# MONITORING BASED COMMISSIONING (MBCX) IN ENERGY AND FACILITY MANAGEMENT

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## ABSTRACT

In this presentation the possibilities to improve facility management by monitoring is introduced based on case studies on the district-level operation center of the city of Kuopio and Aalto University Otaniemi - campus area in the city of Espoo. Also guidance options of public authorities are introduced the advanced role of BSO (Building Supervision Office), city of Oulu, Finland as example. In the presentation the attention is paid also how one can convert from the big mass of data the useful information for stakeholders

## INTRODUCTION

Performance of buildings depends on how the building systems are integrated to operate together. The requirements must be set precisely in pre-design and in design phase (Owner`s Project Requirements). The performance of building in use stage can verified using Key Performance Indicators (KPI`s. The instrumentation of a building must be designed like that, that one can monitor the performance of the building on-line and the and facility managers can follow the performance by KPI`s.

Remote control of buildings is an increasing trend. Local and/or nationwide operation centers can collect huge amount of data from the connected buildings and give response and feedback for the users. In energy and facility management "management by information" is the concept which in best case can optimize the performance of buildings and decrease energy and facility management cost. This means also basic changes in design intents, practices, and in the way of thinking. The procedure is called Monitoring Based Commissioning (MBCx).

It seems to be common that those tasks are not perfectly carried out by existing systems. If the final result is required indoor conditions and energy efficiency, one would have a possibility to monitor the existing conditions from reports, based on instrumentation. Often there are shortcomings in the system, lack of sensors, wrongly positioned or installed sensors and malfunctions. Also reports do not match the user´s needs in many cases.

Energy efficiency does not mean to minimize the energy consumption – it is a question to optimize it. Indoor air quality and indoor conditions must be in proper level, and energy saving (e.g. shortening the running time of ventilation) can cause bigger problems for indoor environment and this way also for work efficiency. Figure 1 shows the average costs of an office building:

- Wages: 86 %
- Space costs: 9 % (including energy costs)
- Furniture 1 %
- ICT & office machines 4 %

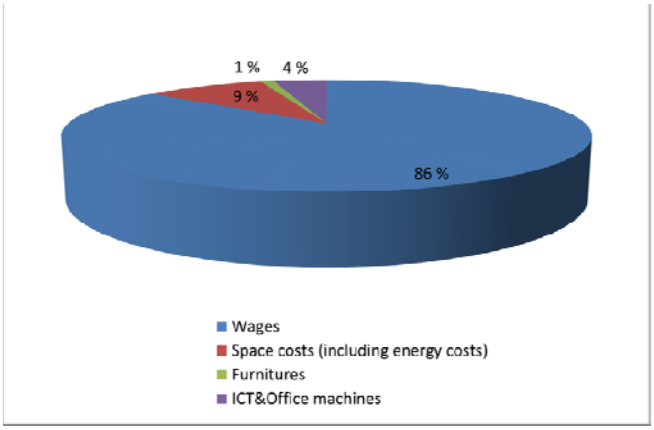


*Figure 1: Average costs of office buildings*

Energy costs in cold climate conditions (Finland) cover approximately 30 % of space costs = 3 % of the total costs. Wages costs include the work efficiency factor – the indoor climate and conditions plays the key role. If one saves 20 % of energy costs, it is only less than 1 % of the total costs. But if the indoor environment is not satisfactory, the effects trough possible weakening of work efficiency are more significant (but more difficult to measure).

In the IEA Annex 47-project, Cost Effective Commissioning of Existing and Low Energy Buildings, a survey on sensor deployment and energy metering was performed by Hiroshige Kikuchi from Japan. The survey included most of the participants from Annex 47. Different actors were surveyed in that study. The motivations for the survey came from

measurement issues and lack of systematic approach to utilize data from measurements for the energy analysis. The most relevant question was “Do existing buildings have enough numbers of sensors to carry out energy management?” The following monitoring level was possible to choose:

- Total energy amount on monthly level;
- Total energy amount on daily and hourly level;
- Energy use measurement by user type (lighting, air conditioning, satellites, elevators, etc.)
- Energy use measurement by system (office system, conference room system, executive office system, computer room system, parking area system, etc.)
- Energy use measurement by floor.
- Energy use measurement by specific machines or subsystems (cooler, heating system, etc.)

This question includes two parts. The aim of the first part was to introduce the current situation and the second part has aim to explain what experts would like to have for proper building energy estimation.. Figure 1 shows current monitoring situation, considering that the survey was in 2007/08. Figure 2 shows what is a required monitoring level regarding the surveyed international experts at that time. The situation has not been changed so much from these years even the scale of monitoring has been extended because of progress in measurement technology and especially in data processing, transfer and communications.

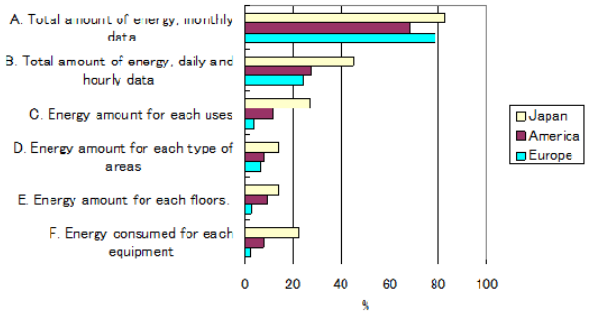


*Figure 1: Monitoring situation*

According figure 2, the biggest need is to increase to determine the energy distribution of various sources. As often said “what is not measured can not be managed” . The recent problem is to evaluate the distribution of electrical energy; the other issue is to have proper information from existing system. A typical example in mechanical ventilation system is the concentration and temperature of exhaust air before the heat exchanger: If there are many rooms in the service area of the ventilation unit, the CO2-concentration and temperature of one single room can not be detected; even they would be over the proper level.

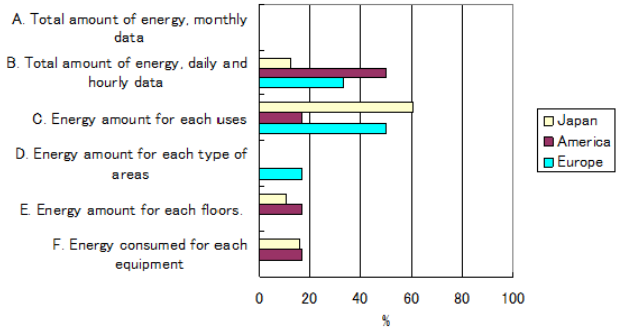


*Figure 2: Required energy management level*

The amount of heating energy has been decreased during last 10 years in Finland; instead of that the consumption of electricity has been increased or remained at the previous level depending what kind of energy saving measures has been carried out. Most part of renovation works have done because of indoor environment problems, building damages and – the most important reason – because of the change in use. By the same the energy efficiency has been improved.

Today the moisture damages are present especially in schools - a number of schools in Finland have been necessary to close or the use of them have been limited. The reasons for damages are supplied roughly uniformly between design, construction and use errors. The problems are mainly raised because of reclamations and various symptoms of users, which have led to condition surveys, energy audits and different actions – but not detected by existing monitoring or building automation system.

There are service providers offering remote control in Finland which have more than 1000 buildings connected. Normally the monitoring level is based on existing building automation system and measurements. There is a need for roadmap, especially for building owners how to improve the quality and information level of their building stock.

The distribution of costs in buildings depends on many factors – e.g. in hotels and spas the biggest cost is cleaning cost. In small and mniddle size industries the energy and building maintenace costs can be relatively small compared with other type of costs. In any case, the final “product” of a building project is required indoor conditions created by various systems: Performance of building envelope, performance of HVAC-systems, weather conditions, type of use and users. The most important factor is the the various systems are integrated to operate together.

## MBCX - MONITORING BASED BUILDING COMMISSIONING

### Building Commissioning

Building commissioning (Cx) means as simplest the procedure which ensures that the building performs "as designed". This procedure begins from pre-design stage and continues during the whole life-cycle of the building. There are many definitions for different type of commissioning but the goal is to verify that the performance of a building meets the requirements.
In USA Building commissioning is often divided into four different types:

- (1) New Building Commissioning (Cx): Method of risk reduction for new construction and major renovation projects to ensure that building systems meet design intent and operate optimally.
- (2) Re-Commissioning (ReCx): Process through which buildings are commissioned again as a check to ensure that systems are functioning as originally planned and constructed.
- (3) Retro-Commissioning (EBCx): Commissioning of an existing building that has never been or was not fully commissioned at its completion.
- (4) Monitoring Based Commissioning (MBCx): Relies on measurements of energy use to diagnose problems, account for savings, and help ensure that savings persist over time.

The procedure is shown in figure 3.

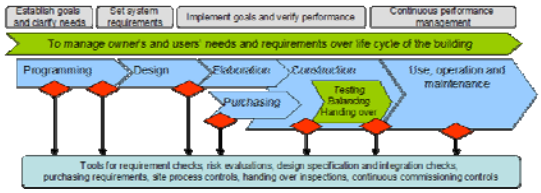


*Figure 3. Cx-procedure*

- The performance of a building will be determined in many respects during pre-design and the design phase.
- The crucial issue is that owner's and user's requirements have been defined precisely.
- By Building Commissioning (Cx) procedure one can verify in the various stages of construction process, that the owner's requirements will be realized.

### Monitoring-based commissioning (MBCx)

Monitoring-based commissioning refers to the practice of continuously tracking energy and other data from a building management system (BMS). The control data points are used to ensure that performance goals are met. Monitoring-based commissioning allows building management staff to ensure that their facility is running properly by utilizing meter data to interpret if or when something goes wrong or energy use does not match up to previously set baselines. This meter data can be viewed and analyzed on customized, web-based applications to ensure complete real-time access. The key to monitoring-based commissioning is that it helps to keep efficiency savings and indoor conditions consistent over time. Monitoring-based data building owners and/or users to recognize areas for improvement in their energy consumption and indoor environment and ensure that energy efficiency measures persist over time. As a summary

- Collecting, storing, analyzing and reporting data (collected through metering equipment) to optimize energy performance and efficiency.
- This process gives end-users the ability to make informed, effective energy decisions

### What is needed

Measurements and monitoring itself does not save anything; but it will form a basis for a proper facility and energy management. This requires that

- the right factors are measured
- the sensors are properly installed
- the data collection and processing are organized
- the results are converted into a form that meets the objectives of the various stakeholders and parties

For reference may be of use the industry operation reports. The goal should be "management by information". The information is generated from the measured data, which itself is useless without filtering and processing.

## COMMISSIONING TOOLS

### Monitoring

If there is a database available, containing information of various buildings of same type, same age or same use it is easy to compare the performance of buildings. Figure 4 shows an example of same type of printing houses (newspapers). There is weather-corrected (standardized heating energy consumption kWh/m3 of 17 printing houses. The printing house which wants to compare its consumption with the other companies is marked by blue column; the other companies with grey colums. Among the same branch it is easy to see the level at which the company's energy consumption is located compared with the competitors. The differences may depend on

different technical solutions but based on this kind of data the facility/manintenance manager can pay attention to heating energy consumption.

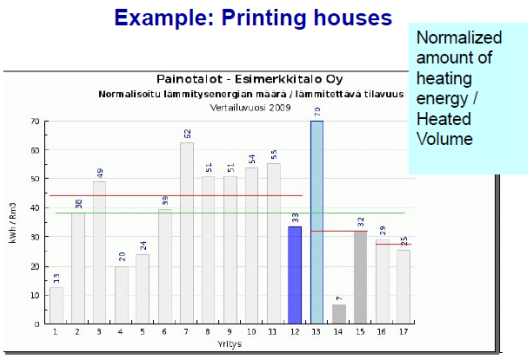


*Figure 4. Printing houses. Heating energy consumption.*

The first step is to find out the reasons for energy consumption (if the consumption is above the median or much highre than the other`s.). It can be realized by energy audit.

Depending on the available data and the customer´s needs it is possible to create different figures and graphs of consumptions etc. In this particular case the companies provide only the monthly consumption of utilities, production figures and also the measures done to improve energy efficiency.

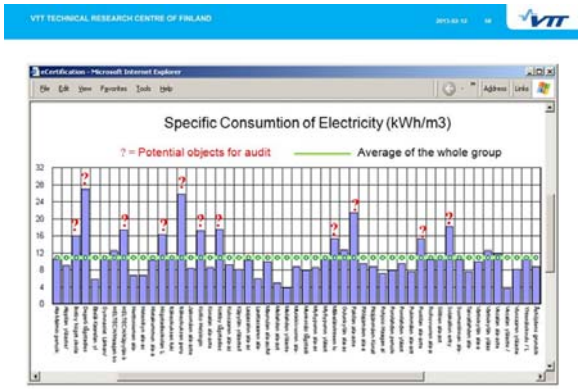


*Figure 5. Schools. Electricity consumption.*

Figure 5 shows and example of electricity consumption of Finnish schools (Helsinki). The question mark indicates the targets where a more detailed analysis should be implemente, if possible.

**Energy audits**

The saving potential, energy distribution, possible investments and pay-back times can be evaluated by energy audit. Figure 6 presents the types of energy audits.

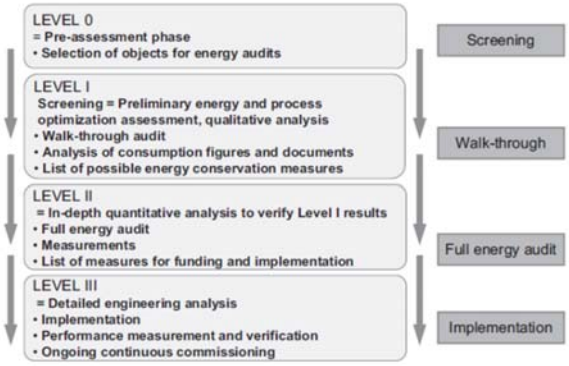


*Figure 6. Various type of energy audits*

In Finland energy auditing is a certified activity, controlled by public-owned energy agency Motiva y (see www.motiva.fi.) Normal energy auditin Finalnd is combination of level II and III. Level I type walk-through audit has been in experimental stage.

**Submetering**

The instrumentation level of existing buildings varies depending on the age, building type and building automation system. Generally the instrumentation level in existing building stock is not in such level which allows MBCx-type activities. Especially the distribution of electrical energy cannot be measured if there is just one main meter. Table 1 shows an estimated electricity consumption of a secondary school. The measurements were arranged just by switching different devices, use groups and units manually on (ventilation units, lighting, plug loads etc) and the by checking the readings every hour. The results are imprecise and only indicative.

Subemetering of electricty

*Table 1: Electricity conumption of a school*

| Test | Power | Partial power | % |
|---|---|---|---|
| Targets | kW | kW | |
| idle run, partial ventilation | 9,4 | 9,4 | 8,7 |
| sports hall | 13,6 | 4,3 | 3,9 |
| kitchen, full ventilation | 54,4 | 40,7 | 37,6 |
| lighting | 89 | 34,6 | 31,9 |
| plug loads (computers etc) | 108,4 | 19,4 | 17,9 |
| Total | | 108,4 | 100 |

Table 1 shows that the lighting and ventilation are the biggest consumers. If the electricity metering would have been arranged by more detailed way, it

would be much easier to analyze the consumption and also to evaluate the possible saving measures.

Figure 6 presents the measured electricity consumption of an regional hospital and health center. There is also central kitchen in a separate building in that area.

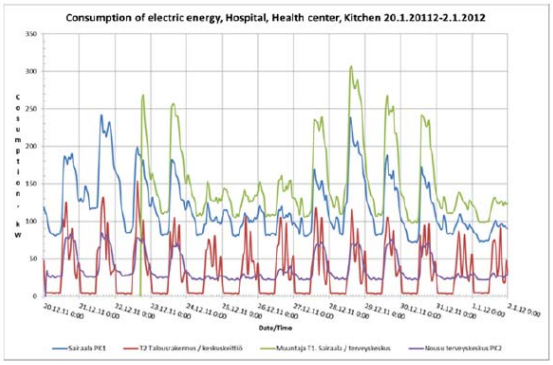


*Figure 6. Electricity consumption of a regional hospital and health center*

There was just one main meter availbale – in a energy efficiency project 44 analyzers were installed and the results can be red and processed in excel-sheet form. In figure 6 the main consumptions of the hospital during the christmas time (blue curve), health center (violet), kitchen (dark red) and hospital+helath center (light green) are introduced. It is impossible to divide the consumption just based on one meter. Previously, before installations, the consumption and invoicing of various consumers was based of cursory assesment.

The instrumentation level can be improved when using the data for commissioning. The measurements can be roughly divided by

Indoor energies of the building

- heating
- warm water
- electricity

Outdoor energies (mainly electricity).

Energy measurements can be divided by

- Building specified consumptions
  - heating
  - ventilation
  - other building services
  - refrigeration devices
  - cooling devices
- User specified consumptions
  - warm tap water
  - plug load
  - home appliances
- Indoor conditions
  - temperatures, IAQ etc.
- Performance measurements
  - performance and efficiency of systems

To meet these requirements, the following additional instrumentations will be preferred (if not available):

- the efficiency of heat recovery (temperatures of extract and exhaust air, supplied air, outdoor air)
- main air flows of ventilation systems (e.g. based on pressure drop over the fan)
- heating energy measurements, hot water measurements
- electricity measurements, also submetering divided by main consumers (kitchen, ventilation, lighting etc. if possible)

## CITY OF KUOPIO - DISTRICT LEVEL OPERATION CENTER

The first district level control and monitoring center of public building stock in Finland started in year 2010 - completed in 2013, the public building stock of 4 communities belongs to the system covering more than 150 000 dwellers (schools, office building, kindergartens, admin buildings, health centers). The aims of the project were

- to save energy costs
- to save resources and climate protection by reducing heating energy and electricity consumption
- to improve the productivity and quality of facility management and

The practical, measurable goals were

- to reduce consumption of heating energy and electricity 3 650 MWh/year in the three communities which joined the center
- to reduce energy costs 180 000 €/year ($ 235 000) in those three other communities

The practical, measurable goals for climate protection were

- reduction of CO2–emissions in the first stage approximately 590 000 kg/year
- in full scale reduction of CO2– emissions 1 088 000 kg/year
- in electricity production reduction of CO2–emissions 700 kg/MWh and in district heating production 220 kg/MWh

The biggest problem was to match up the various existing building automation system together - now one maintenance person in the operation room can take care of all the buildings in the system. No new sensors have been installed; this may be in question in the future. Also the data processing for suitable information for different group of users (energy and facility managers, decision makers etc.) is still in progress. Figure 7 shows the principle of the operation center.

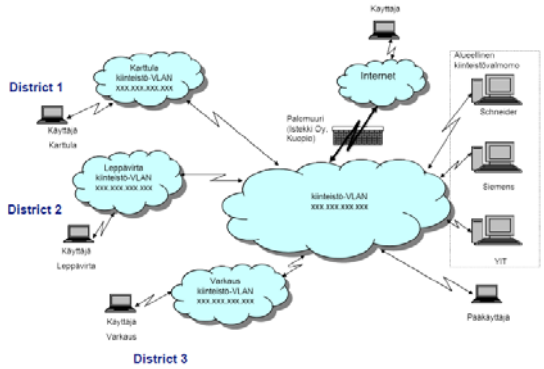


*Figure 7. District-level operation center*

Kuopio is locating in Eastern Middle-Finland. The buildings are connected with district heating system. The heating energy is produced by economical district heating CHP- power plant. The fuel was peat from 1975 on, today peat and wood chips. Modern burning technology can reduce CO2-emissions and small particles-, SO2- and NO-emissions. The city has been years one of the most energy efficient cities in Finland. Table 2 shows the energy and water consumption of the city from 2010 compared with the other cities

*Table 2: Energy consumption in City of Kuopio and in Finland*

| | Kuopio | Average in Finland | |
|---|---|---|---|
| Heat | 30,4 | 42,9 | kWh/m 2 |
| Electricity | 13,6 | 18,6 | kWh/m 2 |
| Water | 100,9 | 127,7 | l/m2 |

Before the distric-level control center, lot of energy saving and energy-efficiency related measures has been done, see figure 7.

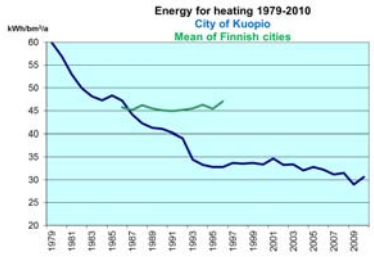


*Figure 7. Heating energy consumption before district-level operation center*

Distric-level operation center will confirm that the energy efficiency of the building stock will stay at the planned level and ensure the proper managing. There are 3 different building autonmation system in use; the next step is to create one upper level system which connects the subsystems.

## ECO-CAMPUS

An international KMEG-project started in 2011 and ended 2014 but the data collection and processing continues. The aim of the project was to contribute to increased energy efficiency in districts and buildings by innovative management and control systems, capable to optimize the local consumption without compromising the indoor environment, occupant comfort and building performance, and by introducing new ICT-enabled business models. The quantitative objective was to save 15 % of delivered energy including electricity and district heat. This should be possible based on on-going commissioning. The pilot area is s c Otaniemi Campus-area of Aalto University. Otaniemi is a part of City of Espoo.In pilot area there are

- Installed LOC" District level control center-server"
- Installed K-MEG wireless sensors approximately 300-400 pieces in 4 buildings
- Installed NIALM meters 9 pieces (electricity)
- Integration of building automation system to LOC in two pilots

Figure 8 shows a sensor-transmitter unit installed in pilot buildings. For instance in one pilot building 130 rooms were equipped with this unit (measured factors: T, RH, CO2, lighting, occupancy).

*Figure 8. Sensor-transmitter unit*

From the area 8 buildings (mainly university buildings and dormitories) were selected for further analysis. Walk-through energy audits were carried out in those buildings. Based on energy audits and consumption and indoor environment monitoring commissioning reports were made. According to results there was lot to do to improve the functioning of the systems up to date; the building owners made the plan to improve facility and energy management in co-operation with service provider (maintenance company). The age of system varies, generally at least 10 years old after repairs and represents the measurement practice of its time. As a reference, based on the results of walk-through audit, for

instance in case of ventilation systems, there must be at least following additional measurements if one will use the metering in commissioning:

- The temperature of exhaust air after the heat recovery unit (indicator in the operating room in the wall of the unit+transmitter to BAS)
- The fresh (incoming) air should be measured from the air supply chamber – not on the roof
- The temperature of exhaust air before the heat recovery unit
- Pressure indicator over the fans in the operation room and transmitter to BAS (for air flow indication)
- Calculation algorithm in the BAS system, with k-values of fans (to convert the pressure drop over the fan to air flow rate)
- Calculation algorithm for efficiency of heat recovery
- Metering for heating and cooling energy of the ventilation
- Indoor environment sensors (RH+CO2) in specified positions
- Report system for ventilation that the users, operators and managers can see in few sheets the performance of ventilation system

In improving energy efficiency by monitoring one can differ the following steps:

1. Determing of the measuring points (Key Performance Indicators)
2. Systematic data collection from substantial targets
3. Ensuring the performance of the sensors and data transfer
4. Analysis of data
5. Illustrative presentation of analysed data for customer´s/owner`s/user`s needs
6. Collection of background information (statistics, available benchmarking results, calculations etc)
7. Decisions based on measured data
8. Benchmarking of the buildings, also comparison with calculation and statistical data
9. Decisionmaking
10. Feedback

## WHAT PUBLIC AUTHORITIES CAN DO

Every building must have a building permission given by Building Supervision Office (BSO). In the City of Oulu (population 200 000) while applying a building permission for a private house-builder BSO Oulu offers consultation free of charge. For professional builders (=companies, engineering/architect offices etc.) there are typically 10-15 seminar days (50-150 participants) on “hot” topics. Number of participants (person days) during the last 10 years is 23 000 for these two consultation activities.

Results of these actions show currently 17% better buildings in energy efficiency compared to minimum level in Finnish building regulations. In retrofitting efforts consultation is more individual for home-owners, for professionals seminar days by themes. The driver to make retrofitting always includes raising up living standards and conditions and can result up to 20-50% better energy efficiency. Persons promoting energy advice belong to BSO Oulu so their influence to most house-builders (75%) is natural and easy to get the connection.

BSO Oulu also has reached their activities to promote improving metering and instrumentation especially in new areas. The aim is to have proper data for instance from distributed renewable energy sources (heat pumps, PV, biofuels etc) and also with the other authorities to develop remote control for larger buyilding stock.

Ongoing development projects in BSO-Oulu are e-Lighthouse funded by NPA-program and Kuivaketju10 funded by Ministry of Environment.

## CONCLUSIONS

In this presentation two case studies were introduced – the first one a realized district-level operation center for public buildings covering 4 communities. The second case was a research and development project in a university campus area. The third case shows how the public authorities can improve the performance and energy efficiency of buildings.

The main problems in existing systems are

- Lot of data is available but…. less information for the needs of users and
- The systems do not necessarily discuss with each other.

District level monitoring system can be commercialized for the use of building owners. The crucial thing is the procedure and how to utilize the data for facility and energy management in evaluating the total performance of a building and the location of the building on life-cycle curve. In Finland there are service providers which have 200 – 1000 buildings connected in their remote monitoring and control system. In remote control system (typically retail chains, building owners of large building stock) the solutions are based on the systems of the service provider. The remote control of public building stock of larger areas is just in the beginning, new plans are in progress in several areas.

Some cities have city-owned companies for monitoring, facility management maintenance, and surveillance (full service). The remote control of large building stock is a reality now; combined the cloud-based date files. The expected benefits can be divided as follows:

- Almost real time remote control via standardized data collection and processing. Improved efficiency and quality of facility and energy management
- Modes and procedures will come more systematic and time management will become more efficient
- Micro-level benefits: Practices of various manufacturers will become more uniform – benefit for users – two-level benefit (alarms, data processing), data security and protection issues
- Biggest advantages will be reached in areas with large building stock
- Flexible and tailor-made service for building owners and various users
- Applicable for all kind of buildings
- Basis for new type service businesses and value chain creation

Many companies have systems covering one part of the planned concept – companies have also systems used in connection with/on building automation systems in energy- and condition management.

- Systems are mainly closed, however and the data generated by different vendors are not always integrated and converted into a form that the effective use would be possible (from data to information)
- Building owners do not necessary want to engage themselves with one hardware supplier- framework model as a solution – they need concepts for bids for solutions (technical and data processing)
- Marketing views must be sorted out – private enterprises have own solutions and they have their own business logic
- Municipalities as target group have lot of common problems but also challenging operational environment

More attention must be paid to the audit of building automation system and also to additional instrumentation. The instrumentation level is designed for technical use and for daily operations; from facility and energy management point of view additional instrumentation and submetering (especially for electricity) is needed, the most important topic is to improve the data processing and reporting.

## ACKNOWLEDGEMENTS

Senate Properties, Aalto University Properties Ltd , Aalto University Student Union AYY, Foundation for Student Housing in the Helsinki Region HOAS, City of Espoo, KMEG R&D Center (www.k-meg.org), Samsung Co (Korea) and its partners, Korean Ministry of Trade and Industry. City of Kuopio, Building Supervision Office Oulu, Technical Research Centre of Finland VTT.

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