The Continuous Commissioning in the European Context: The Project Building EQ

Il Continuous Commissioning nel Contesto Europeo:il Progetto Building EQ

MICHELE LIZIERO – LIVIO MAZZARELLA – MARIO MOTTA

Dipartimento di Energia, Politecnico di Milano

RIASSUNTO

Il Commissioning di edifici non residenziali sia esistenti che di nuova costruzione è una pratica comune negli USA od in Giappone, mentre in Europa può offrire nuovi mercati e sviluppi tecnologici. Quando è presente un sistema di ottimizzazione e continua valutazione delle prestazioni del sistema edificio/impianto, allora parliamo di Continous Commissioning dell'edificio e dei suoi impianti. La presenza di tale sistema viene considerato un prerequisito per la persistenza di una elevata prestazione energetica dell'edificio. La sua implementazione pratica è limitata dalla mancanza di informazioni e dai costi connessi, mentre gli effetti comprovati dall'esperienza possono portare a risparmi energetici dell'ordine del 5-30%.

Il contesto legale ed economico Europeo attuale (Direttiva 2002/91/CE e sua revisione, Direttiva 2006/32/CE, piano 20/20/20, etc.) offre la possibilità di una sinergia tra la certificazione energetica degli edifici e l'obiettivo di ridurre il consumo di energia finale dell'edificio attraverso l'Ongoing Commissioning dei sistemi edificio/impianto, settore che rappresenta il 40% dei consumi energetici della UE. Lo scopo del progetto Building EQ consiste nello sviluppo di procedure e strumenti per collegare la certificazione energetica degli edifici e il Continuous Commissioning, nel caso di edifici non residenziali. L'obiettivo del progetto consiste nell'applicare un monitoraggio "leggero" delle prestazioni degli impianti in modo da identificare potenziali di risparmio energetico attraverso l'ottimizzazione dei set-point e l'identificazione e la diagnosi dei malfunzionamenti. Il tempo di ritorno atteso rimane al di sotto di tre anni.

La memoria ha lo scopo di mostrare i risultati finora ottenuti dal progetto, quali la procedura sviluppata, il set di dati minimo che viene misurato sui 13 edifici dimostrativi in Europa dai sei partecipanti ed evidenziare i risultati attesi per la prossima conclusione del progetto.

ABSTRACT

The Commissioning of both existent and new not residential buildings is a common practice in USA or Japan, whereas in Europe can offer new market and technological developments. When an optimization and a continuous evaluation of the performance of building/plant system is in place, the ongoing commissioning of the building and his system is operating. This is seen as a prerequisite for the persistence of high energy performance of buildings. Its practical implementation is constrained by a lack of data and cost, whereas the effects have been proofed to allow energy savings in ranges between 5 -30%.

The actual legal and economical framework in Europe (Directive 2002/91/CE and his recasting, 2006/32/CE, 20/20/20 plan etc.) offer the possibility to a synergy between the energy certification of buildings and the aim to reduce the final consumption of energy through the ongoing commissioning of building/plant systems, that represent about the 40% of the EU energy consumption. The aim of project Building EQ is to develop tools and instruments for link the energy certification and the ongoing commissioning of not residential buildings. Objective of the project is to apply “light” monitoring of equipment performance in order to identify saving potential through the set-points optimization and the fault detection and diagnosis. Expected payback is under 3 years.

The article aim to show the actual results of the project, like the procedure developed, the minimal data set that is measured on 13 demonstration buildings in Europe by the six participants and highlight result expected by the short coming end of the project.

1. INTRODUCTION

Building commissioning is rapidly becoming an important issue, especially for the reduction of the energy consumption related to the HVAC systems and the comfort of the buildings users. More and more architecture and engineering firms are including commissioning services as a core business component. Building commissioning is often a term associated with new construction projects as a process of ensuring that new buildings and their systems perform as designed. Especially in the USA, UK and Japan market the Commissioning is integrated into the construction process to ensure that owners and investors get good buildings for their investments (Haasl, Sharp, 1999).

Unfortunately, most buildings have never gone through any type of commissioning or quality assurance process and are therefore performing well below their potential. It can be estimated that especially existing buildings can reach an energy savings of about 5-30% by optimizing operational parameters or making small maintenance intervention. Commissioning of existing buildings is also known as retro-commissioning (Haasl, Sharp, 1999).

The project Building EQ aims to develop methodologies and tools that can be used for continuous commissioning and optimization of existing non-domestic buildings using gathered data from the certification process according to the EPBD (i.e., Directive 2002/91/EC on the energy performance of buildings). This is confirmed e.g. by the 2002/91/EC directive recasting (2008/0223 COD), recital 17 (correct information about the energy performance of the building) and article 13-14-15 (inspection of heating and air-conditioning systems).

Continuous Commissioning (CC) can be defined as "an ongoing process to resolve operating problems, improve comfort, optimize energy use and identify needed retrofits for existing commercial and institutional buildings and central plant facilities". CC has produced typical savings of 20% with payback under three years (often 1-2 years) in more than 130 large buildings (Claridge et al., 2002). The CC process focuses on improving overall system control and operations for the building as it is currently used and meeting existing facility needs. According to (Bynum, 2008) a survey of the CC effects have been done on 222 buildings, highlighting a medium energy saving of about 14% considering the total energy use (thermal, electric, etc.); on the average the simple loop tuning and set-point adjustment on the equipment (mainly AHU and pumps) give an energy saving of 13%, the economic saving are on average 5 €/(m^2*a) and the average payback time is 1.6 years.

Continuous commissioning goes beyond an operations and maintenance program, including a comprehensive engineering evaluation that develops operational parameters and schedules to meet occupant needs. An integrated approach is used to implement these optimal schedules to ensure local and global systems optimization. **A key goal is to ensure that building systems remain optimized continuously. To achieve this, continuous commissioning requires benchmarking, pre and post-energy use via metering equipment that is permanently installed.** Data are then continuously gathered and compared against the post-commissioning benchmarks to ensure that the building systems function optimally throughout their life. Steps of continuous commissioning are shown in figure 1.

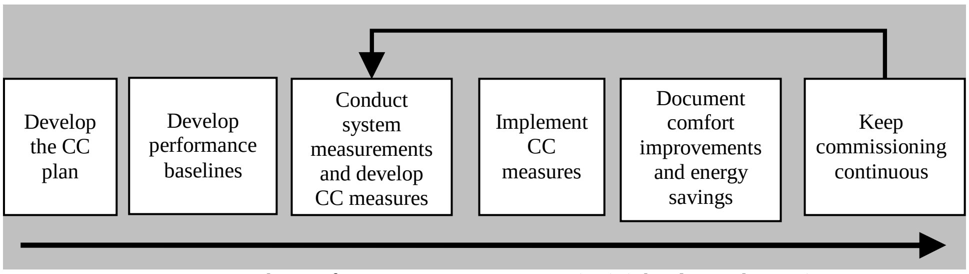

Figure 1 – Phases of continuous commissioning (CC) (Claridge et.al., 2002)

2. THE PROJECT BUILDING EQ

Building EQ started on the first of January 2007 and it will end at the end of 2009. The project consortium includes six research teams, among research institutions and industrial players, from Italy, Germany, Sweden and Finland. Currently the various tools and procedures that have been developed are now tested and evaluated in the demonstration buildings with the aim to reduce the energy consumption by about 20%.

Thirteen demonstration buildings are now under study, and for few of them data of actual consumption and relative analysis are available on the project website. Only existing non-residential buildings with a net floor area of above 3.000 m² have been considered, choosing the demonstration buildings depending on their HVAC equipment (presence of heating, cooling, air treatment and preferably a BAS).

In order to prepare an energy certificate for the building, the data of building envelope and the HVAC systems have been gathered in detail, according the EPBD application of each participant country. On the basis of the certification first hints regarding the plants optimization can be only rarely given, due to the simplicity of the information summarized.

The performance data of the building, preferably hourly or sub-hourly data of energy consumption and further operational parameters, have to be recorded on a centralized data-server. The monitoring and the evaluation activities was supposed to be carried out for at least 20 months, but several building have still to complete or start to be equipped for the data acquisition.

3. PROCEDURE FOLLOWED AND MINIMAL DATA SET

Before all, a four step procedure (Table I, figure 2) have been elaborated by the project team, in order to perform the energy analysis and the benchmarking of the demonstration buildings. This constitute the path followed by the partners through the project.

Table I - Overview over proposed structure

Step No.	Name	Description
1	Simple Benchmark	gather basic consumption and stock data and first classification / baseline of the building performance
2	Certification + data acquisition	Certification according to national implementation and installation a data acquisition device / system.
3	FDD + Optimisation	Refinement of baseline. Introduction of energy saving measures: FDD + Optimisation Calculate and document energy savings
4	Regular Inspection	introduce a regular inspection to maintain efficient operation.

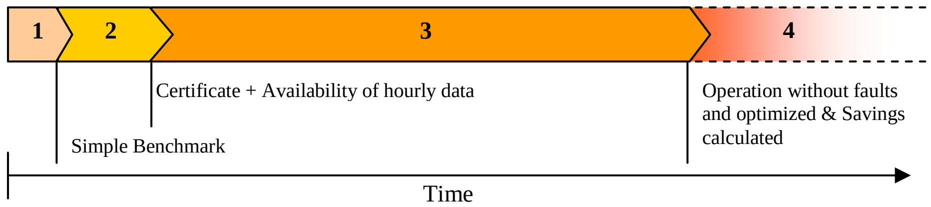

Figure 2 – The four step procedure elaborated by the project team

The first step requires few weeks in order to acquire the relevant historical data on energy consumption. Depending on the presence of BAS or not, data can be differently detailed, being simply energy bills, daily consumption or hourly consumption. Generally the electricity consumption is limited to the bills. It could be also that organizational problem in big building complexes (e.g. university) did not allows to access to any data.

The elaboration of the certificate could be made in few weeks too (the estimated cost for the Italian Buildings is 0.23-0.7 €/m^3, depending on the available data) if Asset Rating is required. Obtain the availability of the hourly data have been differently difficult among the participants, being few months where building was already equipped with BAS or 12-18 months if organizational or technical problems arise (e.g. in the Italian university the contemporary presence of the researchers, the technical staff, the heat management contractor, the plant management technicians, the informatics department lead to a complexity of the data acquisition devices installation). The presence of a general contractor and a clear subdivision of the responsibility of the stakeholders is therefore envisaged.

Once six-seven month of data are available, than the data analysis and the building optimization can start, the process take one year for the first analysis and optimization and then a second year for the verification of the positive effects forecasted. Based on the performance evaluation, energy saving measures have to be implemented in the building. The measures will mainly concern operational parameters and therefore can be implemented at no or minimal cost. Usually these measures will have a payback time of a few months up to 1-2 years. Typically, this will comprise changes in the control by changing or re-engineering the parameters or programs (see also § 1). In some cases minor changes in the installation can be reasonable, too (e.g. changes in the hydraulics).

Finally the process have lead to an optimized building-equipment system. If a continuous verification of the acquired performances is then placed, a Continuous Commissioning procedure is in place.

The objective of Building EQ is to limit the costs of this process, than the minimal data set that have to be gathered for each building comprise only (see also Table II):

- total consumption of fuels, district heating and cooling, electricity, water;
- outdoor air temperature and relative humidity, global solar irradiation;
- indoor air temperature and relative humidity of different zones;
- delivered/return temperatures of main fluid circuits (air and water).

A more detailed data acquisition on specific sub-systems could be implemented if necessary, or after first investigations.

For the full functionality of the tools later explained (before all the visualization) the minimal data set has to be available. The values should be recorded with a time resolution of 5-10 minutes as current values (no averaging over the last measurement interval).

The second phase of the procedure, elaborated by the project team, foreseen to prepare the energy certificate of the building, following the EPBD (2002/91 CE Directive on Performance of the Buildings). This is seen as a baseline for further investigation of the building energy consumption and for the analysis of the building facilities operational parameters.

Table II - Minimum set of gathered data chosen by Building EQ project team

Item	Measured value	possible units	remarks
Consumption	total consumption of fuels	Wh, kWh, MWh	Must be provided as accumulated value
	total consumption of district heat	Wh, kWh, MWh	
	total consumption of district cold	Wh, kWh, MWh	
	total consumption of electricity	Wh, kWh, MWh	
	total consumption of water	m³, l	
weather	outdoor air temperature	°C	own weather station or from weather data provider
	outdoor rel. humidity	%	
	global irradiation	W/m²	
indoor conditions	indoor temperature	°C	choose one or more reference zones for that measurement
	indoor relative humidity	%	
system	Flow / return Temperatures of main water circuits	°C	main heat/cold distribution.
	supply and exhaust air temperature of main AHUs	°C	for major equipment
	supply and exhaust air relative humidity of main AHUs	%	
	control signals of pumps and fans (if available)	0-100%, 0-1 or on/off, 0/1	

Project participants have compared the EPBD application in their countries: Italy, Germany, Sweden and Finland. The application of the EPBD results to be very different in participant countries, considering the calculation method (Asset Rating or Operational Rating) and the level of detail of the analysis of the building performance (e.g., in Italy up to now the energy consumption due to summer cooling is not taken into account).

A list of 133 indicators has been provided to each participant country in order to assess the common baseline, but only 21 parameters seem to be comparable. This is due principally to the fact that Sweden limits the EPBD application to an Operational Rating approach, avoiding to perform a common calculation based on parameter of the facilities and building envelope characteristics. Common parameters are therefore limited to general building data (area, volume, etc.) and to the identification of the main characteristics of the facilities of the building (e.g., heat generation and distribution, etc.). Values of consumption certified are referred to gross volume.

4. TOOLS AND METHODS DEVELOPED

Once carried out the determination of the minimal data set and the analysis of the EPBD application among the participant countries, the development of an European tool for data analysis and visualization started. The objective is to link the EPBD application with the commissioning analysis, then the software implement the following features:

- Data handling,
  general features for storing time series data.

- Data visualization,
  "Intelligent" data visualization on the basis of the minimal data set that reveals "operation patterns".
- Building specific benchmark (CEN model based analysis),
  a simplified model of the building (zones + HVAC) is used for identification of faults and optimization potentials. Models in this context are based on the regulations of the CEN standard as much as reasonable.
- Statistical analysis / simple rule based analysis,
  find correlations between the variables of the minimal data set in order to identify unusual behaviour or faults in operation, respectively.

The tool itself has a modular structure. The kernel is a data storage library which stores measured data. The analysis functions and the importer are modules which can be connected to the data storage. Statistical analysis will be not treated in this paper.

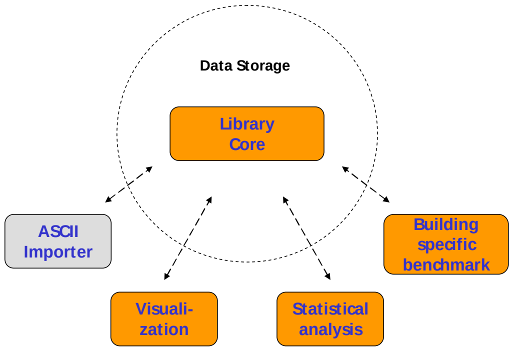

Figure 3 - Schematic of structure of the European tool of the project Building EQ

In order to make the tool easily applicable to many buildings and to have analysis processes automated, a unified point naming convention is a necessary prerequisite. By this convention the user is able to "tell" the tool which data points are available and the tool can identify them automatically. Furthermore the point naming convention assures that data points have unique names (which the original names coming e.g. from the BAS might not have in some cases).

The standard point names are composed of predefined abbreviations for hierarchical categories. The categories start at the building level and go down to the sensor. For the details about this topic refer to Work Package 5 report of the project, that can be find on the project website (§ acknowledgements).

On the basis of the minimal data set predefined visualizations are prepared by the tool. These can be used for manual fault detection and diagnosis either for an initial analysis or for monitoring. Principally the following chart types are use:

- Time series plot
  Chronological sequence of measured values. These plots are not shown, as they are well known.

- Scatter plots (XY plot)
  Scatter plots show the dependency of two variables. Additional information can be gained if the values are grouped. Potentially, several scatter plots can be combined to scatter plot matrices to show the interdependency of more than 2 variables. These plots are used to identify simple control strategies, typically in dependency of the outdoor air temperature. These plots are also called signature.
- Carpet plots
  Carpet plots are used to display long time series of a single variable in form of a colour map which often reveals pattern (like weekly operation patterns). These plots are used to identify operation and occupancy schedules

For the analysis of the data, mainly scatter- and carpet plots will be used as they deliver "characteristic patterns" e.g. for the energy consumption and the system temperatures. Time series will be used as reference chart, in order to check the detailed time sequence of an unusual behaviour that was detected with one of the other charts. Even though the minimal data set will be recorded on an hourly or sub hourly time base, an aggregation to daily or monthly values is reasonable in some cases in order to eliminated dynamic effects. The minimum amount of data for an analysis on the basis of visualizations is about 2-3 months if the data is recorded in a swing season. Otherwise 5-6 months would be appropriate.

For every group or system in the minimal data set (consumption, water circuits, AHUs, indoor climate). These three plot types are generated. Depending on the kind of plot, different filters and grouping might be applied. The time series plots, however, are not shown as they are seldom used only used for analysis. Please refer to the project website www.buildingeq.eu to see interactive example of the graph here shown.

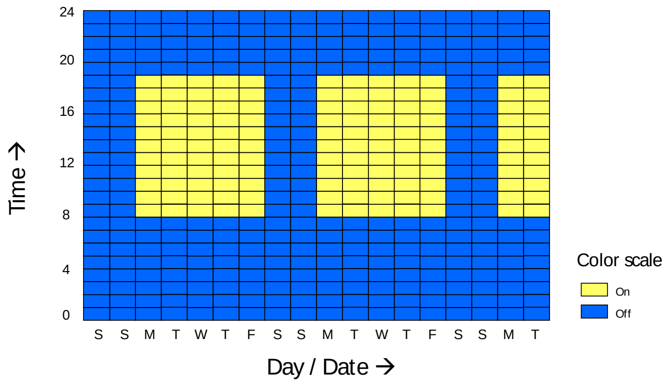

Figure 5 – Ideal carpet plot example (e,g, a fan running Monday to Friday from 8.00 to 18.00.). Here the course of each day runs along the y-axis from the "bottom" (y=0:00) to the "top" (y=23:00) and the days are plotted next to each other accordingly on the x-axis. The measurement value itself is portrayed in different colours. For days having a similar course of measurement values, the colour pattern is respectively similar. Such patterns can be visually identified very quickly. This kind of plots helps to identify occupancy and operation schedules, the timer resolution is 1 hour

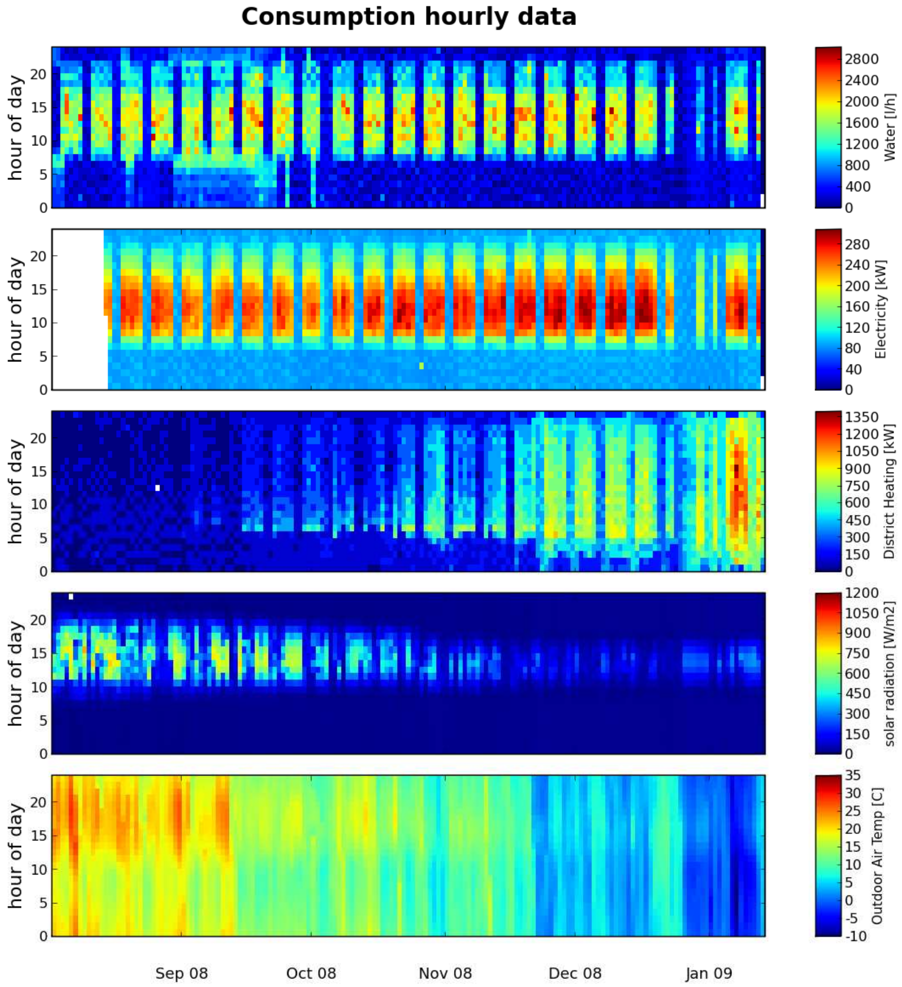

Figure 6 – Carpet plot for real weather and consumption data. This plot shows a real example. Naturally, the patterns are more blured as in the ideal example. Example of carpetplot of consumption values for a non-residential building Electricity and water consumption show the typical daily and weekly operation patterns while heating is blurred in winter at low outdoor air temperatures (OAT). This is due to an OAT dependent control of the operation schedule of the heating. Furthermore a abnormal pattern with increased consumption can be identified for water in September. In December the Christmas holidays can be identified by the reduced consumption values.

The Carpetplot for the consumption data shows the hourly data of the consumption in terms of power (energy consumption) or flow rate (water consumption). Furthermore the outdoor air temperature and the global irradiation are shown as reference.

The main purpose of carpet plots is to identify operation and occupancy schedules and their interrelationship.

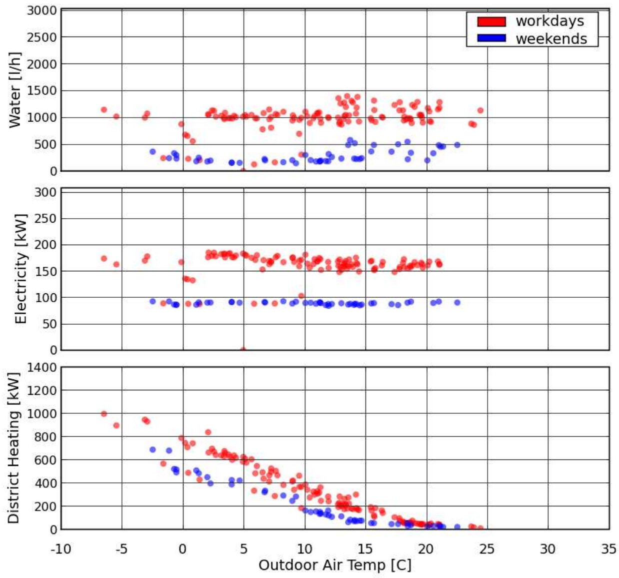

Figure 7 – Scatter plot of energy and water consumption versus outdoor air temperature, grouped by workday and weekends. These plots help to identify weather dependent control strategies. The time resolution for these plots is 1 day. Each dot represents a daily mean value. The plots are also called signature or – for energy – energy signature. Example for scatterplot of consumption versus outdoor air temperature. This building is supplied with district heat, electricity and water. From the difference in electricity and water consumption between workdays and weekends one can conclude that the occupancy during weekends is low. Accordingly one would expect a set back on weekends for the heating which is in fact visible.

The Scatterplot for the consumption data shows the daily means of the consumption in terms of power (energy consumption) or flow rate (water consumption) versus the outdoor air temperature. The data is grouped by workdays and weekends. In the Building EQ project these plots are also called signature (from energy signature).

In the course of the Building EQ project it became apparent that one major drawback concerning the EPBD is the diversity of the different national implementations in the Member States. That is, there is no common data set for all Member States that can be exploited for performance analysis. Consequently, there is no "natural" common basis for the European tool. The consortium therefore decided to make use of simplified models based on CEN-standards and use "condensed" parameters. In this way the model should be valuable for many Member States.

The aim is to provide a model structure for the building zones and the HVAC equipment that uses (very) simple component models but which in turn is able to describe (very) complex system schemes. This model will be used to compare the real measured energy consumption to the model prediction in order to find faults and optimization potentials.

Only 3 principally different component models are necessary for this:

- o Building Zone
- o Air handling Unit (AHU)

o System Component

Figure 8 gives a simplified scheme of the overall system model, showing the three different types of component models. Besides the building zone and the AHUs, all "boxes" in the systems part will be efficiency boxes.

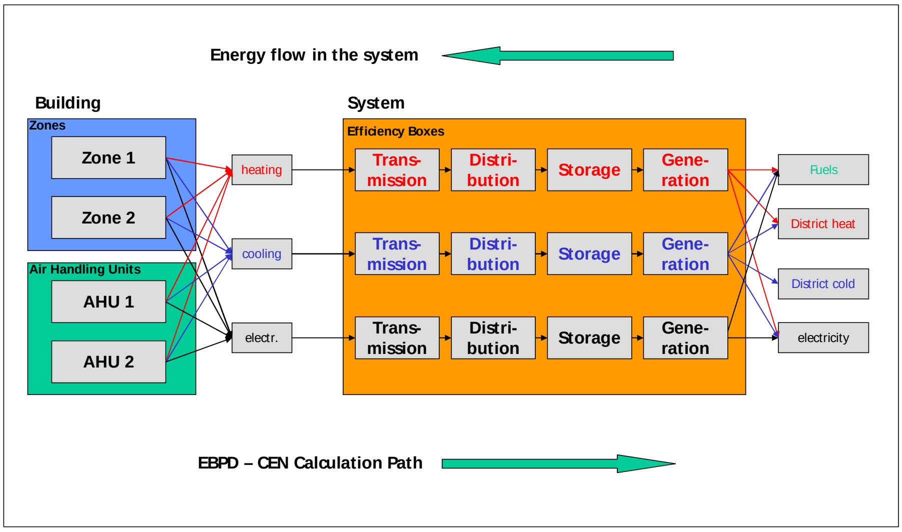

Figure 8 – Simplified model structure of the Building EQ benchmarking tool (based on EN 15243)

In order to be able to compute the thermal behaviour of the building a multi-zone-model has to be applied with several thermal zones according to different utilization and conditions in the building, which consists in the so called simple hourly method according to the EN ISO 13790:2008 Annex B and C (5 resistance 1 capacity model). The simple hourly method has several advantages compared to the others. The most important for Building EQ are:

- It can be easily implemented as it does not require a numerical solver. The calculation is straight forward.
- Hourly schedule, e.g. for set backs and the distribution of load among several emitters or generators can be directly input or calculated without dealing with reduction factors or assumptions.

However, the comparison with the measured consumption data will be done on a daily or weekly time resolution. Climatic data for the calculation will be available from the demonstration buildings as it is part of the minimal data set.

In order to limit the number of parameters of the model, no detailed calculation of thermal characteristics of wall and windows is done inside the tool. General data like overall U-values for walls and windows and optic characteristics for windows are to be necessary instead. Furthermore data for internal gains and for schedules has to be given.

CONCLUSIONS

Project Building EQ aim to link the Continuous Commissioning of non-residential buildings with the energy certification in Europe, which is an unexploited market for the building Commissioning. Considering USA, data shows that this approach applied to both new and existing buildings lead to an average of 14% of energy savings, through a limited investment with an average payback time of 1.6 years. Building EQ investigate the European application developing a set of tools and procedure that consists in a procedure, the acquisition of a minimal dataset through measurement equipments and a software tool. The latter implements enhanced data visualization, structured data storage and benchmarking of the energy consumption via a calculation based on CEN approach. The short coming end of the project will show if Continuous Commissioning procedure applied in Europe leads to results similar to the USA or Japan.

ACKNOWLEDGMENTS

The work presented in this paper has been realised using contributions from the project Building EQ participants and from the ongoing workpackages. The authors thank all the partners directly or indirectly involved in the paper preparation, especially the project coordinator Christian Neumann (FhG-ISE), inviting readers to visit the project webpage www.buildingeq.eu in order to follow the project future results (subscribing the newsletter) and know the project teams.

BIBLIOGRAPHY

Haasl T., Sharp T., April 1999, "A Practical Guide for Commissioning Existing Buildings", Portland Energy Conservation, Inc. and Oak Ridge National Laboratory, DOE, USA

Claridge D. E., Mingsheng L., W. Dan Turner, 2002, "Continuous Commissioning Guidebook", Energy Systems Laboratory, Texas A&M University, Federal Energy Management Program, USA

Bynum, J., 2008 (October). The cost-effectiveness of Continuous Commissioning over the past ten years. 8th ICEBO International Conference for Enhanced Building Operations, Berlin

Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings.

COM(2008) 780 Final of the Commission of the European Communities, proposal for a Directive of the European Parliament and of the council on the energy performance of buildings (recast)

Jagemar L., Olsson D., Building EQ WP 2 report, October 2007, The EPBD and Continuous Commissioning

Neumann C., Jacob D., Building EQ WP 3 report, February 2008, Guidelines for the evaluation of building performance

Neumann C., Jacob D., Mazzarella L., Liziero M., Building EQ WP 5 report, June 2009, Description of the European Prototype Tool for Evaluation of Building Performance and the national tools