EINSTEIN
thermal energy
industry audit

Expert-system for an INtelligent Supply of Thermal Energy in Industry
and other Large Scale Applications

E I N S T E I N - II

Final Report



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EINSTEIN-II Final Report

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Centre de Recherche (CRP) Public Henri Tudor / Centre de Ressource des Technologies pour l'Environnement (CRTE)	LU	Methodology development, Realisation of trainings and audit campaign
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Summary:

This final report of the IEE project EINSTEIN-II gives an overview of the EINSTEIN methodology and tool-kit in its state as achieved at the end of the EINSTEIN-II project (November 2012). Furthermore, the activities and the major outcomes are described.

In the core of the EINSTEIN project is the development of a methodology for thermal energy auditing, supported by an expert-system software tool. An outline of the EINSTEIN methodology is given in chapter 2. The EINSTEIN tool-kit and the EINSTEIN software tool are described in chapter 7. Under the umbrella of a CEN/CENELEC workshop the EINSTEIN methodology has been discussed with experts from outside the consortium, and within this working group a CEN workshop agreement with the title “Good Practice Thermal Energy Audits” is being elaborated (chapter 6).

Within EINSTEIN-II a large number of training courses have been carried out in 10 European countries (chapter 4). For this purpose a standard training programme has been developed and is now available translated into all project languages (english, bulgarian, french, german, italian, slovak, spanish – and part of the material in older versions also in czech, polish and slovene). A total of 256 auditors attended introductory 3 to 4 day training on the EINSTEIN thermal energy auditing methodology, while 101 attended an advanced 2-day course which explored the software in more detail.

The delivery of the EINSTEIN training courses has extended beyond the scope of the project, with EINSTEIN courses now having been given elsewhere in Europe and Africa, incorporation of the EINSTEIN course into masters courses at a Fachhochschule in Germany, and a future course planned beyond the project end date.

A total of 72 energy audits have been carried out in industral and non-industrial companies in 10 European countries (Austria, Bulgaria, France, Germany, Ireland, Italy, Luxembourg, Slovakia, Spain, UK; chapter 5). Participating companies with a high thermal energy demand have come from 7 different sectors (breweries, food industry, pharma/cosmetic, laundries, manufacturing, offices and spas). During the audits the present state of the energy demand of the processes and their supply including the distribution has been displayed and based on this the optimisation potential by process optimisation, heat integration and an optimised energy supply with a special focus on renewable energy sources has been evaluated using economic, energetic and environmental criteria.

For all of these audits a public summary report is available. This collection of audit reports forms a set of good-practice thermal energy audit examples. Within these audits a potential of primary energy savings ranging from few percent up to more than 60% could be detected, with an average of about 20%. 20 out of the 72 audited companies initiated further activities for the detail planning and implementation of the recommended measures.

The activities of EINSTEIN related to standardisation were undertaken to achieve sustainability of specific project activities and results.

A workshop was organised to assess the potentials of the project to contribute to standardisation in various forms. Based on this, the project decided to establish a liaison with already existing standards activities in European Committees for Standardisation (i.e. CEN European Committee for Standardisation and CENELEC European Committee for Electrotechnical Standardisation, the body identified for the liaison being CEN/CLC/JWG 1 – CEN-CENELEC Joint Working Group 1 – Energy Audits)). Parallel to this, it was decided to develop a CEN-CENELEC Workshop Agreement (CWA) based on the procedures and rules for such document (refer to http://www.cen.eu/cen/Products/CWA/Pages/default.aspx, query 2012-12-07).

The CWA describes the methodology of EINSTEIN as an example of good practice for thermal energy audits of industrial processes and can be used as a guide for the implementation of energy audits even if other methodologies for audits are used; this will contribute to disseminating the concept of energy audits in general and also of the specific EINSTEIN methodology. It is supporting the implementation of two European standards (EN 16247-1 "Energy audits - Part 1: General requirements" and EN 12747-3"Energy audits - Part 3: Processes"), the latter at this time (December 2012) being a draft standard.

The CWA will be available in the spring of 2013 at all 33 national member bodies of CEN-CENELEC (refer to http://www.cen.eu/cen/Members/Pages/default.aspx, query 2012-12-07).

Within EINSTEIN-II also a significant progress could be acheived in the development of the EINSTEIN software tool, which is documented in detail in chapter 7.

1 Introduction

Industrial thermal energy (heat and cold) demand constitutes about 28 % of the total final energy demand and produces about 21 % of the CO_2 emissions in Europe. Space heating and cooling in *buildings* contributes another 27 % to the final energy demand. Despite improvements in energy efficiency across Europe over the last decades, there remains a large unexploited potential for reducing energy demand which can be achieved by the intelligent combination of existing solutions and technologies. However, frequently the required investments are not made due to e.g. lack of knowledge and too few resources available for energy auditing.

The EINSTEIN-II project aimed to contribute to a widespread implementation of integrated energy-efficient solutions for **thermal** energy supply in **industrial companies** with a high fraction of low and medium temperature heat demand and for **non-industrial users** of similar demand profiles, such as hospitals, commercial centres, large office buildings, district heating and cooling networks, etc.

To further optimise thermal energy supply, a holistic integral approach is required that includes the possibilities of demand reduction by heat recovery and process integration, and by an intelligent combination of existing affordable heat (and cold) supply technologies, under the given economic constraints.

For this purpose, the **EINSTEIN tool kit for thermal energy auditing** has been developed since 2007 in a collaboration of more than 20 institutes and companies in the Framework of the European projects EINSTEIN (2007-2009) and EINSTEIN-II (2010-2012) and several national and regional projects in Spain, Catalonia and Austria. Apart from the development of the methodology and the tool-kit, within these projects more than 500 energy auditors have been trained in 13 European countries and several other countries world-wide.

The EINSTEIN tool kit, based on an expert system software tool, guides the user through the whole procedure from auditing (preparation of visit and data acquisition), to data processing, to the elaboration, design and quantitative (energetic and economic) evaluation of alternative solutions.

The EINSTEIN II project (2010 – 2012) went beyond what was achieved in the previous projects, setting the following objectives:

- consolidate the EINSTEIN thermal energy audit methodology and extend it to non-industrial uses
- realise an intensive training programme with relevant actors (energy auditors ...) in additional countries, including the larger European countries (UK, France, Germany)
- test and validate the improved and consolidated methodology in an audit campaign in the participating countries
- development of standards and contribution to standardisation activities ongoing in the European Committee for Standardisation - CEN/CENELEC Sector Forum Energy Management SFEM, in CEN/CENELEC BT TF 189 Energy Management and Related Services – General Requirements and Qualification Procedures, in CEN/CENELEC BT TF 190 Energy Efficiency and Saving Calculations, and in the CEN/CENELEC Joint Working Group Energy Audits

In this document the EINSTEIN methodology and the most relevant activities and results of the EINSTEIN-II project are described.

2 The EINSTEIN Thermal Energy Audit Methodology

2.1 Thermal energy in industry and other large scale applications

Thermal energy (heat and cold) demand in industry (2002 figures: about 2.300 TWh/8.400 PJ) is responsible for about 28% of the total final energy demand (Table 1) and 21% of the CO2 emissions in Europe[1]. Space heating and cooling in buildings contributes another 27 % to the final energy demand [DG INFSO 2008].

Table 1. Distribution of final energy demand in the EU in 2002. Source: EU Green Paper on energy efficiency.

2002	Buildings (residential and tertiary		Industry		Transport		All final demand sectors	
	Mtoe	% of final demand	Mtoe	% of final demand	Mtoe	% of final demand	Mtoe	% of final demand
Solid fuels	12.2	1.1	38.7	3.6	0.0	0.0	50.9	4.7
Oil	96.8	8.9	46.9	4.3	331.5	30.6	475.2	43.9
Gas	155.6	14.4	105.4	9.7	0.4	0.0	261.5	24.2
Electricity (incl. 14 % from RES)	121.3	11.2	91.2	8.4	6.0	0.6	218.5	20.2
Derived heat	22.8	2.1	7.5	0.7	0.0	0.0	30.3	2.8
Renewables	29.0	2.7	16.2	1.5	1.0	0.1	46.2	4.3
Total	437.8	40.4	306.0	28.3	338.9	31.3	1082.6	100.0

Even if energy efficiency in industry in Europe has improved in the last decades, there remains a large unexploited potential for reducing energy demand that could be used by the intelligent combination of existing solutions and technologies. In the EU Green Paper for Energy Efficiency the savings potential in industry (without cogeneration) is estimated to be up to 350 TWh/1260 PJ (European Commission [2005]. The European Commission's energy efficiency action plan indicates that 40% of EU's Kyoto targets must be achieved through energy efficiency, in order to succeed with its goals.

Improvement of energy efficiency not only leads to the obvious environmental benefits, but is also economically attractive for the industrial companies: in many cases pay-back times from some months to few years can be obtained. In a typical small or medium enterprise, energy accounts for between 3% and 12% of the operational costs with an energy saving potential of between 15% and 30% [E-Check 2006]. Nevertheless, frequently the corresponding investments are not realised due to some of the following reasons:

- ✗ Lack of knowledge of the companies about possible energy efficient solutions.
- ✗ Energy costs, although being important, are not the first priority of the companies. Investments in energy compete with investments in the improvement of production and products; this leads to a situation where investments into energy conservation are not being done, although they are economic by themselves but lose competition for available money.
- ✗ In addition, most industrial companies do not perceive energy as a discrete issue, but as a component of broader issues such as cost of manufacturing, environmental compliance, safety and productivity. Energy efficiency competes with other issues for limited resources within a company. While capital is the most often cited resource, staff time may be of equal or greater importance. Corporate downsizing has resulted in less staff available to address all issues.
- ✗ Little (zero) budget available for energy auditing

[1] *Figure including electricity generation in industry. Source: http://ghg.unfccc.int. Total fuel combustion for Manufacturing Industries and Construction in the EU in 2002: 583.070 Mio t CO_2*

- ✗ Even in the cases where energy audits are carried out, the auditors often have only a limited knowledge of technological options and do not dare or do not dispose of the means to propose non-conventional innovative solutions.

The EINSTEIN thermal audit methodology aims at overcoming some of the above mentioned barriers and at contributing to a widespread implementation of integral energy-efficient solutions for thermal energy supply.

2.2 Area of application

The EINSTEIN thermal audit methodology focuses on industries and other large scale consumers with a high thermal energy (heat and cold) demand in low and medium temperature ranges up to 400 ºC, such as:

a) industrial sectors:

- ✗ food industry
- ✗ chemical industry
- ✗ paper industry
- ✗ construction of machinery, equipment and automobile
- ✗
- ✗ plastic processingwood processing industry
- ✗ metal surface treatment
- ✗ textile industrymany other industrial sectors

b) non-industrial applications

- ✗ district heating and cooling networks, including also the integration of demands in form of centralised 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, etc.

- ✗ other installations consuming thermal energy, such as sea-water desalination, plants for water treatment, etc.

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

2.3 An integral approach to energy efficiency

In order to optimise thermal energy supply, **a holistic integral approach** (Figure 1) is required that integrates:

- ✗ 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.

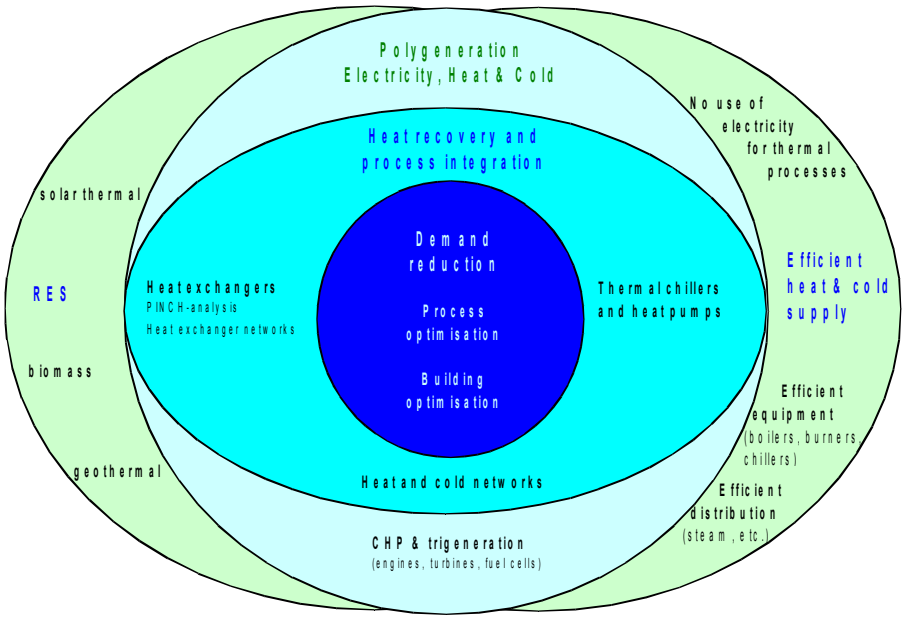


Figure 1: Holistic approach for thermal energy audits ("the view with EINSTEIN's eye"), combining demand reduction, heat recovery and process integration and an intelligent combination of supply technologies.

2.4 The advantages of the EINSTEIN audit procedure

In contrast to many aspects of electricity consumption such as pumps, motors, lighting, etc., where often a list of recommendations and standard measures 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.

In order to overcome these constraints, the EINSTEIN tool-kit uses the concepts described below and allows to process data and to generate proposals in typical small and medium enterprises with medium complexity in 4 – 8 hours of a junior expert working time. The main advantages of the EINSTEIN tool-kit also presented in the Figure 2 are the following:

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

- "**quick and dirty" 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. This often lengthy and time-consuming calculations necessary for

processing these data can be substantially shortened using a limited data set as input to the standardised 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-automatisation 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 web-based or by a short questionnaire**: Taking into account that in many cases for a first quick-and-dirty 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. This questionnaire can be also accessed via a web-page for data submission by distance.

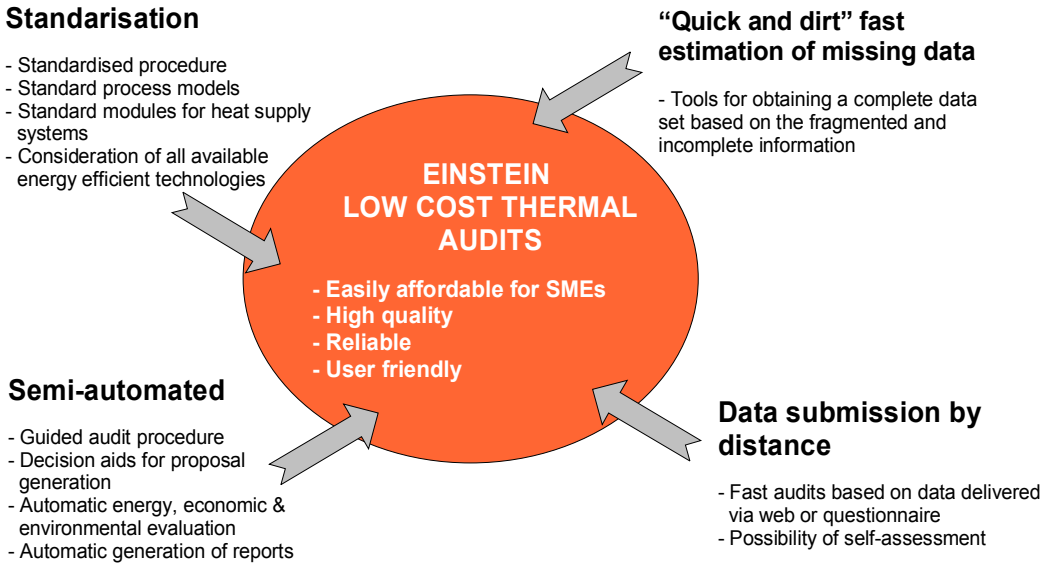


Figure 2: Overview of the EINSTEIN thermal auditing functions for obtaining fast and cheap, but high quality thermal energy audits

2.5 The EINSTEIN tool-kit

The EINSTEIN audit methodology is based on a software tool with decision aids and guidelines forming a complete **expert system**[2] **for thermal energy auditing.** This easy to use expert system software tool, together with the EINSTEIN audit guide forms an **energy-auditing tool-kit** that leads the consultant through the whole procedure from auditing (preparation of visit and data acquisition), over data processing, to the elaboration, design and quantitative (energetic and economic) evaluation of alternative solutions.

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

[2] *An **expert system** is a "class of computer programs (...) made up of a set of rules that analyse information (usually supplied by the user of the system) (...), provide analysis of the problem(s), and (...) recommend a course of user actions (...)." (wikipedia.org).*

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 expert system software tool includes the following modules:

a) Block for data acquisition and processing

Data acquisition is mainly based on a short questionnaire. An additional module helps the auditor to estimate non-available data. A link to information sources on best practice and benchmarks will help to evaluate the state-of-the-art in the company.

b) Block for the generation of a new proposal

This block is formed by the process optimisation module, the heat recovery module, that helps designing and optimising an appropriate heat exchanger network for heat recovery and process integration; and a heat and cold supply module, that helps to select and to dimension the most appropriate supply equipment and heat or cold distribution systems.

c) Block for the energetic, economic and environmental evaluation of the new proposal

The energetic performance of the system is determined by a system simulation module. Based on the energetic performance, an economic and environmental evaluation is automatically generated by the *economicanalysis* module.

d) Block for generation of reports for the presentation of the new proposal to the company

Automatic reports are generated in a format that can be directly presented to the company. The report contains information on the technical design of the new proposal, the investment cost of the measure, and an economic roadmap for its implementation.

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

3 The EINSTEIN-II Project

The project EINSTEIN-II was a project co-funded under the Intelligent Energy Europe Programme with a duration from July 2010 to October 2012. In the following the work plan of this project is described.

3.1 Overview of the EINSTEIN-II Work Programme

Within the EINSTEIN-II project there were three main vertical lines of activity (trainings, energy audit campaign, standardisation; WP 2, 3 and 4 respectively), supported by two horizontal activities (methodology development – WP5, and dissemination – WP6) that back these three main lines delivering the necessary input (WP5) and disseminating their output (WP6). The work programme is completed by the project management tasks (WP1) and by the IEE dissemination activities (WP7).

Main lines of activity:

- **training (WP 2).** A well skilled community of EINSTEIN energy auditors has been built up in the partner countries. After EINSTEIN-II, and together with the auditors trained already in EINSTEIN I, more than 500 skilled EINSTEIN auditors in 13 European countries are available. Training in EINSTEIN II has been carried out on the improved methodology that has been developed in WP 5. A certificate for EINSTEIN energy auditors has been issued.

- **energy audits (WP 3).** 72 energy audits have been carried out in the partner countries. Energy audits in EINSTEIN II aimed at getting a more detailed insight about the potential and still existing shortcomings and need for improvements of the EINSTEIN audit methodology by comparing EINSTEIN results with conventional calculations “by hand”.

- **standardisation (WP 4).** Interaction with standardisation in the field of energy management and energy audits was established. At the same time, standardisation activities were initiated by EINSTEIN using the framework European standardisation is offering within the CEN/CENELEC environment

Horizontal lines of activity - supporting actions:

- **methodology and tools (WP 5).** The EINSTEIN energy auditing tool-kit composed of an audit guide and a software tool has been substantially improved with respect to user-friendliness, adding some technical features, and extending its usability for non-industrial users. Furthermore a detailed technical documentation has been elaborated in order to support the standardisation activity and to improve the transparency of the methodology.

- **dissemination (WP 6).** Dissemination activities such as conferences, newsletters, etc. have been carried out in order to bring the right message (and the results of the present project) to the right actors. Focus will be set on obtaining bi-directional communication in form of feedback and collaboration to the development and improvement of the methodology from outside the consortium.

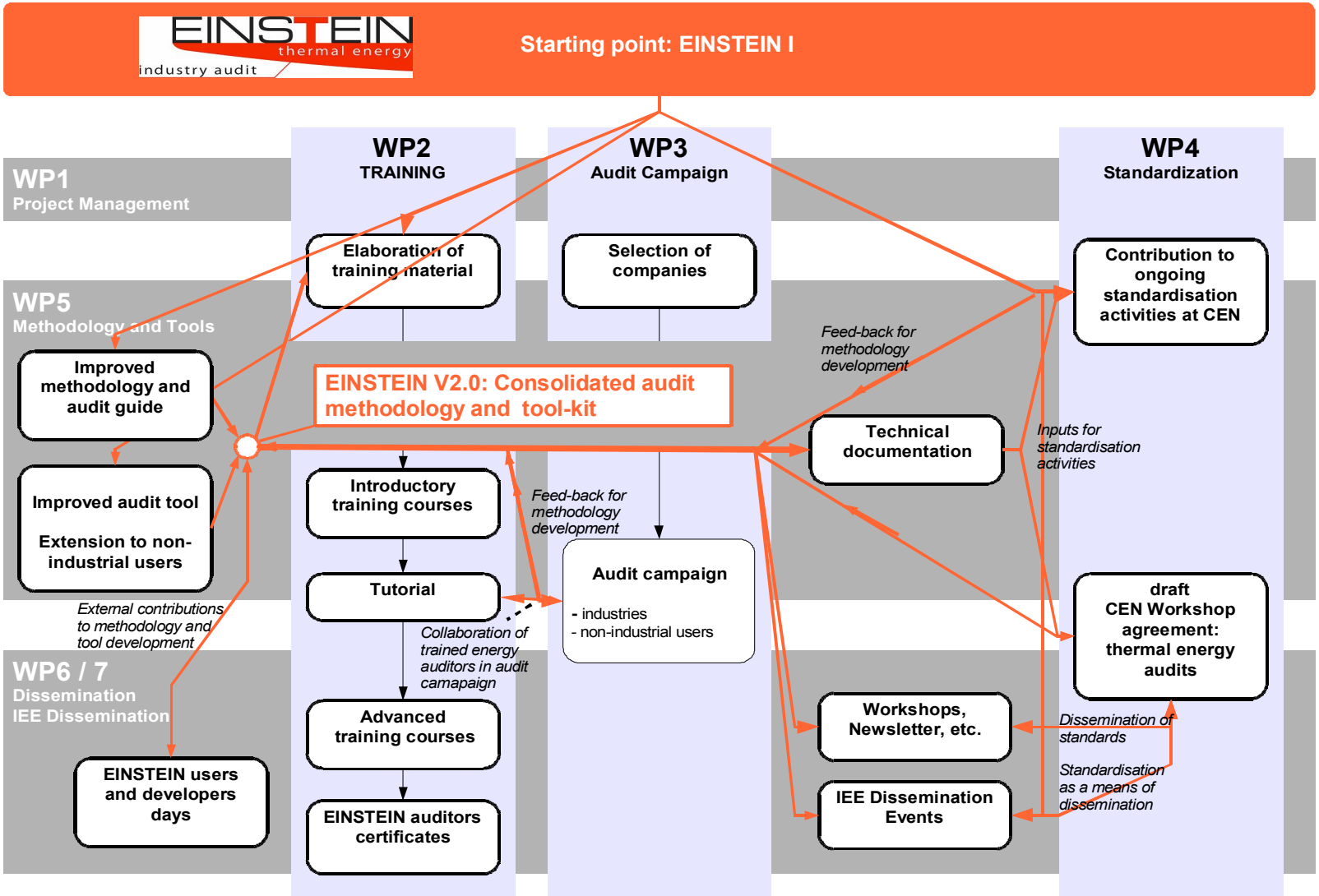


Figure 3: Overview of the EINSTEIN-II Work Programme

3.2 Results and Impact

The real outcomes of the EINSTEIN-II project have been compared with the initial targets.

The average relative primary energy savings of 19% are very close to the initial estimate of 20%. The same is valid for the average size of the companies (19.030 vs. 20.000 MWh of primary energy consumption). The RES share is – with 15% - somewhat smaller than predicted (75% of the predicted value).

These average values however should not be used as representative values that can be extrapolated to whole industrial sectors or non-industrial applications, for the following reasons:

- all ratios vary strongly from case to case
- the selection of companies has not been representative, but depended on the “ease of access” in each country. Both industrial and non-industrial companies from a great variety of sectors have been analysed.
- the results depend strongly on the boundary conditions and optimisation criteria applied (e.g. expectations on economic performance, system and energy costs, etc.).

Table 2. Comparison of predicted and real performance

Performance indicators fixed at the beginning of the project		end of the project (June 2012)	2 years after project (2014)	2020
Number of audits		144	1000	4000
- EINSTEIN-II audits		72		
- other audits triggered by EINSTEIN-II		72	928	3928
Number of initiated projects		36	-	-
Number of realised projects (*)		7	250	1000
Primary energy savings (**)	**GWh**	**28**	**1000**	**4000**
	toe	2.411	86.124	344.498
Renewable energy production triggered (***)	**GWh**	**5,6**	**200**	**800**
	toe	482	17.225	68.900
Reduction of GHG emissions triggered (iv)	**tons of CO2**	**7.234**	**258.373**	**1.033.493**
Yearly savings of energy cost (v)	M€	0,84	30	120
Cumulative investment in sustainable energy (vi)	**M€**	**4,2**	**150**	**600**

Predicted savings in EINSTEIN-II audits		
initial target equivalent to 72 audits	end of the project (October 2012)	ratio real / target
72	72	
288	**259**	**90%**
24.804	22.280	
57,6	**39,5**	**68%**
4.961	3.398	
74.411	**38.654**	**52%**
8,64	7,58	**88%**
43,2	**29,5**	**68%**

Degree of implementation	
end of the project (October 2012) – implemented audits	ratio real / target
72	
n.a.	n.a.
20	**56%**
5	**71%**
n.a.	**n.a.**
n.a.	
n.a.	**n.a.**
n.a.	
n.a.	**n.a.**
n.a.	**n.a.**
n.a.	**n.a.**

(*) 25 % of projects proposed as a result of audits, only 5 % at very short term WITHIN the project duration
(**) 20 % of a supposed average consumption of 20.000 MWh/year
(***) substituted primary energy consumption; RES share supposed to be 20 % of total primary energy savings
(iv) average of 3.0 t CO2 / toe primary energy saved
(v) supposed average rate of 3 c€/kWh primary energy
(vi) average simple pay-back period: 5 years

(*) categories "further analysis contracted", "detailed planing contracted", "inviting offers for equipment" and "implemented"
(**) on category "implemented"
See Figure 4.1 in D3.2/D3.3 report

Table 3. Comparison of average ratios: predicted vs. real

Average ratios initial estimate at the beginning of the project vs. real			
		initial estimate	real
Average PE-consumption typical company	MWh	20.000	19.030
Average PE-savings	%	20%	19%
RES Share	%	20%	15%

3.2.1 Success story 1: EINSTEIN trainings

There has been a very positive uptake of EINSTEIN trainings in almost all partner countries. EINSTEIN training activities have also taken place beyond the ones foreseen within the project:

- The EINSTEIN training course has been included in the master courses of the Fachhochschule Trier, Germany for the years 2011-2012 and 2012-2013, which has been facilitated by project partners TUDOR (initial contact provided by AEE INTEC). This training will possibly be continued also in the future.

- The EINSTEIN training package has been used by project partners AEE INTEC within the UNIDO project "Low Carbon in the agro-food industry" for training courses held in Uganda (Kampala – 27 attendees) and Macedonia (Skopje – 14 attendees).

An additional advanced EINSTEIN training session has already taken place after the end of the project on November 26th/27th 2012 in Valence, France. This training carried out by ENERGYXPERTS has facilitated by project partner CCI DROME. Trainees from this course will complete the full training cycle and elaborate a project work, so that in case of success additional certified EINSTEIN auditors will be available.

3.2.2 Success story 2: EINSTEIN audits

By many companies there was a positive take-up of the proposals presented (at the end of the project out of 72 companies 20 had initiated some further detail planning steps and out of them 5 already had implemented (some of) the proposed measures. More than 50 % have the intention to apply some or all of the recommended measures in the future after necessary further investigation (Figure 3.4.2.1). An average primary energy saving potential of close to 20 %, and in some companies up to more than 60 % has been detected. For details see the D3.2/D3.3-report.

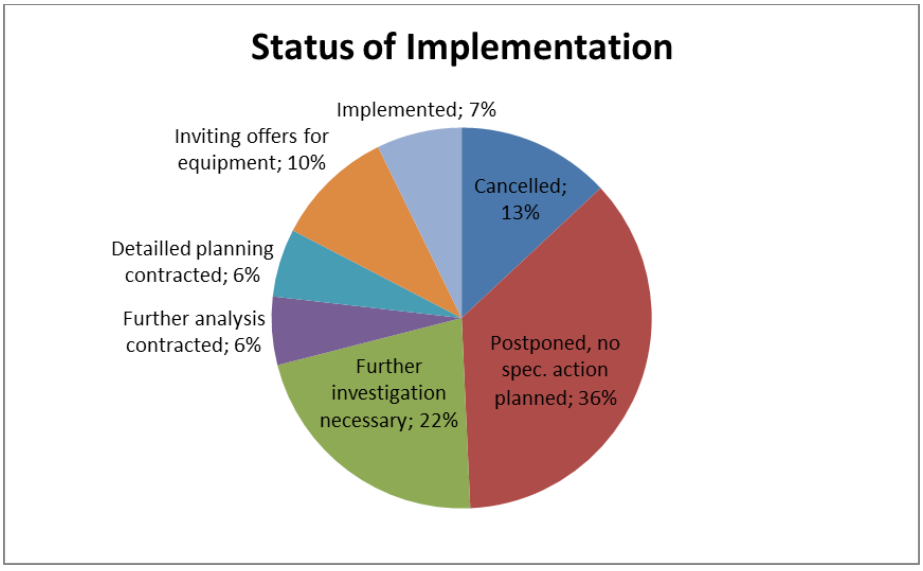
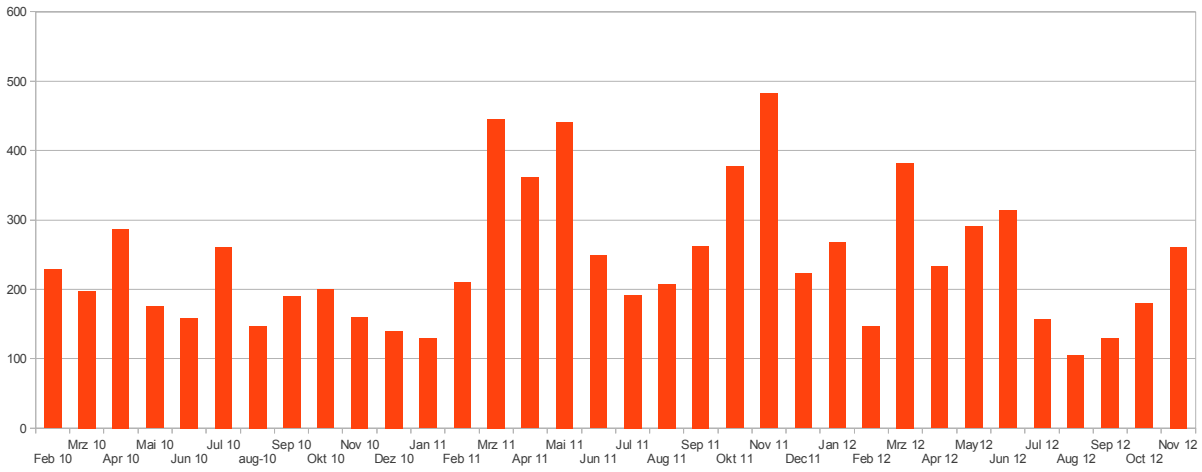


Figure 4: Status of implementation of the proposed EINSTEIN energy saving measures

3.2.3 Success story 3. Distribution of EINSTEIN tool-kit

The materials forming the EINSTEIN Tool Kit have been disseminated via the EINSTEIN web page (www.einstein-energy.net). Since its generation until 30.11.2011, a total of 12.666 downloads of the EINSTEIN software tool have been counted in 109 countries world wide. Since the EINSTEIN II project more than 7.000 downloads have been counted. While during EINSTEIN-I, almost 75 % of downloads were focused in Spain, since EINSTEIN-II running new countries increased their share, especially Germany, France, Italy and Austria. About 70 % of downloads since the project start in July 2010 are in the EINSTEIN-II countries.

The number of registered EINSTEIN users increased from 37 (end of EINSTEIN-I) to 107, and 416 persons are registered to the EINSTEIN-News mailing list, receiving the EINSTEIN newsletter and periodic updates on EINSTEIN. Beyond the EINSTEIN-II trainings, 117 persons downloaded the introductory EINSTEIN training material.



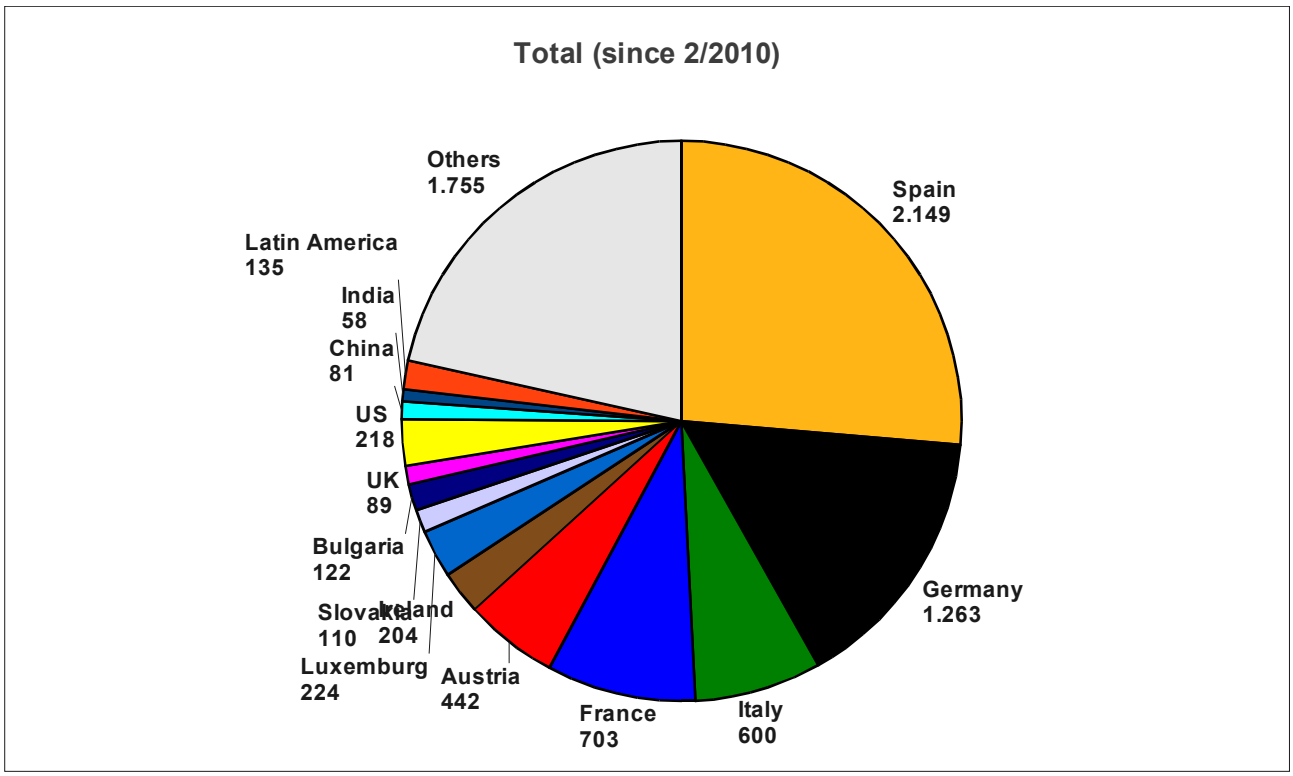


Figure 5: Evolution of downloads of EINSTEIN Software tool since February 2010. Above: total downloads per month (above); below: total downloads by countries (further details available at www.sourceforge.net/projects/einstein).

4 EINSTEIN Trainings

4.1 Structure and content of EINSTEIN trainings (incl. tutorial and criteria for certificate)

A standard training programme on the EINSTEIN methodology has been developed. This training programme consists of introductory and advanced training courses, together with the possibility for trainees to carry out a project work and obtain certification as an EINSTEIN energy auditor.

Elements of the EINSTEIN training course:

- Introductory course: 21 hours of lecture / practice
- Advanced course: 14 hours of lecture / practice
- A project work: about 100 hours of homework to develop a project using EINSTEIN

Since 2007, introductory and advanced training courses on EINSTEIN, for energy auditors have taken place in Austria, Bulgaria, Czech Republic, France, Germany, Ireland, Italy, Luxembourg, Poland, Slovakia, Spain and the UK.

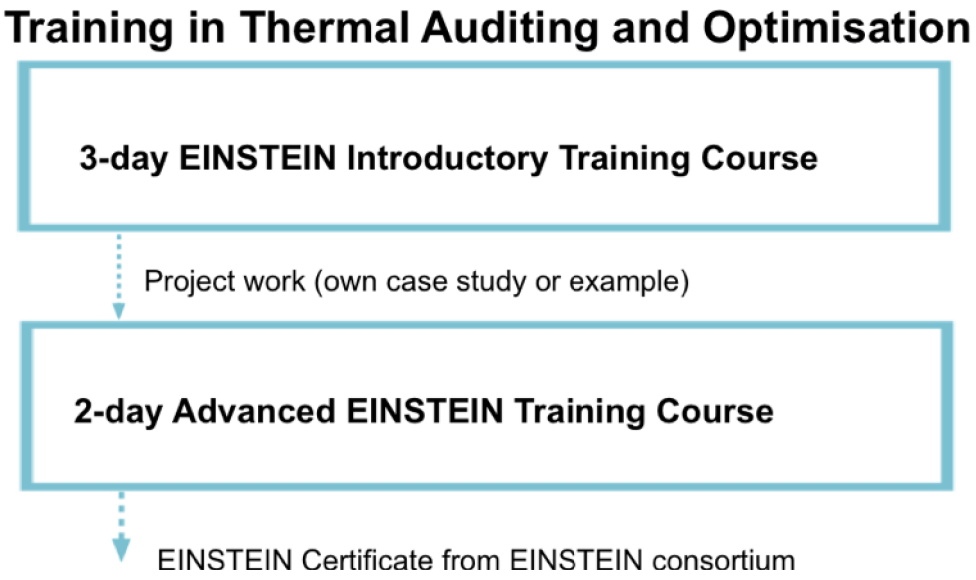


Figure 6: EINSTEIN training course structure

4.1.1 EINSTEIN Introductory Training Course

The EINSTEIN introductory course has a duration of 3 days that are dedicated to the EINSTEIN methodology and software tool application. As a complement to the introductory course, there is also an optional additional 1-day block to refresh on the fundamentals of thermal energy. Within the EINSTEIN training materials, the content of such an introductory course has been defined.

The content for the introductory training course includes an overview of both the methodology and the software tool itself. Trainees are brought through the individual modules and main features of the tool. Significant time is dedicated to students using the software tool in practice, through a series of examples. At the end of the introductory course, trainees should be in a position to carry out simple audits using the tool on their own.

4.1.2 Advanced EINSTEIN Training Course

Once trainees have completed the introductory course they can then go on to the advanced EINSTEIN training course. This course takes 2 days and gives trainees the opportunity to deepen their knowledge of the possibilities offered by the EINSTEIN methodology.

4.1.3 Project Work, Tutorial and Certification

At the end of the training activities, successful trainees, who receive a positive evaluation of their project work performed applying the EINSTEIN methodology, obtain the final certificate certificate as an EINSTEIN energy auditor. The contact details of certified EINSTEIN energy auditors are listed at the project website.

For more information and to see the full content of the training programme visit:
www.einstein-energy.net/training-activities

Who can participate?

EINSTEIN training is suitable for energy auditors, energy managers and people working in the field of energy efficiency. Participants should have:

- A technical or engineering background
- A basic knowledge of energy systems, thermal and process engineering

Professional experience in (private and public) manufacturing and service companies or in energy or engineering consultancies is helpful

How to organise an EINSTEIN training course

If you would like to organise an EINSTEIN training activity please contact one of the project partners authorised to give certified EINSTEIN training courses (*):

Company / Institute	Contact person(s)	e-mail
energyXperts.NET (Spain, Germany)	Hans Schweiger Claudia Vannoni	info@energyxperts.net
AEE INTEC (Austria)	Jürgen Fluch Christoph Brunner	j.fluch@aee.at c.brunner@aee.at
CRP Henri Tudor (Luxemburg)	Alexandre Bertrand	alexandre.bertrand@tudor.lu
Cork Institute of Technology (Ireland)	Eileen O'Leary	eileen.oleary@ctc-cork.ie

(*) State October 2012. For an updated list see www.einstein-energy.net/training-activities

4.2 Overview of the EINSTEIN Training Course Content

4.2.1 Introductory Training Course

The introductory training includes the following elements:

- An overview of the EINSTEIN tool and the methodology
- A step-wise progression through the tool using examples and emphasising practical use of the software by the trainees. Trainees are brought through the following steps:
  - ✗ Data acquisition and input
  - ✗ Checking data for completeness and consistency, and overview of the present state
  - ✗ Developing and modelling alternatives including:
    - Optimising the process
    - Evaluating potential for heat recovery and designing a heat exchanger network.
    - Design of alternative hot and cold supply systems
    - Economic assessment
  - ✗ Evaluating and reporting the outcomes.

4.2.2 Advanced Training Course

The advanced training includes the following elements:

- How to handle “tricky” items in EINSTEIN including, for example, dealing with drying processes, how to input live steam, modelling condensate return, and modelling processes as a black box.
- More detail on specific features including cooling and using EINSTEIN for buildings.

You can find out more on the content of the course at www.einstein-energy.net/training-activities

4.3 Training activities realised within the EINSTEIN-II project

Training in the EINSTEIN thermal energy auditing methodology and associated software was carried out across ten countries, namely Austria, Bulgaria, France, Germany, Italy, Ireland, Luxembourg, Slovakia, Spain, and the UK. A total of 256 auditors attended 3 to 4 day introductory training courses on the EINSTEIN thermal energy auditing methodology, while 101 auditors attended an advanced 2-day course which explored the software in more detail. In total there were 17 introductory courses and 10 advanced courses; these were delivered in 2011 and 2012.

Certification of 10 auditors has been completed and their details are available at www.einstein-energy.net/. A standardised certification process is now in place and can be used in future courses given by any of the technical partners of the project.

Training packages covering the material have been prepared and are publicly available on the project web-site. Feedback from trainees has been used to improve the software over the course of the project duration.

The delivery of the EINSTEIN training courses has extended beyond the scope of the project, with EINSTEIN courses now having been given elsewhere in Europe (Macedonia) and Africa (Uganda), incorporation of the EINSTEIN course into masters courses at Fachhochschule Trier in Germany, and a future course in France planned beyond the project end date.

4.4 Trainees' feed-back

The largest proportion of trainees attending the training courses were those from the consultancy sector. The large number from SMEs would also indicate that those involved were often self employed consultants.

The feedback from trainees can be summarised as follows:

- Nearly all participants found the EINSTEIN tool useful and greatly admired the concept. It was regularly noted that the tool is unique for the industrial sector.
- Many participants requested that more time be given to the practical use of the tool, as it required time to understand and work through the examples, get familiar with the terminology and the tool interface. In general, many felt that too much was being fitted into the time allocated.
- The participants found the trainers very helpful and experienced.
- In terms of improving the tool, participants frequently referred to the following:
    - An improvement to the interface is required to make the tool more user friendly.
    - Consistency check was unclear and needs greater explanation.
    - It isn't always clear which data is required to be input - this could be made more apparent in the cases of specific types of equipment.
    - Some particpants requested a clearer user guide and updated supporting documentation to be made available. On-line training materials were also suggested.

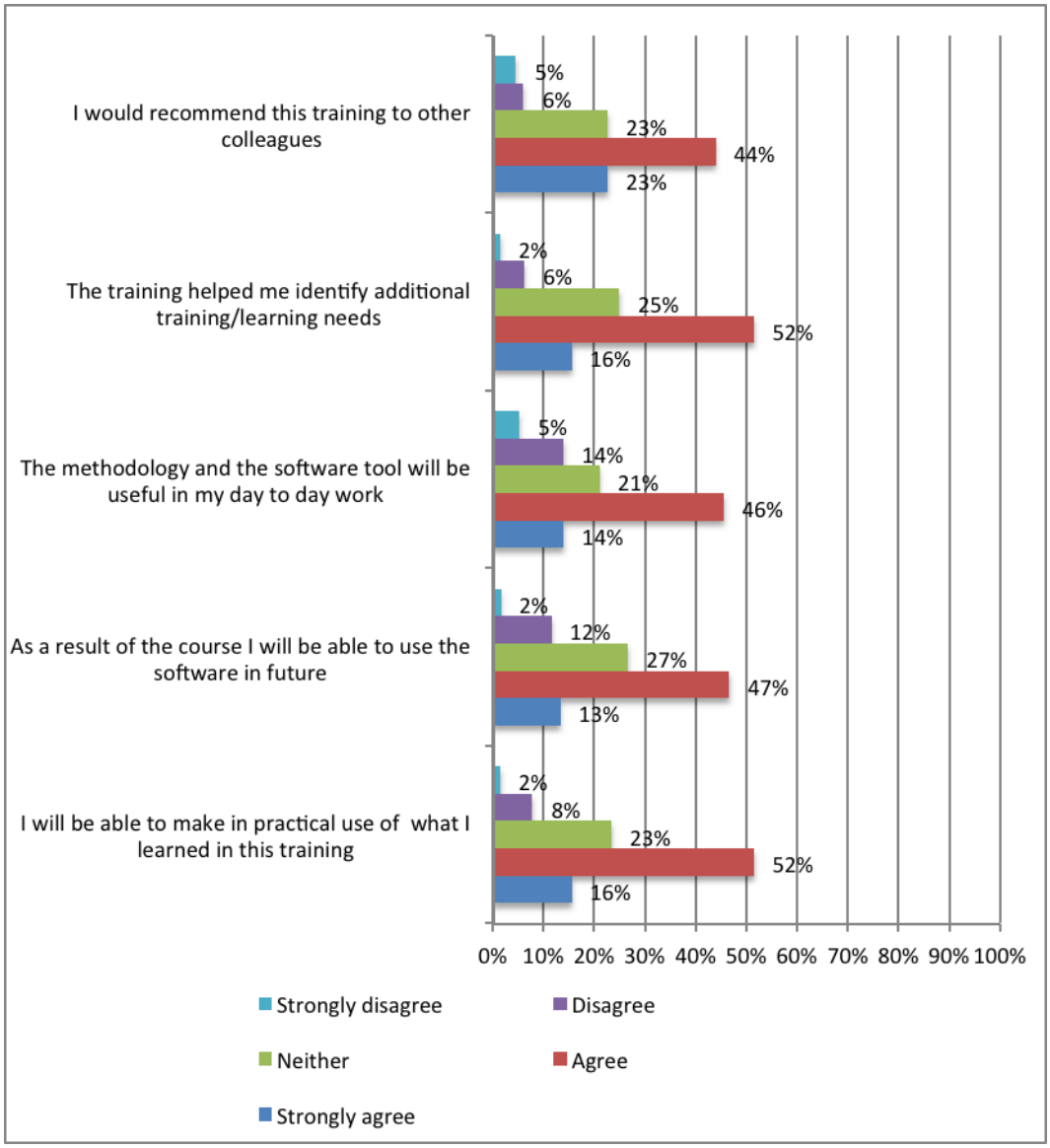


Figure 7: General evaluation of the EINSTEIN advanced training courses by the trainees

5 EINSTEIN Audits

5.1 The EINSTEIN-II audit campaign

The main objective of the EINSTEIN-II audit campaign had been the performance of fast energy audits. The energy audits were carried out by the technical core group formed by the partner AEE INTEC, ENERGYXPERTS, CRP HENRI TUDOR and CIT. In total 72 companies (industries and large non-industrial users of heat and cold) have been selected in the 10 partner countries supported by the local partners. Except of industrial applications, a strong focus was also set on big buildings (19, spas included).

Besides the performance of the audits the main objectives of the audit campaign were a testing / demonstration of the new and improved version of the tool-kit developed in parallel, an increase of the experience and quality on the industry sectors audited and an increase of experience and quality also in countries, where audits have been carried out already in EINSTEIN-I (2007-2009).

Table 4. Overview of audits performed in the partner countries divided into sectors

Country / local partner		INDUSTRIES (numbers and sectors)	NON-INDUSTRIAL USERS (numbers and sectors)	TOTAL
Austria	AEA, AEE	8	3	11
France	CCIDRÔME	6	-	6
Germany	ZAB	5	5	10
Italy	TCA	8	-	8
Spain	COCIM	5	3	8
UK	WMEC	5	4	9
Ireland	CIT	4	-	4
Luxembourg	CRP HENRY TUDOR	2	1	3
Bulgaria	AKU	6	4	10
Slovakia	SCPC	3	-	3
Total		52	20	72

It was a lot more difficult to find companies willing to participate in such a project although the audits had been offered (almost) for free and the only costs for the companies had been the time necessary for data acquisition and meeting with the project team:

- Excess supply of audits with poor quality: In recent years in most of the countries many energy auditors offer an audit to the companies which are generally willing to do these. But the audits and the outcome of these are of very poor quality while they are very expensive resulting in the fact that many companies block as soon as they hear about energy audits.

- Audit offered for free: Especially in western countries (UK, France, Ireland, etc.) companies had not been willing participating in an audit offered for free. Unexpectedly people combine “free audits” with very poor quality not worth spending time on data acquisition.

Therefore, it had been a challenge to find 72 companies willing to participate in the project and providing their data for a present state evaluation although an anonymous attendance was offered. Nevertheless it can be stated that the use of all available dissemination channels increased the knowledge of the EINSTEN methodology and software besides the dissemination and training activities.

The selection of the companies was mainly based on contacts and dissemination of the local partners. The focus was to acquire companies and/or big buildings with a big thermal energy demand for heating and cooling and a respectively high potential for optimisation. As it can be seen in Figure 8 most of the companies come from the food and beverage sector with total 47%. 28% can be allocated to building (offices and spas) and 10% to manufacturing companies. The rest of the companies had been laundries respective

pharma industries. Generally in all participating countries a wide range of branches and sub-branches of the most thermal energy consuming companies could be covered.

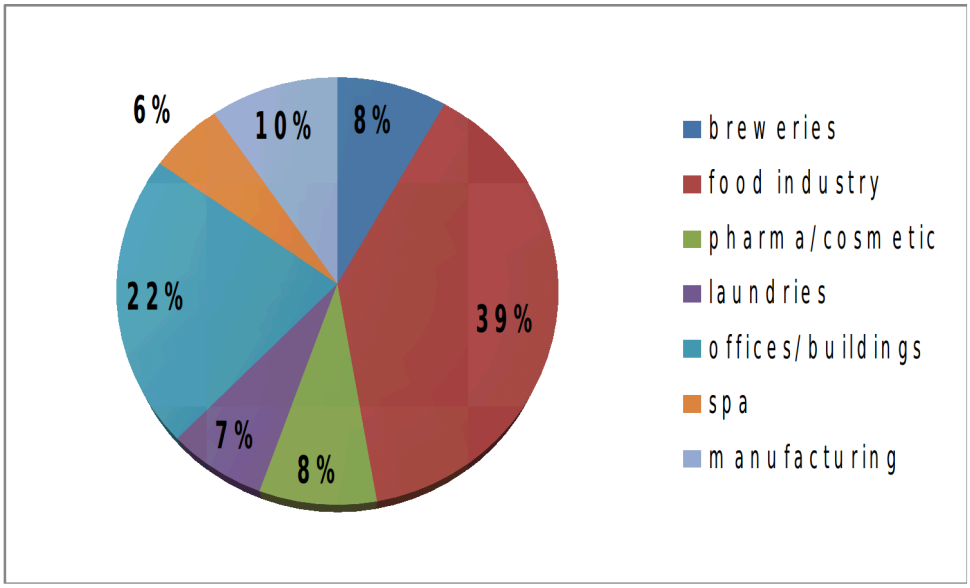


Figure 8: Allocation of the companies audited to different branches and sub-branches

Table 5 gives a list of the companies audited. A public summary of each of the audit reports is avaialble on www.einstein-energy.net/downloads.

Table 5. List of companies audited. (***) Company name not disclosed for reasons of confidentiality.

audit number	country	country code	sector	company name	auditor
01	Austria	AUT01	Hospitals	***	Austrian Energy Agency
02	Austria	AUT02	Industrial laundries	***	Austrian Energy Agency
03	Austria	AUT03	Breweries	***	AEE INTEC
04	Austria	AUT04	Production and treatment of metals	***	AEE INTEC
05	UK	UK01	Offices and other non-residential buildings	***	AEE INTEC
06	BUL	BUL01	University and school buildings	***	AEE INTEC
07	LUX	LUX01*	Breweries	***	CRP HENRI TUDOR
08	IRL	IRL01	Fish processing	***	CIT - Cork Institute of Technology
09	GER	GER01	Fruit and vegetables processing	***	ENERGYXPERTS
10	Spain	ESP01	Plastics industry	***	ENERGYXPERTS
11	France	FR01	Breweries	La Grihète	ENERGYXPERTS
12	UK	UK02	Offices and other non-residential buildings	***	AEE INTEC
13	UK	UK03	Hospitals	***	AEE INTEC
14	UK	UK04	Production and treatment of metals	***	AEE INTEC
15	UK	UK05	University and school buildings	***	AEE INTEC
16	UK	UK06	Fruit and vegetables processing	***	AEE INTEC
17	UK	UK07	Offices and other non-residential buildings	***	AEE INTEC

audit number	country	country code	sector	company name	auditor
18	France	FR02*	Fruit and vegetables processing	***	CRP HENRI TUDOR
19	Spain	ESP02	Plastics industry	***	ENERGYXPERTS
20	Italy	ITA01	Fruit and vegetables processing	VIS Srl	ENERGYXPERTS
21	Spain	ESP03	Pharmaceutical and cosmetic industry	***	ENERGYXPERTS
22	France	FR03	Pharmaceutical and cosmetic industry	***	ENERGYXPERTS
23	Austria	AUT05	Industrial laundries	***	Austrian Energy Agency
24	Austria	AUT06	Industrial laundries	***	Austrian Energy Agency
25	Austria	AUT07	Industrial laundries	***	Austrian Energy Agency
26	Spain	ESP04	Production and processing of meat	Transformación Ganadera de Leganés S.A.	ENERGYXPERTS
27	France	FR04	anonymous **	***	ENERGYXPERTS
28	Austria	AUT08	Manufacture of bakery and farinaceous products	***	AEE INTEC
29	Austria	AUT09	Manufacture of cocoa, chocolate and sugar confectionery	***	AEE INTEC
30	SVK	SVK01	Plastics industry	***	AEE INTEC
31	SVK	SVK02	Automotive	***	AEE INTEC
32	SVK	SVK03	Manufacture of equipment and furniture	***	AEE INTEC
33	GER	GER02	Breweries	***	ENERGYXPERTS
34	Austria	AUT10	Hospitals	***	Austrian Energy Agency

audit number	country	country code	sector	company name	auditor
35	France	FR05*	Fruit and vegetables processing	***	CRP HENRI TUDOR
36	BUL	BUL02	University and school buildings	***	AEE INTEC
37	BUL	BUL03	University and school buildings	***	AEE INTEC
38	Italy	ITA02	Production and processing of meat	***	ENERGYXPERTS
39	Spain	ESP05	Offices and other non-residential buildings	***	ENERGYXPERTS
40	Spain	ESP06	Offices and other non-residential buildings	***	ENERGYXPERTS
41	France	FR06*	Manufacture of bakery and farinaceous products	***	CRP HENRI TUDOR
42	BUL	BUL04	University and school buildings	***	AEE INTEC
43	BUL	BUL05	Manufacture of bakery and farinaceous products	***	AEE INTEC
44	BUL	BUL06	Dairies	***	AEE INTEC
45	Spain	ESP07	Offices and other non-residential buildings	Edificio Arturo Soria (OHL)	ENERGYXPERTS
46	BUL	BUL07	Biodiesel	***	AEE INTEC
47	GER	GER03	Thermal baths	***	ENERGYXPERTS
48	GER	GER04	Manufacture of bakery and farinaceous products	Märkisch Edel (Eberswalde)	ENERGYXPERTS
49	Italy	ITA03	Industrial catering	CAMST	ENERGYXPERTS
50	BUL	BUL08	Fruit and vegetables processing	***	AEE INTEC
51	GER	GER05	Thermal baths	***	ENERGYXPERTS

audit number	country	country code	sector	company name	auditor
52	GER	GER06	Thermal baths	Naturtherme Templin	ENERGYXPERTS
53	GER	GER07	Fruit juices	***	ENERGYXPERTS
54	BUL	BUL09	Production and treatment of metals	***	AEE INTEC
55	Spain	ESP08	Breweries	***	ENERGYXPERTS
56	LUX	LUX02*	Hospitals	***	CRP HENRI TUDOR
57	Italy	ITA04	Plastics industry	C.I.B.	ENERGYXPERTS
58	IRL	IRL02	Fish processing	***	CIT - Cork Institute of Technology
59	IRL	IRL03	Dairies	***	CIT - Cork Institute of Technology
60	IRL	IRL04	Manufacture of ice cream	***	CIT - Cork Institute of Technology
61	GER	GER08	Offices and other non-residential buildings	DIN – Deutsches Institut für Normung	ENERGYXPERTS
62	GER	GER09	Thermal baths	Thermalbad Bad Saarow	ENERGYXPERTS
63	LUX	LUX03*	Plastics industry	***	CRP HENRI TUDOR

audit number	country	country code	sector	company name	auditor
64	UK	UK08	Fruit and vegetables processing	***	AEE INTEC
65	UK	UK09	Breweries	***	AEE INTEC
66	BUL	BUL10	Fruit and vegetables processing	***	AEE INTEC
67	Austria	AUT11	Industrial laundries	***	Austrian Energy Agency
68	Italy	ITA05	Manufacture of bakery and farinaceous products	***	ENERGYXPERTS
69	Italy	ITA06	Industrial catering	***	ENERGYXPERTS
70	GER	GER10	Food Industry **	***	ENERGYXPERTS
71	Italy	ITA07	Manufacture of cocoa, chocolate and sugar confectionery	***	ENERGYXPERTS
72	Italy	ITA08	Manufacture of bakery and farinaceous products	***	ENERGYXPERTS

5.2 Audit procedure applied

Within the audits the EINSTEIN methodology had been used and the EINSTEIN software had been further developed considering the requirements of the case studies. The companies had been contacted by the local partners and after showing their interest, the EINSTEIN check list and questionnaire was sent to the responsible persons in the companies ensuring that the data was available resp. measurements could have been done. The idea was that some data and basic information on the processes (technologies, temperatures, etc.), the energy supply and the distribution system was available before a visit at the company. Thereby, the auditor should be already well prepared identifying the most important questions and optimisation potentials.

During the visits most of the data necessary for the audit could have been collected. At least a detailed time schedule for the handover of the data was developed together with the company supported by emails and phone calls during the modelling phase in EINSTEIN.

The results of the evaluation of the present state were discussed and verified directly with the companies to ensure the propriety of the models and the high quality of the following alternatives designed in EINSTEIN.
In the phase of development of alternatives the three main steps of EINSTEIN were obeyed:

- Process optimisation
- Heat recovery network
- Change of the energy supply

Firstly a possible process optimisation based on the EINSTEIN database and the knowledge of the auditor was discussed and evaluated together with the company and secondly a heat recovery network was designed in EINSTEIN. Both measures focus on the reduction of the energy demand of the whole company before a change in the supply system is suggested. Especially the design of the heat recovery network (based on the pinch algorithm implemented in EINSTEIN) had been discussed with the energy managers of the companies as local frameworks have to be considered to ensure the feasibility of the suggested heat exchangers.

The third main focus of an energy audit based on the EINSTEIN methodology is the design of an alternative energy supply system. Thereby, existing boilers and chiller should be optimised or substituted by more efficient boilers and chiller or technologies with a special focus on renewable sources as solar thermal or a CHP. These, included in EINSTEIN, had been discussed with the companies during the data collection in order to develop joint ideas implemented in EINSTEIN. The target is not to develop single solutions but an optimised system combining different approaches. Therefore, several different proposals had been developed based on discussions with the companies and ideas of the energy managers as well as the auditors.

Finally, these approaches had to be evaluated on their technical feasibility and compared to the present state in an energetic, economic and ecologic evaluation. For the economic efficiency investment and operation costs had been evaluated based on the equipment suggested. Moreover possible funding schemes in the countries were implemented in the audit.

Thereby the developed solutions and the present state are compared based on the following criteria:

- Primary energy demand
- Process and supply heat
- Environmental impact (CO_2 emissions, radioactive emissions, etc.)
- Investment costs
- Annual costs
- Additional cost per saved energy
- Internal rate of return

Generally the focus was not to develop only the best possible solutions but also the solutions with the highest potential for realisation in the company.

Together with the company the most reasonable solution was selected and the results of the audits were presented directly at the company if possible. Especially in Slovakia and Bulgaria these presentations had been done by the local partners due to translation problems. The results of the audits were the EINSTEIN reports, generated automatically, a report based on a template developed within the project and generated

by the auditor and a presentation. All audits are summed up in the project Deliverable D3.1 downloadable under www.einstein-energy.net.

A side-effect of the performance of the audit campaign is the further development of the EINSTEIN database implemented in the software tool. Benchmarks and BATs could have been expanded by the results of the projects.

Within this work package also a follow up was performed. Therefore, all companies had been contacted after several months or weeks in order to evaluate the status of possible realisation of the measures suggested. The idea was to find out if the measures suggested had been or will be realised and whether the companies need a further support.

The idea of the project was to develop conclusions for different branches and countries based on the audits in order to identify the sectors with the highest energy saving potential. These results are very hard to obtain as the 72 audits cover a very wide range of sectors and sub-sectors. Generally it can be stated that there is still a very high potential for optimisation in all countries and sectors. This includes the process optimisation and especially heat recovery that is not realised in most of the companies. The substitution of the existing energy supply by more efficient technologies and renewable energy sources offers an even higher potential for the increase of energy efficiency and the reduction of fossil CO_2 emissions.

The audit campaign has proven the technical quality of the audits, the tool-kit effectiveness and the global impact at market, company and regional level. Due to the fact that audits in very different countries, different sectors and sub-branches have been performed by different auditors the standardisation and applicability of the audit methodology could have been verified. The capacity building activities together with the involvement of the industrial partners and the dissemination activities organised at EU level will ensure that the energy audit practices will continue after the end of the project.

5.3 Outcomes of EINSTEIN-II audits

As part of the Intelligent Energy Europe-funded project EINSTEIN II, a systematic follow-up of the EINSTEIN audits was performed: to give support to companies with their decision making and to learn about their technical and non-technical barriers against proposed saving measures. The report evaluation of follow-up reports, estimation of energy saving potential (D3.2, D3.3) summarises all audits performed on a quantitative level, including all relevant information (e.g. primary energy consumption, primary energy savings, energy consumption and possible savings on fuel level, information on potential savings of CO_2 emissions and total energy costs, and others).

In addition, the report provides feedback from all countries to all audits, based on a standardised, short questionnaire including questions on the current decision stage of the implementation of the energy saving measures and reasons for implementing or not implementing so far. Moreover, general comments on the audits were summarised.

It was planned as described in the contract to summarise results for those countries / partners who participated and were responsible for audits also in EINSTEIN I: The long term evaluation should have been included in this task. There were different difficulties in performing this task: First of all the audit summary of the EINSTEIN I audits differed quite considerably from the EINSTEIN II reports and did not include the summary table as defined for EINSTEIN II audit reports, the quality of EINSTEIN I audits were therefore not comparable with EINSTEIN II. In addition the tool itself was developed even further. On a company level very often the contact person changed and it was difficult to find the new person. In addition sometimes the companies changed. Those were the main reasons why this data was not compiled.

Further it was planned to extrapolate or estimate the potential impact of the performed audits on a regional and/or national levels. The consortium agreed that this will not be done as this information would be totally misleading. As mentioned above it turned out that the saving potential from companies does not depend on the size, sector or country. It depends on the very specific situation of the company and the measures already implemented as well as on the national and/or regional frameworks. But general data on the average primary energy and CO_2 saving potential and payback time is given in this report.

5.3.1 Main results

The main results of the audits were:

Of the 72 audits conducted, 67 companies were evaluated in detail (some data was missing for the other 5).The total primary energy consumption of those companies in present state was 1,370 GWh including as main energy carriers natural gas with 617 GWh (45%) and electricity with 701 GWh (51%). The total energy costs were 45.4 million EUR.

The proposed measures from the EINSTEIN audit reports would save 259 GWh or 19% of total primary energy consumption. 33 of the energy audit reports recommended measures leading to primary energy savings between 6.2% and 30% (see Figure 1). The main proposed energy saving measures are mentioned in table 1. Heat recovery and combinations of CHP or solar thermal and heat recovery accounted for the bulk of proposed saving measures. The gas consumption would increase by approximately 20%. The electricity consumption would be reduced by 52%. This is due to the fact that, particularly for the bigger plants, combined heat and power plants were suggested which would produce electricity (and deliver the electricity sometimes to the grid) but also would need additional gas. All EINSTEIN CHPs are heat led (heat operated), that means that the total amount of heat produced during the electricity production can be used within the company. Therefore in comparison with the grid the electricity is produced in a more efficient way and primary energy is saved by the CHP. These savings in primary energy would correspond to savings of 17% of total energy costs.

Table 6. Number and kind of saving measures proposed in the EINSTEIN audit

Kind of saving measure proposed	Number of energy audits proposing the energy saving measure
Stand-alone proposals (only one kind of saving measure) proposed)	**Sum 30**
Boiler efficiency	2
CHP	7
Heat recovery	12
Solar thermal	6
Process optimisation	3
Combination of two different saving measures	**Sum 21**
Heat recovery and boiler efficiency	2
Heat recovery and CHP	10
Heat recovery and solar thermal	7
Process optimisation and chiller	1
Process optimisation and solar thermal	1
Combination of three different saving measures	**Sum 16**
Combinations, incl. process optimisation, heat recovery and CHP (all 3 of them)	**10**
Other combinations of at least three different saving measures (excl. mentioned above)	**6**

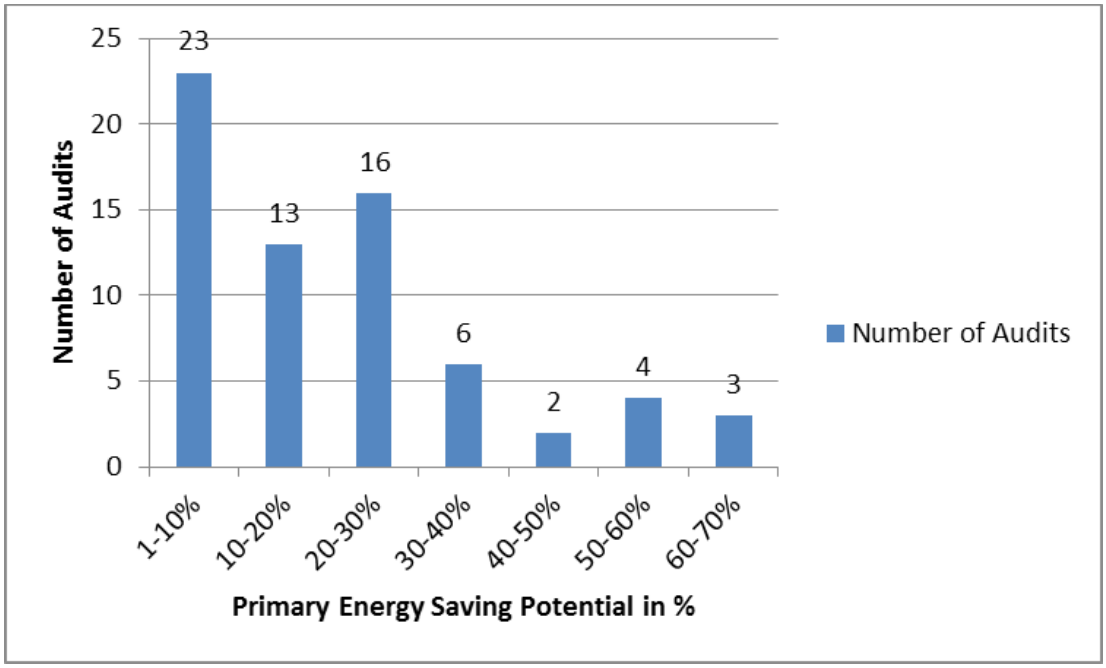


Figure 9: Number of audits as a function of primary energy saving potential

Table 7. Results of the proposed savings of the EINSTEIN audits

Total CO_2 emissions, current status	281,894 t p.a.
Total CO_2 savings	38,654 t p.a.
Total CO_2 savings in %	14%
Total energy costs, current status	45,365,764 EUR p.a.
Savings total energy costs, incl. O&M and annuity [EUR]	7,579,826 EUR p.a.
Savings total energy costs, incl. O&M and annuity [%]	17%
Own investment (excl. subsidy)	3,778,448 EUR
Total investment (incl. subsidy)	29,465,904 EUR
Renewable energy production triggered [MWh]	39,452 MWh
Investment in sustainable energy	4,658,874 EUR

For the status of the implementation of the energy saving measures all local partners in the different countries called all audited companies to ask for the status of the implementation of the saving measure, the main reasons for implementing or not implementing and for lessons learned or other issues. The Austrian Energy Agency developed a template to be filled in for this purpose. The individual country results are shown in the next chapter.

From the 69 companies evaluated 9 cancelled the implementation of the proposed saving measures, 25 postponed their decision. 15 companies believe that further investigation is necessary, four already contracted further analysis, four already contracted detailed analysis, seven are inviting offers for equipment and five already implemented the proposed (or at least some of the proposed) saving measures. This means that more than the half of the companies audited is planning to invest in energy saving measures.

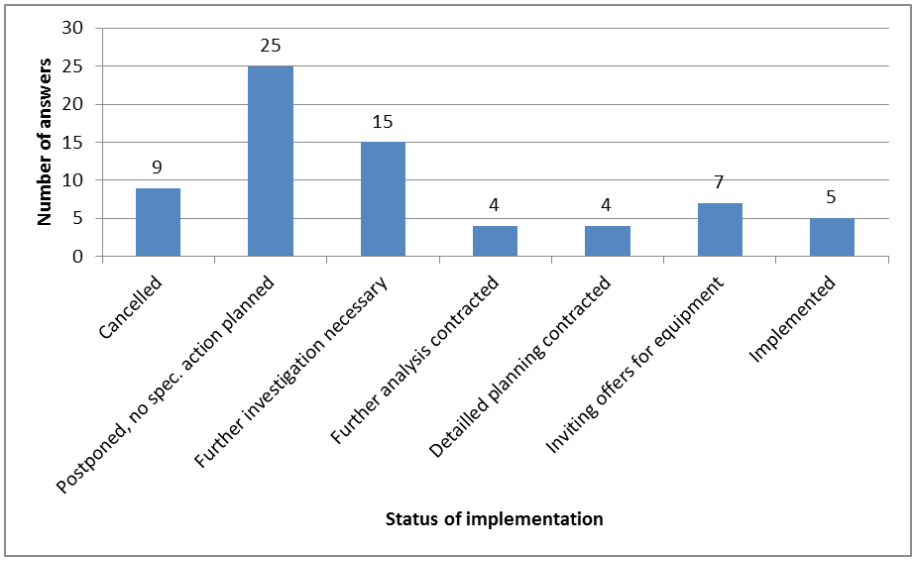


Figure 10: Status of implementation of the proposed EINSTEIN energy saving measures

Concerning the main reasons for not implementing the energy saving measures (so far), financial reasons rank foremost (38% in total: in eight cases financial risk, in five cases too long pay-back and in three cases too high initial costs for equipment was stated), followed by "not the right time" (in 13 cases or 31% of the answers). Other reasons such as too high technical risk and lack of time (each one two answers), not enough accurate data, personal reasons or unclear responsibility (three cases each) were not seen as the main issues.

Figure 4-: Reasons for not implementing or delay in the implementation of the proposed EINSTEIN energy saving measures

For the reasons for (planned) implementation of the saving measures proposed within the EINSTEIN reports, 22 companies answered that the high expected energy savings and the corresponding monetary savings are the main reasons. In four cases personal engagement could be identified.

5.3.2 Summary and Conclusions

The kind of saving measure, the corresponding saving potential and the payback is dependent on the following facts:

- First of all it depends on what is already implemented in the company. This is especially true for heat recovery systems, but also e.g. CHP.
- Second, some saving measures are country-specific.
- CHP is dependent on the subsidies for the construction of the CHP and the feed-in tariff. Especially Spain and Germany seem to have quite good conditions[3]. In other countries (like Austria) there is only a subsidy of 10% but no feed-in tariff for fossil CHPs.
- For solar thermal the solar radiation is crucial, therefore e.g. in Ireland no solar thermal plant was suggested, whereas in Bulgaria in half of the audits solar thermal was proposed. On the other hand, even for solar thermal proposal other circumstances are also relevant, e.g. in Spain in not a single case solar thermal was proposed.[4]

[3] *In most Spanish audits CHP has been proposed due to the existing feed-in tariff. Nevertheless, in 2012 feed-in tariffs have been eliminated within the packages of saving measures for mitigation of the financial crisis.*

[4] *In almost all Spanish audits solar thermal has been considered as one of the possible alternatives. Nevertheless, these proposals remained a 2nd choice due to the economic criteria applied, which was a pay-back period of not more than 4 years.*

Therefore, no generally valid rules for saving measures in a country or an enterprise can be given. This is why such a tool as EINSTEIN, starting with a detailed analysis of energy consumption and considering the specific situation of a certain company is needed. Another advantage of EINSTEIN is that no specific energy saving measure is preferred, but all different solutions are evaluated. To sum it up:

- EINSTEIN provides the different audit-steps and the software.
- EINSTEIN has no focus on a single technology or sector.
- EINSTEIN facilitates the evaluation of all possible solutions and their combinations.
- EINSTEIN is appropriate for fast audits (in the sense that e.g. a result is a proposal for a heat exchanger, incl. proposed power, but not a detailed feasibility study for this single heat exchanger).

A conclusion on whole sectors and countries is not possible or difficult due to the small number of audits performed. The results highlight that the potential for energy reduction by heat recovery and process optimisation is far from being fully utilised. Therefore, a special weight has to be set on this topic. The economic feasibility of further measures depends strongly on the national and local frameworks and particularities. By the integration of renewable energy sources as solar thermal as well as CHP energetic, environmental and economic useful proposals can be offered to industries and big buildings in order to secure the attractive location of the companies as well as to reach defined environmental targets.

Furthermore the target of the audit campaign to further develop and adapt the EINSTEIN tool to the needs of an audit in different sectors and buildings has been fulfilled. By this the suitability of EINSTEIN for all sectors and buildings is proven, as all proposals and ideas can be evaluated in an objective and independent manner. Therefore, the auditors are provided with a very useful tool.

6 Standardisation

Standardisation is a significant means to make knowledge available to any interested party. EINSTEIN chose standardisation to make its methodology for energy auditing available to a large community, going beyond the originally targeted group of auditors to be trained to apply EINSTEIN.

The experiences gained in EINSTEIN audits are exceptionally valuable and thus should to be disseminated in a form additional to the ones traditionally used in a project, e.g. publications or training material. Standardisation and resulting publication as standard or specification is one of the means available beyond the traditional ones.

DIN as partner in the EINSTEIN-II project ensured on one hand the application of already existing standards in the project where appropriate, while on the other hand supporting the transfer of results of the project into standardisation. Here, collaboration with the respective joint working group of CEN (European Committee for Standardisation) and CENELEC (European Committee for Electrotechnical Standardisation) was initiated and contributions were offered to on-going standardisation; the most significant result was, however, the development of a specification (CEN Workshop Agreement CWA), where e.g. the integrated approach on energy audits, pursued by the project, was presented as "good practice". The CWA will be available to any interested party and is available at any of the 33 national member bodies of CEN.

Further information on the CWA and its availability can be retrieved at http://www.cencenelec.eu/News/Brief_News/Pages/TN-2012-013.aspx (query 2012-12-07). See also https://www.einstein-energy.net/trends-analysis-workshop

7 The EINSTEIN Tool-Kit

7.1 Overview on the EINSTEIN Tool-Kit

In the core of the EINSTEIN tool-kit there is the audit methodology, described in the EINSTEIN audit guide, and the EINSTEIN expert system software tool.

Within the EINSTEIN tool-kit in addition complementary tools can be found, such as a check-list and a questionnaire for data acquisition, a survey of existing auditing tools and manuals, and – new since EINSTEIN-II, a collection of 72 good practice thermal energy audit examples.

For more information and a free download of the tool-kit go to: www.einstein-energy.net/tool-kit

7.2 The EINSTEIN expert-system software tool

The EINSTEIN methodology is supported by an expert system software tool that guides the user through the whole auditing procedure spanning from data acquisition, processing and estimation to the design and quantitative (energetic and economic) evaluation of alternative solutions.

In practice, EINSTEIN:

- calculates the total thermal energy demand of complex heat and cooling energy consumers, and breaks it down into different components;
- helps to estimate key data. Algorithms for the estimation of missing but relevant information help carry out a preliminary quick assessment based on very little data;
- provides a database on process optimisation possibilities;
- by means of pinch analysis and semi-automatic heat exchanger network design, assesses saving opportunities through heat recovery and process integration;
- based on a reduced heat demand, shows the technical alternatives for the integration of energy efficient and renewable energy supply systems and evaluates them through a dynamic system simulation;
- offers a comprehensive evaluation. The preliminary design of the most promising options also includes the evaluation of environmental impact and economic performance.

The EINSTEIN Software Tool is:

- **Appropriate for both fast and detailed assessments**. Data processing is optimised and allows for quick proposal development.
- **High quality**. The software tool provides quantitative figures on potentially achievable energy and economic savings through refurbished heat supply systems that integrate the most energy efficient technologies (e.g. heat recovery, CHP and renewable energies).
- **A Comprehensive Package**. EINSTEIN combines features from pinch analysis tools to system simulation tools for specific technologies within one comprehensive package. So, a detailed simulation of complex systems is possible, combining different supply technologies and heat exchanger networks, even for users that are not familiar with sophisticated system simulation tools.
- **Reliable**. The data processing includes a completeness and consistency check procedure to detect inconsistencies and missing data.
- **Proven in Auditing Practice**. EINSTEIN has been used successfully for energy audits by project partners from international consortia in more than 200 industrial and non-industrial facilities.
- **Free and open source**. Everyone can freely download, use and modify the EINSTEIN software tool under the GNU GPL licence. Users can also contribute to its development and share their experience with the EINSTEIN community.

7.2.1 Modules of the EINSTEIN software tool

The following scheme gives an overview of the modules of the EINSTEIN software tool

Data Acquisition and Analysis Module

- ✗ Consistency and Completeness Checking and Benchmarking
- ✗ Breakdown of Energy Consumption and Supply by Processes, Equipment, Temperature Levels, Time

Process Optimisation Module

- ✗ Recommendations for Technological Optimisation

Heat Recovery Module

- ✗ Pinch Analysis
- ✗ Design of Optimised Heat Exchanger Network

Energy Supply and Renewables Module

- ✗ Design of efficient Supply System (Utilities): CHP, Heat Pumps, Solar Thermal, Biomass, Efficient Chillers, Boilers and Burners

Simulation and Evaluation Module

- ✗ Dynamic System Simulation of the Whole System (Processes, Buildings, Distribution and Heat Exchanger Network, Utilities)
- ✗ Economic and Environmental Evaluation

Reporting Module

- ✗ Automatic Report Generation

Data Acquisition and Analysis Module

- Consistency and Completeness Checking and Benchmarking
- Breakdown of Energy Consumption and Supply by Processes, Equipment, Temperature Levels, Time

The EINSTEIN software tool contains a questionnaire for structured and systematic data acquisition. Entered data is automatically checked for consistency. A procedure for estimation of non-available data is included. Using a benchmarking database, the current energy consumption of the company is compared with the typical standard values of similar companies or processes.
The tool automatically generates 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 data acquisition
- Consistency and completeness checking
- Procedure for estimation of un-available data
- Benchmarking

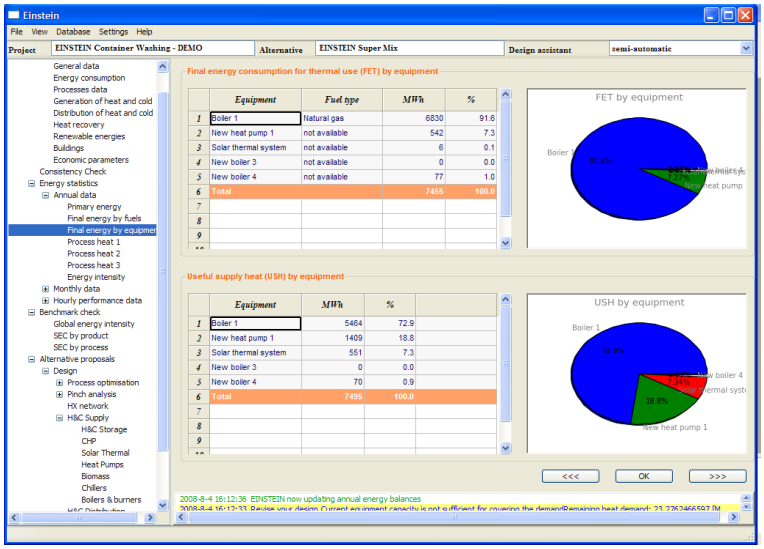


Figure 11: Breakdown of present state energy consumption: heat supply by equipment

Process Optimisation Module

- Technological Optimisation

As a first step after data acquisition and analysis, the process optimisation module shows the variety of options to reduce process heat and cooling consumption at its origin by selection of efficient process equipment and procedures. The module provides information on best available technologies for important unit operations (e.g. washing, drying, sterilisation etc.).

Tools:

- Database of best available technologies and process optimisation measures for different unit operations and branches

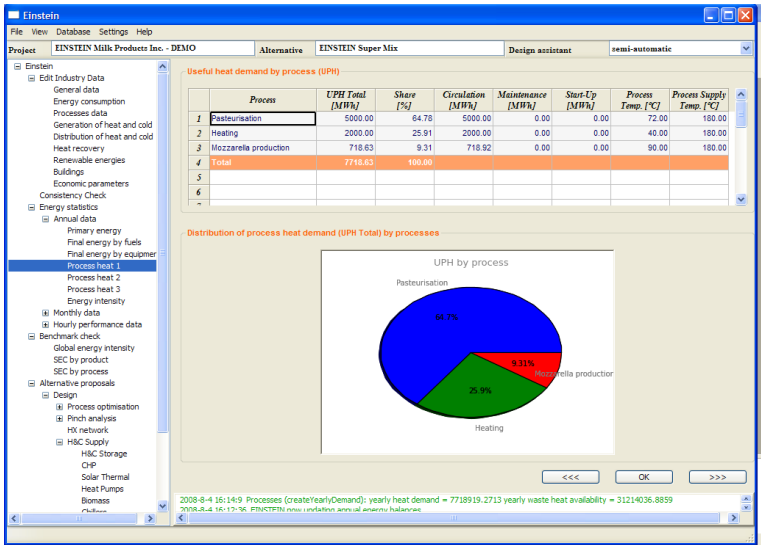


Figure 12: Breakdown of present state energy consumption: process heat demand by processes

Heat Recovery Module

- Pinch Analysis
- Design of Optimised Heat Exchanger Network

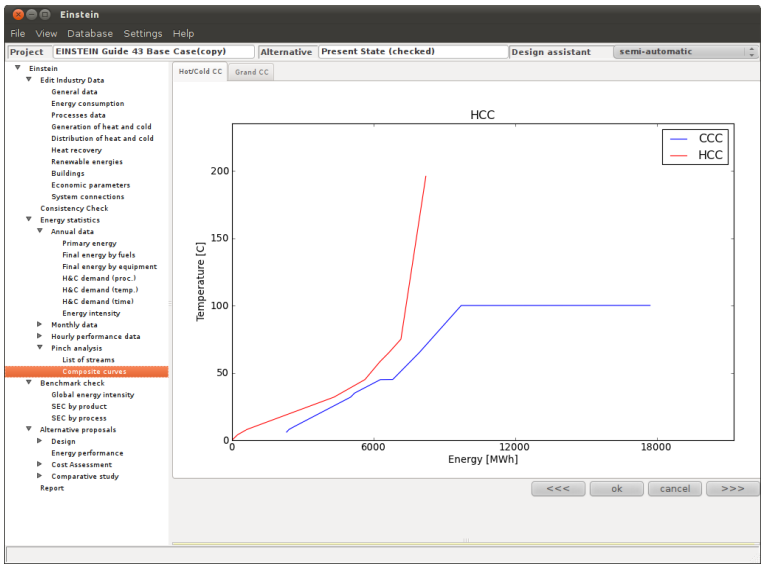


Figure 13: Hot and cold composite curve of a company

The heat recovery module helps in designing and optimising an appropriate heat exchanger network for heat recovery and process integration. For this purpose, EINSTEIN analyses process and utility streams as well as available waste heat, 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); definition of energy targets
- Automatic and/or manual design of optimised heat exchanger network

Energy Supply & Renewables Module

- Design of Efficient Supply System (Utilities): CHP, Heat Pumps, Solar Thermal, Biomass, Efficient Chillers, Boilers and Burners

The heat and cooling energy supply modules help to select and design the most appropriate energy supply equipment and distribution systems. EINSTEIN analyses 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 sizing of utilities
- Databases on energy supply equipment

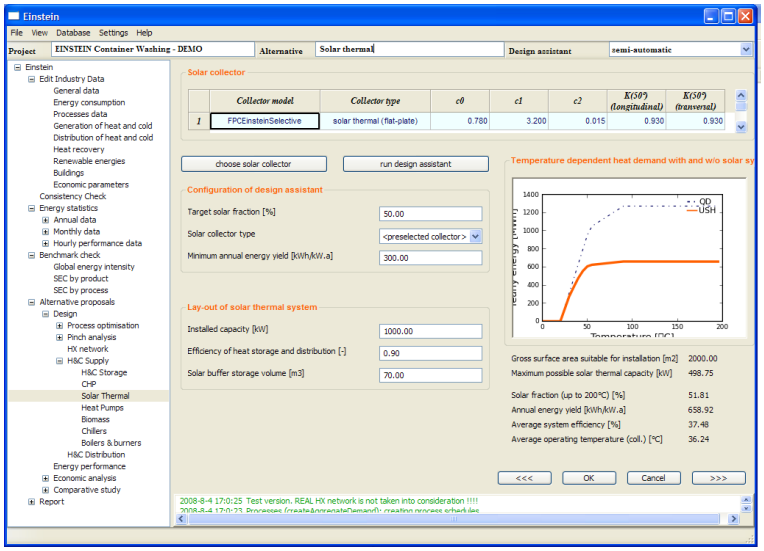


Figure 14: Design assistant for solar thermal systems

Simulation and Evaluation Module

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

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

Tools

- Dynamic system simulation of the whole system
- Automatic and/or personalised economic analysis

- Environmental evaluation

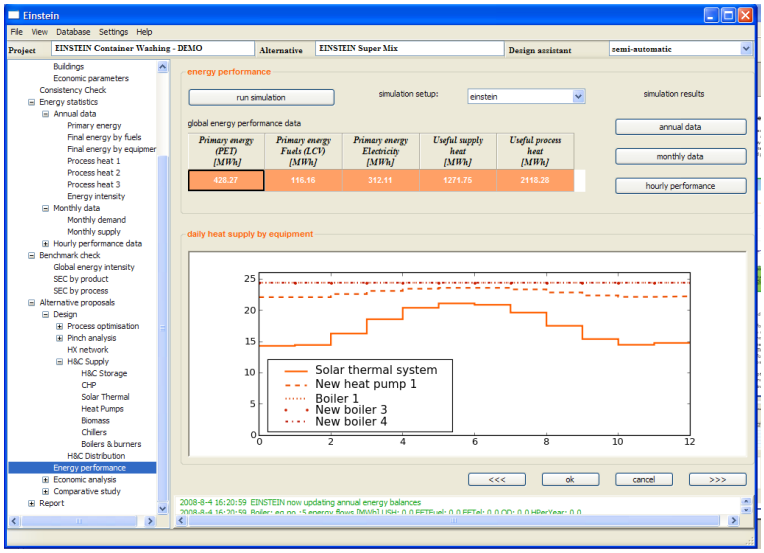
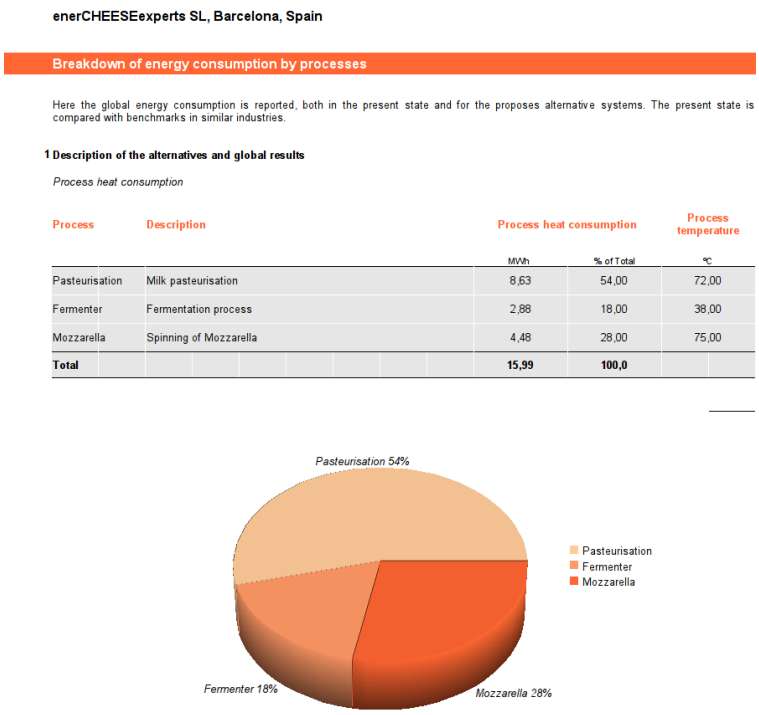


Figure 15: System simulation with EINSTEIN: contribution of different heat supply sub-systems to total demand

Reporting Module

- 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 spreadsheet in open document format) can be edited, printed and delivered to the audited company.



enerCHEESExperts SL, Barcelona, Spain

Breakdown of energy consumption by processes

Here the global energy consumption is reported, both in the present state and for the proposes alternative systems. The present state is compared with benchmarks in similar industries.

1 Description of the alternatives and global results

Process heat consumption

Process	Description	Process heat consumption		Process temperature
		MWh	% of Total	°C
Pasteurisation	Milk pasteurisation	8,63	54,00	72,00
Fermenter	Fermentation process	2,88	18,00	38,00
Mozzarella	Spinning of Mozzarella	4,48	28,00	75,00
Total		**15,99**	**100,0**	

Figure 16: Example sheet of the EINSTEIN audit report

7.3 New Developments in EINSTEIN-II

In November 2012 EINSTEIN Version 2.2 has been released. Version 2.2 is the final result of the work in the Framework of the project IEE-EINSTEIN-II. An intensive testing of this release has been carried out in 72 energy audits carried out by the EINSTEIN developers team and several more energy audits carried out as project work from EINSTEIN trainees.

With respect to the older versions V1.0 and V1.1 from the EINSTEIN-I project a large number of substantial improvements of the software have been carried out:

7.3.1 Detailed time schedules

The user may now define generic time schedules for any process within the system with full flexibility:

- any daily profile
- seasonal variation
- holiday periods

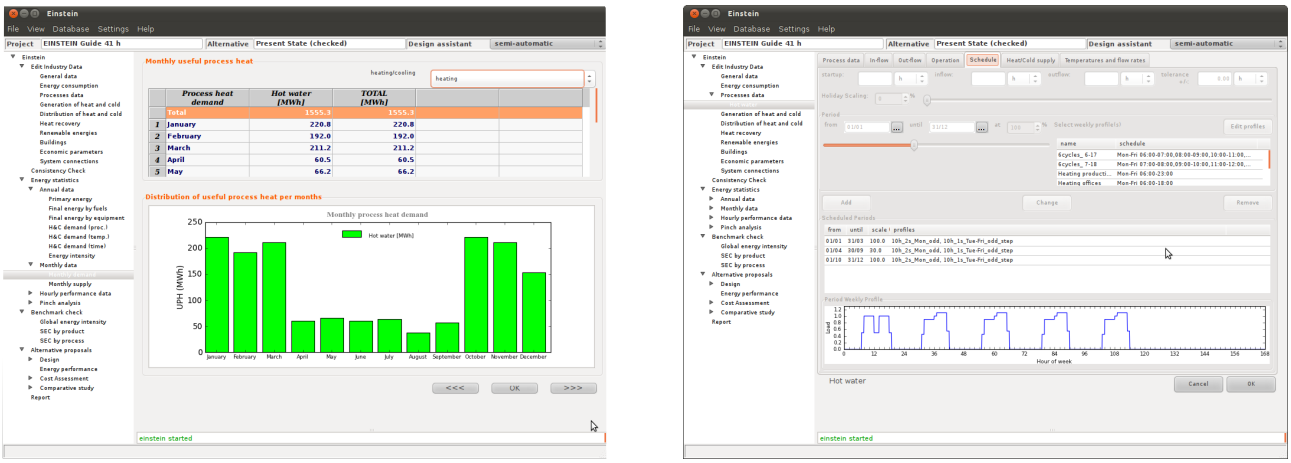


Figure 17: Example for a detailed time schedule in EINSTEIN 2.2. Left: Seasonal variation; right: weekly variation of demand

7.3.2 Multiple in-/outgoing flows to a process

It is possible to specifiy as many incoming and outgoing flows to a process as needed. In the example below a model of a drying process is shown with fresh air, recirculation air and product to be dried as incoming flows.

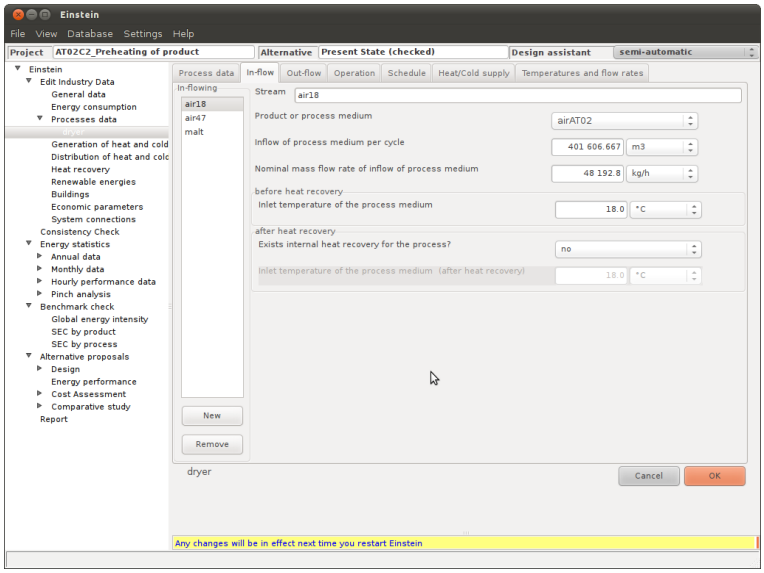


Figure 18: Example for a process with 3 incoming flows (drying process).

7.3.3 Full support for cooling

One of the major extensions of developments within EINSTEIN-II has been the full extension of the EINSTEIN software to cooling. Now nearly all equipment relevant in cooling systems in practice can be modeled:

- air- and water-cooled compression chillers
- air- and water-cooled thermal chillers (absortption, adsorption)
- dry and wet cooling towers
- fresh or ground water cooling, ambient air cooling

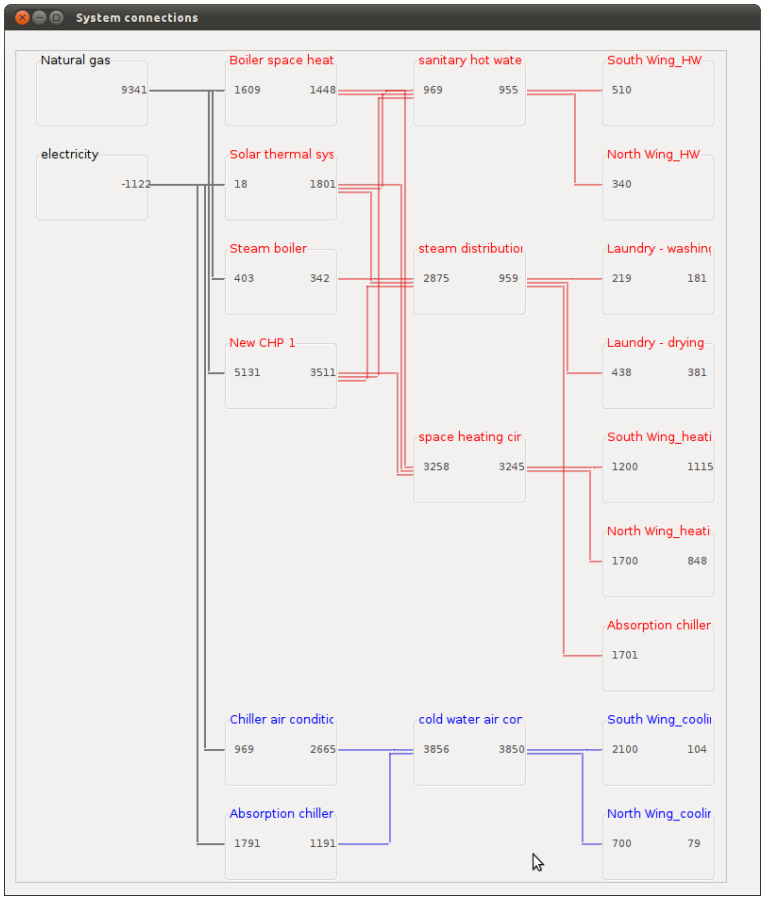


Figure 19: Energy flows in a complex system with heating and cooling demands (hospital)

7.3.4 Extension of EINSTEIN to non-industrial applications

In order to apply EINSTEIN also for non-industrial applications, it has been necessary to develop a module for buildings within EINSTEIN. The user may input information on building heating demands, that then is used by EINSTEIN for system optimisation.

In order to simplify user entry and use required data to a minimum, there is the possibility of an automatic generation of both daily and seasonal distribution of the heating, cooling and hot water demands.

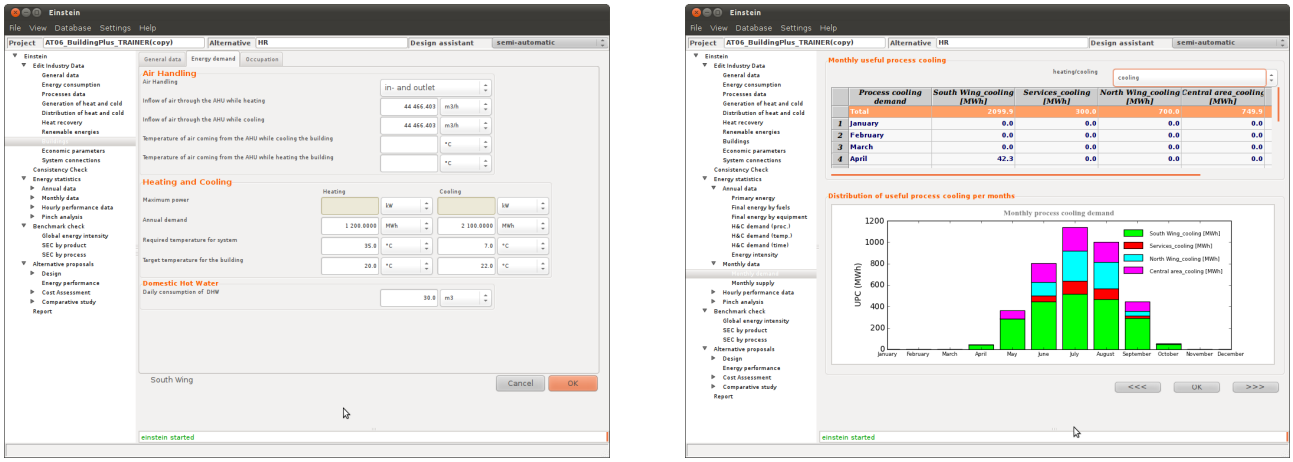


Figure 20: EINSTEIN building module: Left: data entry; right: typical seasonal distribution of cooling demand

Air handling units in buildings are treated separately from the other heat and cooling demands, in order to allow for heat recovery and interaction of other supply systems with the air handling.

EINSTEIN 2.2 furthermore allows for differentiation between indoor temperature and heating system temperature.

7.3.5 Complete re-programming of the heat recovery and system simulation module

The heat recovery module of EINSTEIN Version 1 had several limitations, that led to the decision to implement a fully new module:

- Closed and proprietary code (the owner of the code was no longer EINSTEIN project partner)
- Difficulty to extend the existing module to new requirements (multiple flows in processes, support for cooling, etc.)

Therefore, the heat recovery module has been completely re-programmed from scratch as open source module fully integrated into the EINSTEIN environment.

The system simulation kernel of EINSTEIN has been modified in order to integrate the new heat recovery module, so that a significant speed-up of heat recovery calculations could be obtained.

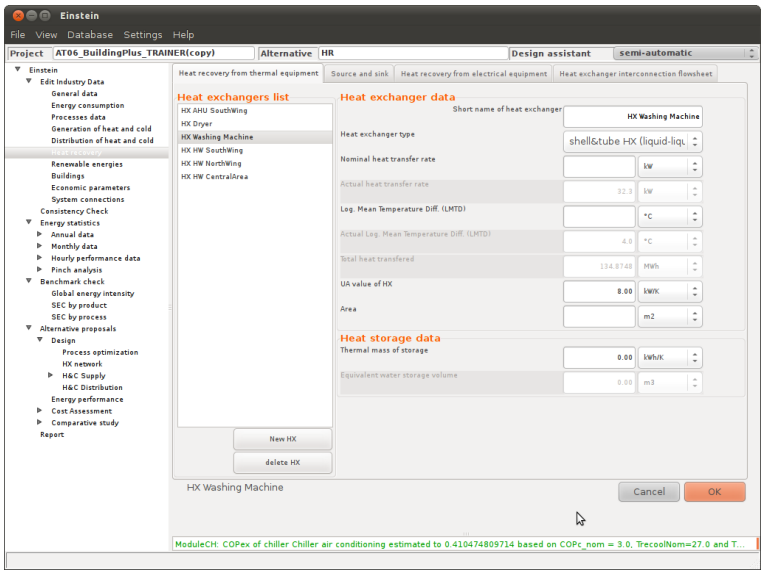


Figure 21: Screen shot of the heat exchanger questionnaire

Additional features of the new heat recovery odule:

- possibility of serial connections in heat exchangers, improvement of output
- possibility of use of waste heat in heat distribution (pipes)
- heat exchanger network auto-design: compatibility with new simulation engine / calculation mode
- list of streams as additional data output

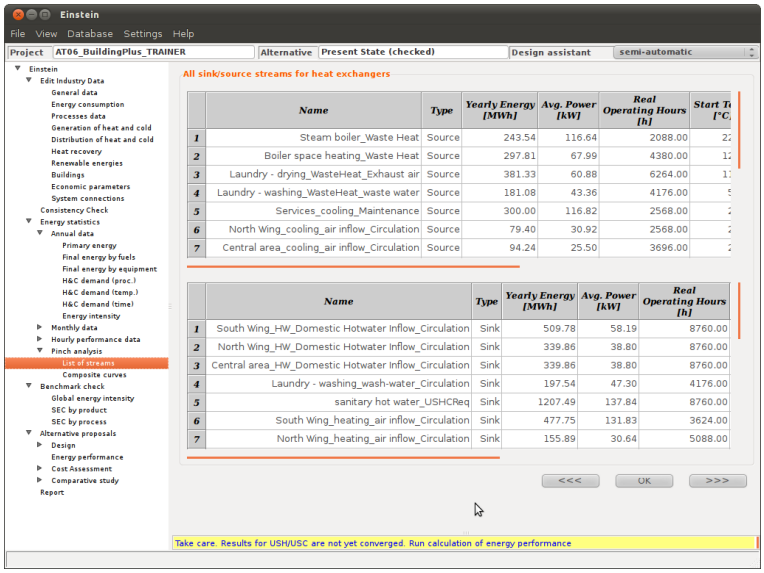
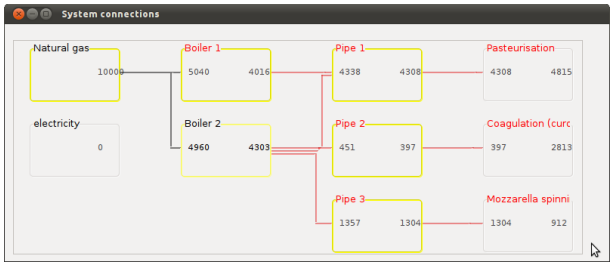


Figure 22: List of streams as additional output of pinch analysis module

7.3.6 User friendliness: support to error tracking in consistency and completeness checking

- highlighting of paramaters involved in conflicts, missing data and data calculated by EINSTEIN by colours in GUI
  - colour highlighting in data entry questionnaire
  - colour highlighting in graphical block scheme (connection editor)
- improvement of error tracking:
  - addition of explanatory text to error messages
  - direction to relevant page of data entry questionnaire in case of missing data
  - listing of data that maybe possible causes of conflicts
- local consistency checking after saving of data for each data block (equipment, processes, etc.)
- better tracking of convergence and termination criteria: graphical display, tracking of both average and maximum error



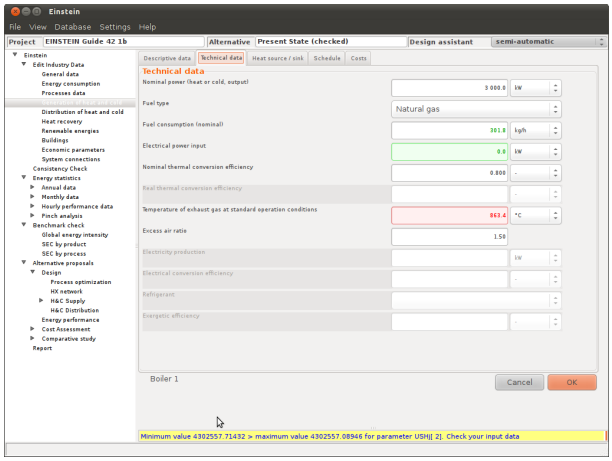


Figure 23: Colour highlighting of data conflicts and possible error sources in consistency and completeless checking

7.3.7 Improvements in heat and cooling supply modules

- Equipment modules (general):
  - all relevant equipment parameters now can be displayed and modified via the questionnaire
  - data entry (display) for economic parameters (investment, O&M costs) added

- Chiller module:
  - New chiller type: water cooled chiller with dry cooling tower now possible
  - Automatic calculation and consistency checking of exergetic efficiency
  - New default chiller database: best-available-technology chillers from Eurovent database.
  - Design assistant: possibility to select and add new chillers from database

- CHP module:
  - Possibility to separately define purchase and sales tariffs and feed-in tariffs / primes for self-generation

- Solar thermal:
  - Possibility to add solar thermal systems in present state

- Heat pumps:
  - a speed up of the heat pump simulation code
  - possibility of connecting heat pumps to heat exchangers / heat recovery system

7.3.8 Improvements in simulation engine

- Speed-up of iterative calculations in simulation engine (limitation of simulations in iterative cycles to those components with variation in input parameters)

- Process modeling: differentiation between process temperature and minimum supply temperature to processes

7.3.9 Improved user handling

- a graphical installer for MS-Windows XP, Vista and 7

- better plots in the graphical interface by integration of the matplotlib – library

- graphical display of system block scheme for visualisation of the interconnections of equipments, pipes and processes and for display of energy flows (see Figure 19 above)
  heat flows from heat exchanger network now added to the plot

- Project data entry:
  - possibility of changing process name and description also for checked state (fully or parly finalised projects). distinction between project name and company name
  - possibility of changing alternative names and description
  - addition of project properties, such as responsible author, creation and modification date
  - display of currently active object (process, equipment, ...) at the bottom of the active data entry questionnaire panels
  - display of processes in the main tree. possibility to reorder processes
  - a flow chart graphical input for process and pipe parameters for an easier understanding of the meaning of the parameters especially useful as support for beginners

- Database editors:
  - an improved editor for all EINSTEIN data bases
  - substitution of codes by explanatory text in all panels of data base editors

- Support to process and building optimisation:
  - possibility for changing processes with detailed time schedules and building heating and cooling demands in alternative proposals
  - consideration of actual building occupation hours and building holidays for cooling and hot water demands

- Graphics for quick comparison of energy and economic performance of alternatives
- restructuring of GUI: including pinch analysis in energy statistics of present state
- automatic input / output data conversion from mass to volume units now active in almost all places where useful
- elimination of many innecessary warning and error messages

7.3.10 Documentation

- Complete version of technical manual
- Improved user manual

7.3.11 Stability improvements

- higher stability by fixing GUI bugs that led to freezes of the whole application
- exhaustive testing and lots of bug fixes

7.3.12 New languages and internationalisation

- Bulgarian
- French
- Slovak

- full support for british units
- internationalisation: now all relevant submenus are internationalised (included in translation).