CONTINUOUS COMMISSIONING BASED ON THE EUROPEAN ENERGY PERFORMANCE OF BUILDIGS DIRCTIVE AND INTELLIGENT MONITORING

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ABSTRACT

The Save Project **BuildingEQ** "Tools and methods for linking EPBD and continuous commissioning" develops technologies to derive baselines from the information collected during the energy assessment process and rules which are able to automate intelligent monitoring procedures.

The implementation of the EPBD in the participating European countries is quite different. Therefore a 4-step procedure was developed in the framework of the Building EQ project. This procedure follows a general top-down approach. The idea is to put effort in form of measurements and analysis only where and when necessary. The transition from one step to the next than has only to be performed if certain criteria are fulfilled.

For each step we give rules how to derive baselines taking actual weather and utilisation data into account. In addition a minimal data set of measured data was proposed

INTRODUCTION

Continuous Commissioning as Part of Energy Management

Energy management is a permanent process in an organisation aiming at optimizing the amount of energy consumed in buildings and its processes. In practice this means most often reducing the current consumption by changes in operation and maintenance or by investments to retrofitting and new technologies. Good energy management is based on the information received by energy assessment activities and starts from an understanding how a building uses energy.

An energy assessment includes:

- analysis of energy streams in the target (e.g., building stock, building, system, etc.),
- evaluation of existing saving potentials
- development of recommendations on an effective utilization of energy.

The scope and depth of the assessment may vary. The depth of energy assessments can be classified into three levels and a pre-screening phase. The three levels differ in their objectives, scope, methodology, procedures, required instrumentation, and approximate duration.

- The Level 0 assessment is a pre-screening visit to the site and the purpose is to select the facilities for the Level I assessment. In this phase the situation of metering and monitoring must be checked and collection of basic information will be started.
- The Level I assessment is a preliminary energy and process optimization opportunity analysis consisting primarily of a walk-through review and analysis existing documents and consumption figures.
- A Level II assessment will follow the Level I assessment to verify the Level I assumptions, and to more fully develop the ideas from the Level I screening analysis. The Level II effort includes an in-depth analysis in which all assumptions are verified.
- The Level III assessment is a detailed engineering analysis with implementation, performance measurement and verification (M&V) assessment, and fully instrumented diagnostic measurements.

This paper interprets Continuous Commissioning (CC) (Continuous Commissioning® and CC® are both registered trademarks of the US by Texas A&M University.) as energy assessment during the operation of a building. It assumes that an assessment as described has already been undertaken and therefore the most important energy conserving measures (ECM's) including investments and adaptation of operation are already installed. Thus no major wastes and inefficiencies are remaining. CC than has the goal to make the energy savings due to the assessment sustainable by avoiding new wastes or inefficiencies. CC is introduced as a tool which is based on regular inspections during operation to improve energy efficiency and to cut costs. CC therefore is considered to be the fourth level of energy assessment. This is also shown in Figure 1. It should however been noted that CC does not require a Level II or Level III assessment before. Rather it might be started after each of the energy assessment levels using the information on the energetic behaviour of the building available at this state.

- Select building from building stock **Level 0**
- Perform **Level 1** analysis
- Perform **Level 2** EA using a multi zone model (e.g. from annex 46)
- Extend Level 1 EA through
  - Short term measurements
  - Simulation kernel based on hourly methods including system simulation (e.g. Energy+)
  - Detailed descriptions of loads
  result is **Level 3** EA
- Replace short term through long term measurements, adapt demand model and introduce model based EM – **Level 4**
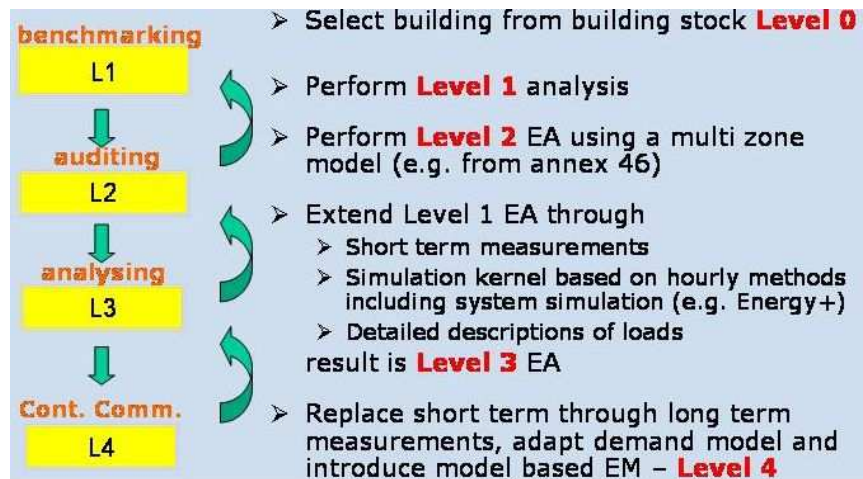
Figure 1   Continuous Commissioning in the context of energy assessment (from IEA ECBCS Annex 46)

Why Continuous Commissioning

Users request a comfortable and healthy indoor environment, but they no longer accept the excessive use of natural resources or polluting the outdoor environment. The heating, ventilation and air conditioning (HVAC) industry seeks solutions to fulfil these higher requirements. One tendency is leaving the time of low efficiency stand alone products and entering a period of high efficiency integrated systems. Moving from simple products to large systems enables one to develop more efficient and flexible solutions, but it also leads to a higher level of complexity. Continuous commissioning is one of the new approaches to manage the complexity of today's building and HVAC systems. The primary obstacles that impede the adoption of commissioning as a routine process for all buildings are lack of awareness, lack of time and high perceived costs.

The major tasks in a continuous commissioning process are Fault Detection and Diagnosis (FDD) and optimisation of operation to meet the changing user's demands for comfort with a minimum of primary energy. FDD in the field of building operation is still in its infancy. The first attempts of systematic FDD in buildings go back to the late 80s. Many different approaches have been tested theoretically or in the lab but the systematisation is missing.. Furthermore, the wealth of different models and approaches which have been tested positively by the scientific community has not yet made it to the field. The number of commercial FDD tools that are available on the market is quite low and many of the tools are still under development. However resent research efforts develop promising solutions.

The situation with optimisation is similar. We have learned to understand very well the optimisation of stand alone components but lack on experiences how to optimize the whole building system. Therefore with many Building Energy Management Systems (BEMS) – especially if they are part of an Facility Management –system – questions arise like

How should one consider the instrumentation level and location of essential measuring points? What can one do with the existing level of instrumentation and what is needed for short-term measurements? What is the validity and performance of existing meters? Do they operate properly?

Consequently we have a need for energy assessment during operation.

CONTINUOUS COMMISSIONING

Definitions

The "Continuous Commissioning Guidebook" of the Federal Energy Management Program gives the following definition for continuous commissioning:

"Continuous Commissioning is an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify retrofits for existing commercial and institutional buildings and central plant facilities."

Furthermore the following general phases for CC are given:

- Develop the CC plan
- Develop performance baselines
- Conduct system measurements and develop CC measures
- Implement CC measures
- Document comfort improvements and energy savings
- Keep commissioning continuous

CC as a 4 – Step Procedure

Introducing a continuous commissioning process to a building can thus be described as a multi-level process. The process will be a top-down-approach that starts on the building level and goes down to selected single components if necessary.

The available information for the building (stock data and measurement) will increase from step to step and will increasingly enable more detailed analysis of the building performance.
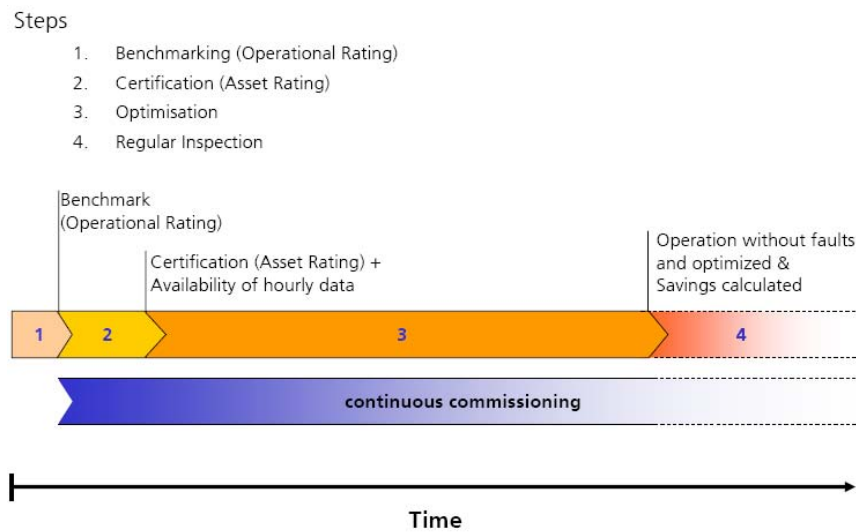
Figure 2:   Scheme of the 4-step procedure on a time scale

Figure 2 describes our view on continuous commissioning as a 4-step procedure on a time scale. Steps 1 to 3 correspond to the energy assessment levels 1 to 3 discussed earlier. It is important to notice that the continuous commissioning approach can be introduced right after step 1 as a classification of the building is available already at that stage. To make this clear: whatever level seems to be appropriate to assess a specific building we strongly recommend to observe the building behaviour continuously to make sure it stays in the condition reached after the assessment.

In order to arrive at that systematisation, we have to define each single step with respect to:

- Stock data
- Measured data
- Performance Metrics / Evaluation Techniques
- Outcomes / aims of the step

The following Tab. 1 gives an overview over the most important elements of the 4-step procedure. Details are given in the WP3 report of Building EQ.

In summary: continuous commissioning is a systematic procedure where the purpose is to

- evaluate the existing energy consumption on a daily basis
- identify of the saving measures due to changes in building usage and user behaviour
- detect and diagnose faults in an early stage
- report the findings in quarterly energy reports.

CC Provides Energy Assessment Technologies for Energy Management during Operation

Energy management is a process which goes on over the whole life cycle of a building. Phases such as planning, commissioning, auditing and operation control contribute essential to energy management.

Continuous confirmation of the energy efficiency is necessary primarily because

- HVAC systems like all technical systems have to be checked against faults and faulty operation
- Changes in building utilisation have to be taken in account and might need changes in the definition of comfort and in system operation

Continuous confirmation of the energy efficiency is obtained through continuous commissioning (energy assessment during operation)

For the analysis of energy saving opportunities similar rules hold as for the energy assessment team. The team which performs the continuous commissioning has to keep in mind: the aim may not be in identifying all saving opportunities but concentrate on the low-hanging fruit and no-cost measures.

Identifying no-cost measures during continuous commissioning requires knowledge about the systems and there operation. This are usually things related to operation schedules, set points and operation of the energy using systems. The knowledge has to be condensed into targets for the operation and the associated energy consumption. Identifying long-payback measures is derived from fault detection and diagnosis. Examples are the systems need thorough improvement (change of boiler, installing a new chiller with free cooling, etc.).

Ending up temporarily with no saving potential is not unusual. If the building is very simple and there are not many energy using systems or if a more complex building is very well operated (e. g. through the application of CC) there may not be any saving opportunities without a major renovation. The comment from a client with a large building stock is: zero potential is a good result; it shows that everything is working as it should and the O&M staff knows what they are doing.

	Step 1	Step 2	Step 3	Step 4
Name	Simple Benchmark (Operational Rating)	Certification (Asset rating)	FDD + Optimization	Regular Inspection
Description	Gather basic consumption and stock data and first classification / baseline of the building performance	Certification according to national implementation of the EPBD.	analysis of the building performance, identification and implementation of energy saving measures and optimization of performance	Maintain optimized performance by ongoing (minimal) monitoring
Stock Data	minimal building description	Depending on national implementation	Additional stock data according to individual needs	No additional stock data needed
Measured Data	Utility bills / own meter readings (yearly / monthly)	Minimal data set developed in Building EQ	Additional measurements according to individual needs	Reduce to minimum
Performance metrics Evaluation techniques	Benchmarks / signatures	Depending on national implementation	Evaluation: visualization, statistical analysis, model based approaches Metrics: to be developed	Energy consumption as major metric
Further Actions	None	Installation of data acquisition (hourly data)	Implementation of energy saving measures	None
Outcomes	First classification + baseline (y / m)	Certificate Theoretical benchmark (AR) Hourly data available	Faultless / optimized operation Energy saving measurements introduced Documentation of energy savings	Persistence of energy efficient performance

Tab. 1: 4 – Step procedure of Building EQ - overview

Thus the main difference between energy assessment and continuous commissioning is that through continuous commissioning one can identify ECM's which might lead to considerable energy savings while through continuous commissioning one avoids developments which need to be corrected through ECM's. Consequently there are some essential differences standard energy assessment and energy assessment during operation. They include:

- The savings can not be proven direcly. An "optimized building" can not be improved. Inefficiencies and wastes which are eliminated as soon as they start to appear can not be proved through energy savings in bills.
- The potential savings (according to our experiences 5% to 10% per year) are in the bandwidth of the usual uncertainties and therefore always can be argued.

- The personnel to perform CC need not to be specialists but rather are well trained standard service personnel. However it is desirable to support them by methods provided by intelligent energy management.
- Due to this, payback times for efforts in continuous commissioning should be less than one year or less than 5% of the energy costs.
- The benefit of the operator is than primarily through the continuous operation of the systems and the continuous satisfaction of his customers

Saving Potential due to Continuous Commissioning

Continuous commissioning avoids waste and helps to detect inefficiencies. In the frame of this paper we defined continuous commissioning as energy assessment during building operation. We also assume that the building is optimised through a preceding energy assessment and most of the identified energy conserving measures were undertaken. Thus we consider in this sense optimized buildings and building operation.

According to our experiences deviations between 5% and 10% from the optimised state occur. This is due to changes in utilisation, due to minor errors in operation and due to general aging of the equipment. Continuous commissioning helps to avoid these deviations and keeps operation near the optimum. Unfortunately one can not prove this in a concrete situation except if it was agreed on a baseline derived from simulation.

Therefore continuous commissioning is frequently introduced as part of the normal operation process or as a follow up measure of an energy performance contract to guarantee the promised savings over the duration of the contract.

CC Needs Targets to Evaluate Actual Consumptions

To identify wastes and to detect inefficiencies targets for the consumption are necessary.

Targets are usually derived during the commissioning process. The target data than reflect the accuracy, the details and the time and spatial resolution applied during this process. In the framework of the Building EQ project the described 4-step procedure tries to combine the outcomes of the certification process according to EPBD with Continuous Commissioning. For each of the four steps we can derive performance indicators with different spatial, functional (components, major consumers) and time resolution. Results are included into Tab. 1.

In Figure 3 we describe a general scheme to compare targets expressed through performance indicators (PI) with measured consumption data and to derive possible actions to improve energy efficiency. This scheme might be implemented either by human intelligence or by knowledge based computer programmes.

In the frame of Building EQ we try to develop performance indices and rules which help to avoid increases of inefficiencies and wastes thus making energy conserving measures sustainable.
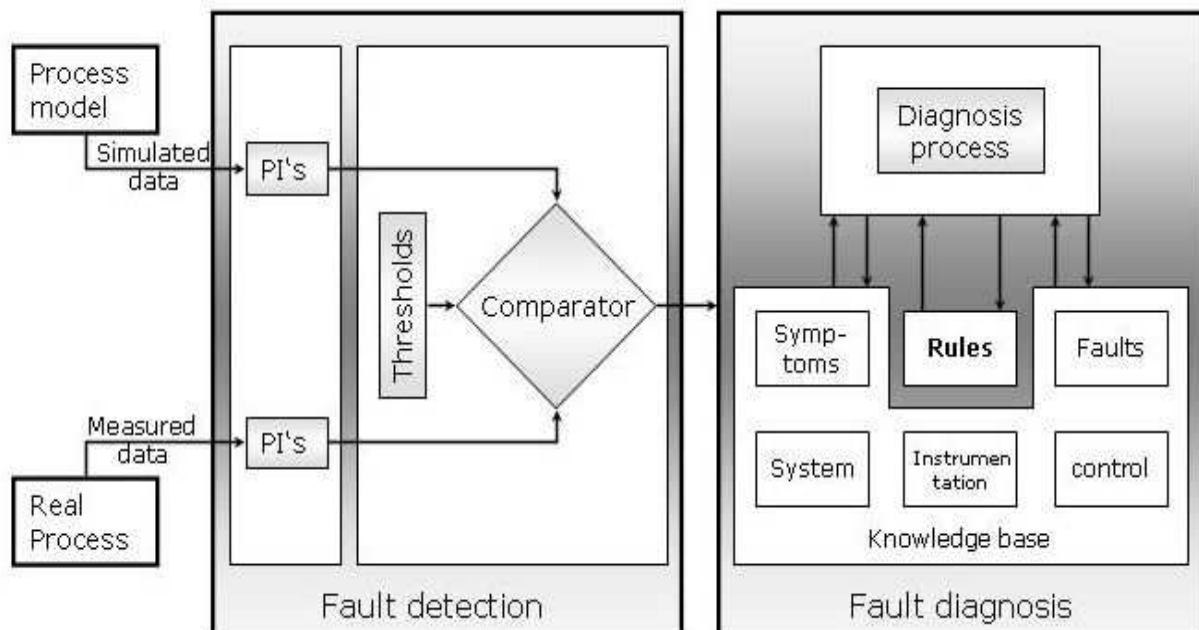

Figure 3: Building EQ scheme to compare targets and actual consumption and to derive recommendations during Continuous Commissioning

IMPLEMENTATION OF CONTINUOUS COMMISSIONING

At the beginning of the last chapter we have identified 6 phases for CC. All of them can be supported by tools

Following our special view on continuous commissioning CC plan and CC performance baseline are the result of the preceding energy assessment. However they have to be adapted to the building conditions whenever major changes in the building (renovation), the building technology (maintenance) or the building utilisation (operation) occur.

To conduct system measurements and to develop CC measures we need

- To install meters and sensors
- To collect data
- To interpret the data and
- To recommend appropriate CC measures

The implementation of the CC measures and the documentation of the comfort improvements and the energy savings are necessary next steps and the basis of keeping commissioning going on.

Counters and Sensors

Counters and sensors are necessary to collect measured data. Today they should allow remote inquiries on a flexible basis. Wireless sensors and intelligent counters are becoming popular, because they avoid additional efforts for wiring work.

The data have to be collected for transfer to the energy management server. This requires functionalities typical for a building energy management or building automation system (BEMS or BAS). If any such system is available it should be used to fulfil as much as possible of the data collection task. If this is not possible or too expensive simple solutions based on intelligent but cost effective data loggers are available on the market. They could be implemented stand alone (mini building automation system) or in connection with any of the other systems if they provide data in a transparent way.

The data have not only to be collected and made consistent but also interpreted and reported. The most common methods for the interpretation of monitored data are described in the next subchapter. Samples for visualisation are given on the Building EQ homepage. Software to perform such interpretations is available on the market both as commercial and open source. Usually these software packages also allow generating energy reports on a monthly, quarterly or yearly basis.

To reach the goals of CC requires not only reports but also actions. Therefore the tools should also support to find such actions and to initiate them by informing the responsible people. Energy managers can do this by evaluating the data (intelligent monitoring) but also may be supported by methods called rule based monitoring (see right half of Figure 3). Figure 4 shows how these tools might become integrated in a continuous commissioning system.
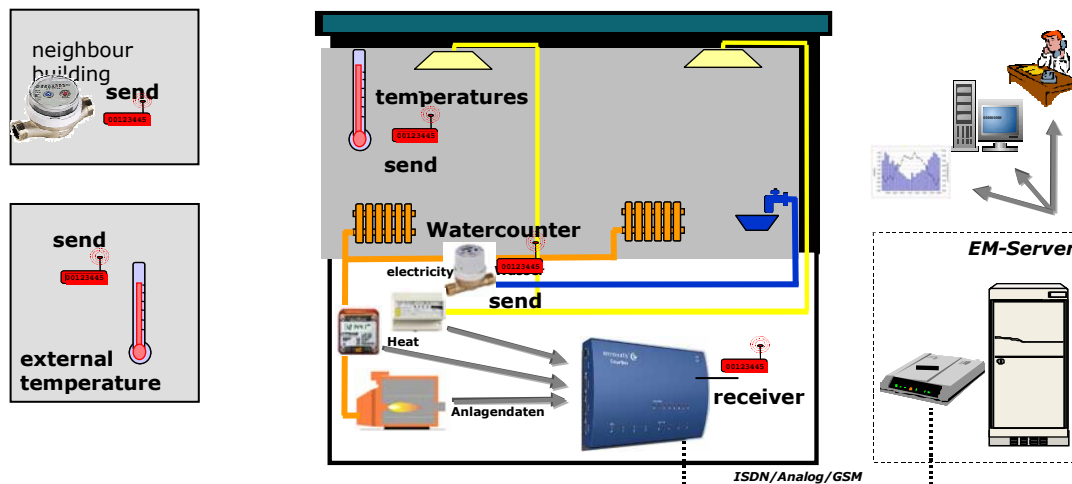

Figure 4: Components of a Continuous Commissioning System

Data Collection – the Minimum Data Set of Building EQ

Data acquisition and data logging are the original domains of Building Automation. Building Automation Systems (BAS) are frequently proprietary, integrated software/hardware environments. The absence of BAS standardisation coupled with competition for market share results in independent/non-compatible system develop-ment. BACnetTM was developed to provide an open (non-proprietary) protocol specification that allows building automation controllers of different manufacturers to communicate with each). Vendor competitiveness has resulted in BAS that provide additional functionality for an enhanced understanding of performance. Consequently BAS are becoming more complex over time and are difficult for the average operator to understand.

BAS focus on system operation and include alarm functionality for pre-programmed important

criteria. EM Systems on the other hand primarily focus on the major energy consuming devices in a facility. Organisations are now realising the benefits of utilising both systems. However frequently energy managers do not have the data, information and tools need to provide optimal results. Maintenance records, energy and efficiency reports and trend analysis should be accessible to energy managers but in many cases are not. If they are used correctly, measured HVAC time-series are descriptive of building performance but are wholly dependent on strict boundary conditions (weather, control strategies etc.).

To scope with this situation a minimal data set for continuous commissioning was developed in the projects Building EQ. This is described in Tab. 2.

item	Measured value	unit	time resolution*	remarks
consumption	total consumption of fuels	kWh	h	e.g. gas, oil, biomass
	total consumption of district heat	kWh	h	
	total consumption of district cold	kWh	h	
	total consumption of electricity	kWh	h	
	total consumption of water	m³	h	
weather	outdoor air temperature	°C	h	own weather station or from weather data provider
	outdoor rel. humidity	%	h	own weather station or from weather data provider
	global irradiation	W/m²	h	own weather station or from weather data provider
indoor conditions	indoor temperature	°C	h	choose one or more reference zones for that measurement
	indoor relative humidity	°C	h	choose one or more reference zones for that measurement
system	Flow / return Temperatures of main water circuits	°C	h	main heat/cold distribution. "Main" in this context refers to the distribution **in** the building and not to a primary distribution such as a district heating system.
	supply air temperature of main AHUs	°C	h	only if supply air is thermodynamically treated
	supply air relative humidity of main AHUs	%	h	only if supply air is humidified / dehumidified

Tab. 2: Minimum data set from BuildingEQ (*h= hourly)

Interpretation of Monitored Data - Intelligent Monitoring

Intelligent monitoring is the most popular way to analyse measured data. The data are visualized in different contexts to allow people to interpret them most easily. Such contexts include

- Comparison of yearly data from similar buildings to perform benchmarking
- Comparison of temperature corrected yearly data from one building and several years to

control system development and maintenance

- Comparison of temperature corrected monthly data from one building and several years to visualise consequences of ECMs
- Comparison of monthly data from one building with outdoor temperatures to prove that the temperature control is active
- Comparison of daily data from one building with outdoor temperatures to prove that weekend set back is active

- Comparison of hourly data from one building with outdoor temperatures to prove that temperature control is functioning and night set back is active
- Comparison of yearly, monthly, daily or hourly data from different units (e.g. apartments) of one building to make the user behaviour more transparent
- Comparison of yearly, monthly, daily or hourly data from different units (e.g. rooms) of one building unit to make the behaviour of inhabitants more transparent
- Energy signatures typically display energy consumption versus outdoor air temperature. The characteristics of an energy signature (inclination, change points, intercepts) can be used for gross fault detection. It is also possible to derive correlations between the quantities displayed. They might be used as simple process models as indicated in Figure 3
- Scatter plots or XY-plots to visualise the dependency of two variables. Energy signatures are typical XY-plots. Note time dependency is lost in XY-plots.
- Carpet plots are a special way to visualize one variable over a period of time, especially if the time period is long. The can be displayed for several months or even a whole year. The value of the variable is displayed as colour. Thus, e.g. plotting an On/Off control signal, produces a typical pattern which is easy to recognize
- Box plots (also known as a box-and-whisker diagram or candlestick chart) are a way to display statistical data analysis in a graphical way

Scatter-, carpet- and box plots are especially suited for analysing, since they reveal the characteristics of the energy consumption and the system temperatures.

Classical Time series plots however are a valuable reference for a closer examination of the time dependency.

Important additional features of visualisation are filters and groupings.

A selection of measured values / variables by certain conditions is called filter in the context of this paper. An example is the selection of all measured values above a certain outdoor air temperature. Therefore with a filter the behaviour of the system under selected conditions can be studied.

Grouping the data means that the data is divided up (grouped or split) by a certain variable e.g. weekday and weekend. Therefore it is possible to compare different operational modes

FIRST EXPERIENCES WITH A REAL BUILDING

For samples for visualisations for intelligent monitoring see the home page of the Building EQ project

Interpretation of Monitored Data Based on Experiences Derived from the European Energy Performance of Buildings Directive

Independent from its depth each energy assessment will result in a better understanding of the behaviour of the building and its technical systems. This can be used to formulate rules on the expected behaviour. Such rules include

- Leakage control of water counter
- Control of maximum or minimum temperatures
- Control of electrical power of selected consumers
- Time dependent average consumption

Differences between measured values and the rules can result in various actions. They include

- e-mail or SMS to maintenance
- visualisation for control
- activation of fault detection and diagnosis methods

A scheme to realize this was already described in Figure 3

If detailed models are available we can derive from the Level 2 and Level 3 analyses more stringent rules for the system behaviour. Usually the calculation results are available in form of time series. This is similar to the measured data. To compare both measured and calculated data one has to make both consistent using time dependent performance indices. As described earlier one now might draw conclusions and initiate actions.

Usually monthly data are not sufficient to do this. Instead at least hourly simulations should be used. Therefore presently we are investigating what accuracy could be obtained if we operate a calculation model for the optimized building using actual weather data and the actual data of utilisation

Recommendation of Appropriate CC Measures

Once a fault based discrepancy between targets and actual performance was detected reasons for the discrepancy have to be found. This is called fault diagnosis in Figure 3. As can be seen there fault detection requires quite a lot of knowledge in different areas like the sysem and its instrumentation and control, possible faults and the symptoms which are early indicators for their appearance. As indicated before we will start experimenting with simple actions like notifications or visualisation of critical situations only. From this we will learn about possible next steps.

The Building EQ consortium will evaluate the developed methods and tools in at least 12 demonstration buildings from the 4 participating

countries. In order to prepare an energy certificate (Asset Rating) for the building, data on the building envelope and the heating, cooling and ventilation systems will be gathered in detail. The certificate were prepared by the project team and are published on the Building EQ homepage. Based on the certification, first recommendations regarding an energetic optimisation of the buildings can be made.

One of the buildings is the multi purpose building of the University of Stuttgart. The building is used to help research groups overcome shortages of both office or laboratory space. Therefore, we observe a frequent change of use. As a result, this requires more elaborate technologies to adapt the HVAC system operation to the temporary energy demand.

Description of the Building
The building is quite new (erected in 1995) and therefore does not show any major deficiencies. It is constructed according to the German building regulations applicable in 1995. It has a total of 4 floors and a net floor area of 9,100 m². There is a large exhibition hall in the center of the building. It is surrounded by laboratories and offices. The HVAC concept is flexible so that it can be adapted for different uses. Presently the air flow rate reaches a value up to 50,000 m^3/h. It is divided into the 4 main utilisation areas: technical rooms, laboratories, hall and offices and other rooms. Heat is provided by the central heating station of the campus.

Figure 5: Different views of the multi purpose building of the University of Stuttgart

Result of Certification
The asset rating was based on DIN V 18599 for non housing buildings.
The building was erected in 1996. Nevertheless it fulfils the requirements of EnEV 2007 the German

implementation of the EPBD for existing buildings. This is primarily due to the low transfer coefficient (calculated as 0,58 W/m^2*K) This has to be compared with the values of the reference building (existing buildings (1,92 W/m^2*K) and new buildings (1,37 W/m^2*K)).

As a consequence and considering the HVAC – Systems and the energy carrier used the primary energy demand is only 256,4 kW/m^2*a compared to 357,6 kW/m^2*a for the reference building. The building even meets the requirements for new buildings which would be 255,4 kW/m^2*a. We have made similar experiences with other demonstration buildings in the Building EQ projects. This indicates that the reference values given in the EnEV should be - at least for some of the building types – re-evaluated.

Adjusting the internal temperatures and the air volumes of the ventilation and air conditioning system to the actual conditions (Individualverfahren not conform with EnEV 2007) further reduces the primary energy demand to 215,5 kW/m^2*a.

Planed Performance of the Building
Prior to the erection of the building a heat requirement certificate according to the law in 1995 was issued (Wärmeschutzverordnung). The heating demand was calculated to be 530.333 kWh/a.

In Figure 6 we give energy consumption data as measured for the years 2001 to 2004. The heating energy data are degree day corrected in Figure 7. During the years 2001 to 2004 the consumption was nearly constant, but almost 50% higher than exspected. Therefore in 2005 recommissioning took place and measures were proposed to reduce energy consumption. From this a reduction of the heating energy consumption of 35% and of the electricity consumption of 13% was predicted. This was described in more detail a German report on the so called CAMPUS project which can also be downloaded from the Building EQ homepage.

The expected savings were achieved in the first year after the energy assessment (2005). This is also shown in Figure 7. However an increase of the heating energy consumption occurred in 2006. To analyse this in more detail we give in Figure 8 the monthly data for heating energy consumption.

From this we take that the energy conserving measures went in operation only at the end of January 2005. Everything worked well. However, starting in February 2006 the heating energy consumption increased by 10% to 20 % and later by up to 50%. In July 2006 the wrong behaviour became obvious. However it took till October 2006 to correct the faults. Since than, no serious errors occurred as can be seen from the correlation between outdoor temperature and heating energy consumption as shown in Figure 9.

Need to Automate Continuous Commissioning
In the analyses performed up to now for the multi purpose building we have applied steps 1 to 3 of the

4 – step procedure developed in Building EQ using human intelligence.

The problem was that this could be applied only sporadically and after major deviations from the optimal behaviour have been noted. Thus due to the commissioning in 2005 energy efficiency could be increased by more than 35%. After one year of operation energy consumption increased again (more than 10% compared to the optimal behaviour). This indicates that a continuous control of the consumption might avoid inefficiencies and wastes of this order. This experience is backed from other monitoring projects too.

However wastes and inefficiencies occur rather randomly. Therefore automatic procedures to detect trends on a short term basis seem to be desirable. One scheme to do this was proposed in Figure 3. We plan to experiment this idea in the frame of Building EQ in more detail to make it more concrete and to find its limitations.
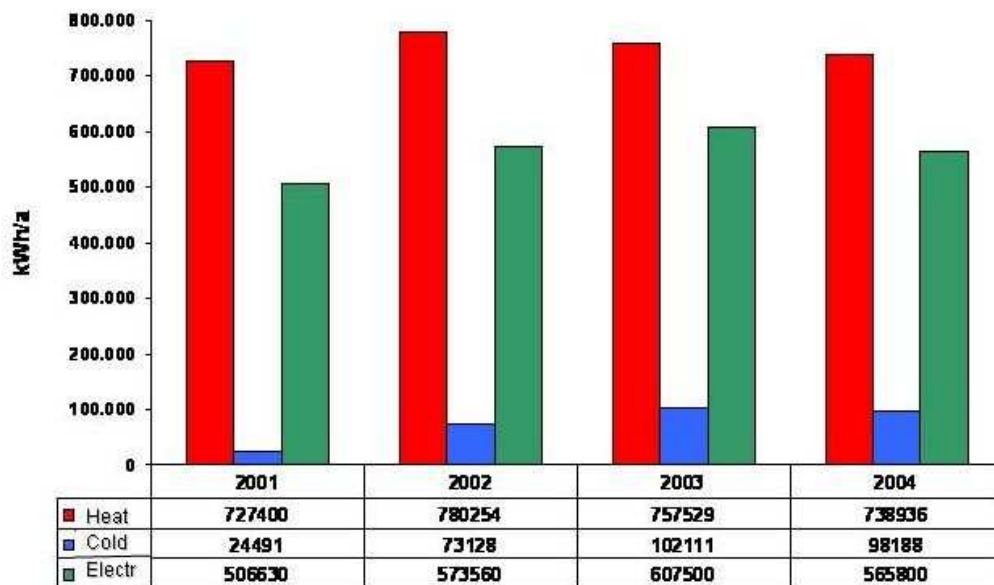

	2001	2002	2003	2004
Heat	727400	780254	757529	738936
Cold	24491	73128	102111	98188
Electr	506630	573560	607500	565800

Figure 6: Energy consumption of the multi purpose building prior to the assessment in 2005

	2001	2002	2003	2004	2005	2006	2007
Wärme	743.731	839.401	772.831	735.739	489.055	545.026	503.346
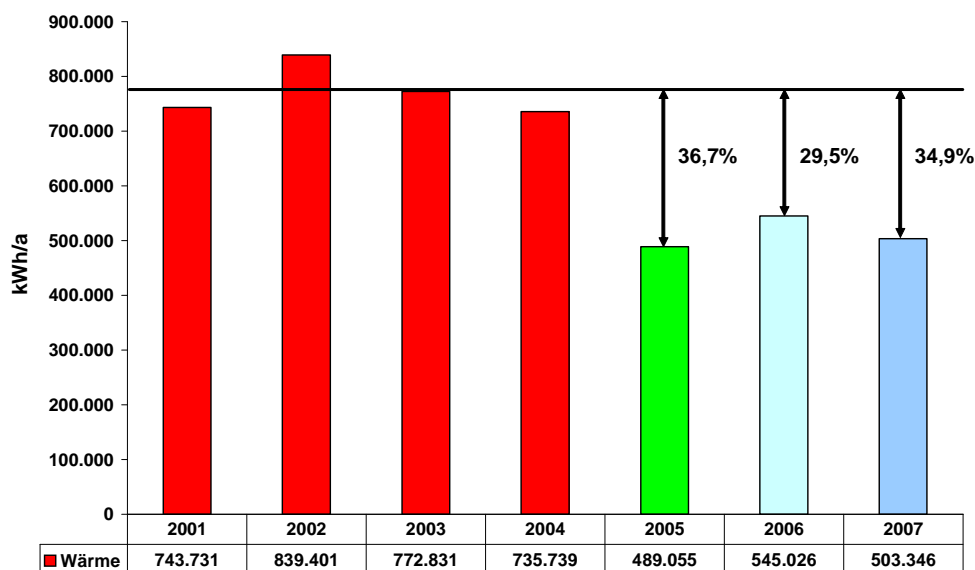
Figure 7: Heating energy consumption during the years 2001 and 2007 (degree day corrected)

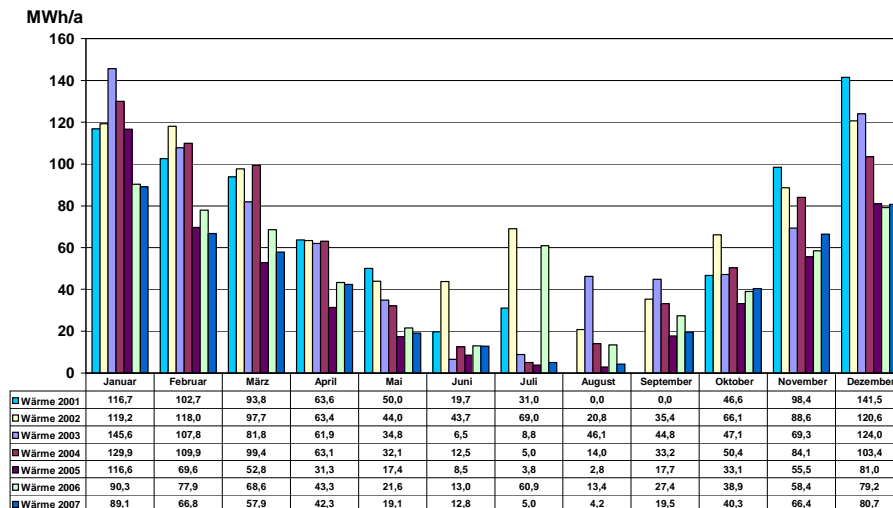|	Januar	Februar	März	April	Mai	Juni	Juli	August	September	Oktober	November	Dezember
Wärme 2001	116,7	102,7	93,8	63,6	50,0	19,7	31,0	0,0	0,0	46,6	98,4	141,5
Wärme 2002	119,2	118,0	97,7	63,4	44,0	43,7	69,0	20,8	35,4	66,1	88,6	120,6
Wärme 2003	145,6	107,8	81,8	61,9	34,8	6,5	46,1	44,8	47,1	69,3	124,0
Wärme 2004	129,9	109,9	99,4	63,1	32,1	12,5	5,0	14,0	33,2	50,4	84,1	103,4
Wärme 2005	116,6	69,6	52,8	31,3	17,4	8,5	3,8	2,8	17,7	33,1	55,5	81,0
Wärme 2006	90,3	77,9	68,6	43,3	21,6	13,0	60,9	13,4	27,4	38,9	58,4	79,2
Wärme 2007	89,1	66,8	57,9	42,3	19,1	12,8	5,0	4,2	19,5	40,3	66,4	80,7

Figure 8: Monthly heating energy consumption during the years 2001 and 2007 (degree day corrected)
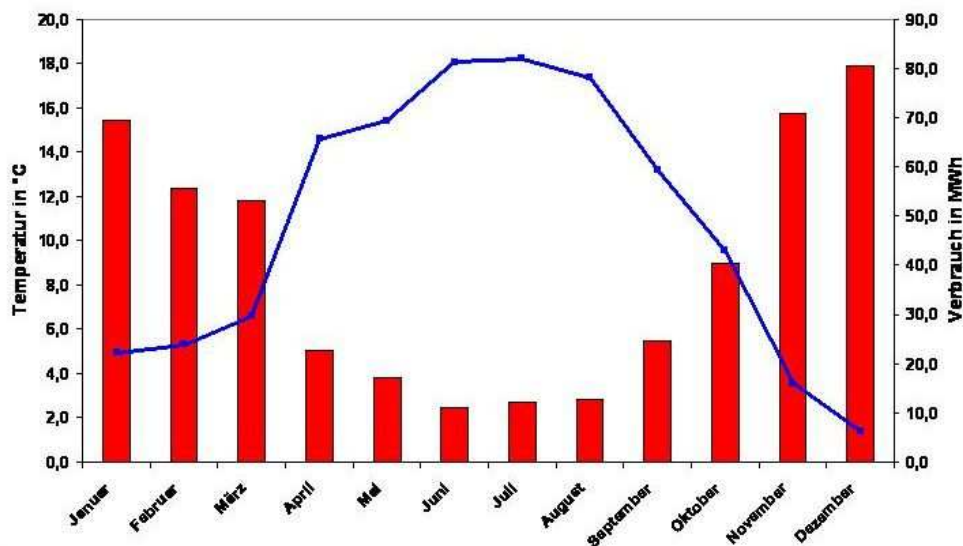

Figure 9: Correlation between outdoor temperature and heat consumption as an example of intelligent metering

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http://www.buildingeq.eu/

Save Project **Intelligent Metering** "Energy Savings from Intelligent Metering and Behavioural Change
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