects (evolution of production volume foreseen, other important changes or projects)

Fuel and electricity bills:

- get a quantitative overview of present energy consumption and tariffs paid
- historical data for the previous years if available
- monthly data if available, or qualitative information about seasonality of the demand

Description of the production process (flow chart):

- which production lines exist in the company
- which are the product flows and the different processing steps

Description of the different processes:

- which of the processes are consuming heat and cold
- which quantities of product are processed
- which temperature levels are used (in the heat supply, in the process itself)
- how many times operates the process and during how much time

Description of the heat and cold supply system

- technical data of the equipments (boilers, chillers, etc.)
- temperature and pressure levels in the heat distribution and in the processes

Description of the buildings, production halls and stores:

- data on consumption for space heating and cooling if available
- surface area, occupancy

Annex B
(informative)

The EINSTEIN audit tool kit for quantifying potential energy savings

B.1 Characteristics of the EINSTEIN tool kit

EINSTEIN is in itself a methodology that works out energy efficient solutions for production processes based on energy saving and renewable energy sources.

It calculates the total thermal energy demand from consumers of complex heat and cooling energy and breaks it down into different components. It evaluates process optimization possibilities and indicates demand reduction through the use of efficient technologies. It analyses the production system by a Pinch Analysis to assess saving opportunities through heat integration between various process streams. Based on a reduced heat demand EINSTEIN shows the technical alternatives for the integration of energy efficient and renewable energy supply systems and evaluates them in a detailed cost calculation.

B.2 Modules of the EINSTEIN software tool

B.2.1 Data acquisition and analysis module

This module provides for and results in

- Consistency and Completeness Checking and Benchmarking
- Breakdown of energy consumption and supply by processes, equipment, temperature levels, time
- Pinch analysis

The EINSTEIN software tool contains a questionnaire for structured and systematic data acquisition. Data will be automatically checked for consistency. A procedure for estimation of non-available data is included With a benchmarking database the current energy consumption of the company is compared with the typical standard values of similar processes.

The tool generates automatically a breakdown of the total energy consumption and supply by processes, utilities, temperature levels and time, both in graphical and in table format.

Tools

- Questionnaire for the data acquisition
- Consistency checking
- Procedure for estimation of non-available data
- Benchmarking

B.2.2 Process Optimization Module

This module provides for and results in

- Technological Optimization and Pinch analysis

As a first step after the data acquisition and analysis, the process optimization module shows the variety of options which are available to improve the efficiencies of the processes and the equipment installed. The module summarizes new and best available technologies for important unit operations (washing, drying, sterilization etc.) and enables the synergy between technologies used in different sectors.

Tools

- Database of best available technologies and process optimization measures for different unit operations
- Identification tool for optimization possibilities for the technology and equipment used in the processes

B.2.3 Heat Recovery Module

This module provides for and results in

- Calculation of Optimized Heat Exchanger Network

The heat recovery module helps designing and optimizing an appropriate heat exchanger network for heat recovery and process integration. For this purpose, EINSTEIN analyses process and utility streams and waste heat/cooling demand and identifies the potential for heat recovery by Pinch analysis. It takes into account energy demand and availability including the time schedules of processes.

Tools

- Pinch analysis: calculation of energy demand and availability curves (composite curves); defining of energy targets
- Automatic and/or manual design of optimized heat exchanger network

B.2.4 Energy Supply & Renewables Module

This module provides for and results in

- Design of efficient supply system (utilities): CHP, Heat Pumps, Solar Thermal, Biomass, efficient chillers, boilers and burners

The heat and cold energy supply modules help to select and design the most appropriate energy supply equipments and heat or cold distribution systems. EINSTEIN analyzes the following supply-options: combined heat and power, heat pumps, solar thermal systems and biomass, efficient chillers, boilers and burners.

Tools

- Design Assistants for automatic design and dimensioning of utilities
- Databases on energy supply equipments

B.2.5 Simulation and Evaluation Module

This module provides for and results in

- Dynamic system simulation of the whole system (processes, buildings, distribution and heat exchanger network, utilities)
- Economic and Environmental Evaluation

EINSTEIN performs a dynamic system simulation (calculations on hourly basis) of the entire system (processes, distribution, heat exchanger network and supply utilities).

Based on the resulting global energy performance data an economic and financial evaluation is carried out. Economic analysis may be based on all parameters that influence the economic performancesuch as investment costs and depreciation, energy costs (fuels and electricity) , operation and maintenance costs, and a lot of other cost cocepts such as fees for legal requirements, income from sales of substituted equipment, etc.

As a result of economic analysis the user gets synthetised data on economic performance such as required investment, rate of return (IRR), pay-back and net present value (NPV).

Tools

- Dynamic system simulatin of the whole system
- Automatic and/or personalised economic analysisEnvironmental evaluation

B.2.6 Reporting Module

This module provides for and results in

- Automatic Report Generation

EINSTEIN automatically creates an exhaustive audit report that summarises the main results of the analysis on both the present state and the energy saving alternatives. The report (a spreasheet in open document format) can be edited, printed and delivered to the audited company.

Annex C
(informative)

Knowledge management of audit expertise

Every audit implemented adds onto the knowledge of the auditor; this presents a significant experience that can be made available for subsequent audits.

Any.case study carried out is a new experience, with own peculiarities, that should be incorporated into the stock of experience that can be made accessible to any auditor for future audits. This process of collective learning can be managed in different ways and on different levels:

— Information can be shared within the auditing company, institute or network. The data, once introduced into a data base can be accessed for future audits, e. g. for being used as an additional benchmark for similar industries, as a source of ideas on which type of measures can be proposed.

— Information can be shared within a community that uses the same methodology or the same tools, e. g. EINSTEIN. In any subsequent update of the respective tool-kit, new projects developed by the users will be incorporated. Aspects of confidentiality should be taken into account.

  NOTE EINSTEIN offers the web-page www.einstein-energy.net to share experiences; alternately, a copy can be sent by e-mail to the EINSTEIN developers at info@energyxperts.net

— Support of users through other users by exchange of opinions, suggestions, solutions, support.

NOTE EINSTEIN offers an e-mail forum for EINSTEIN users for this purpose with subscription instructions at https://lists.sourceforge.net/lists/listinfo/einstein-users

Annex D
(informative)

Literature

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