COMPARISON BETWEEN THE CONTINUOUS COMMISSIONING^{SM} PROCESS AND METHODS USED FOR ENERGY EFFICIENCY IN NORWAY – RESULTS FROM A CASE STUDY

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Summary

For a long period of time Norwegian energy authorities has focused on different types of energy conservation measures and this has lead to the development of particular energy efficiency methods. The historical development of these methods is described and they are compared to the Continuous Commissioning^{SM} (CC^{SM}) method from the Texas A&M University. There are only small differences between the CC^{SM} method and the traditional Norwegian energy efficiency methods. It seem that the CC^{SM} is more extensive than the Norwegian methods. The method of CC^{SM} is implemented for use in Norway in a small school building. The aim was to reduce the energy consumption and to ensure optimal thermal comfort. The building is a primary school, built in 1997. The building has had increasing energy consumption over the last four years, and there has been complaints regarding low temperatures during the winter. The case study was conducted as a master thesis study and was limited in time and comprehensiveness due to restrictions of the assignment. Further work is necessary to draw any final conclusions.

Keywords: energy efficiency measures, continuous commissioning, compurgation, case study

INTRODUCTION

Many buildings in Norway show significant deviations between design requirements and actual performance. The problems may be related to errors made during the design phase, during the construction of the building, during the commissioning process, or it may be caused by incorrect operation of the technical systems, lack of maintenance or altered use of the building.

The commissioning process has mainly been viewed as a status at the end of a building project (taking-over), and not as a continuous process that spans from the design phase throughout the operational phase. For a long period of time Norwegian energy authorities has focused on different types of energy conservation measures and this has lead to the development of particular energy efficiency methods. The historical development of these methods are described and compared to the Continuous Commissioning^{SM} (CC^{SM}) method.

There are only small differences between the CC^{SM} method and the traditional Norwegian energy efficiency methods. The development of the Norwegian methods over time has been motivated by problems occurring in different phases of the energy efficiency scheme. It seem that the CC^{SM} is more extensive than the Norwegian methods.

The method of CC^{SM} is implemented for use in Norway in a small school building. The aim was to reduce the energy consumption and to ensure optimal thermal comfort. The building is a primary school, built in 1997. The building has had increasing energy consumption over the last four years, and there has been complaints regarding low temperatures during the winter. With its 1600 m^2, 134 occupants, hydronic heating and 3 air handling units, it is a suitable building for a first implementation of CC^{SM}. The case study was conducted as a master thesis study and was limited in time and comprehensiveness due to restrictions of the assignment.

NORWEGIAN ENERGY AND ENERGY CONSERVATION POLICY

We live in a period that faces major challenges in terms of limited energy resources, while the natural balance of the physical environment is in the process of being interrupted by excessive reliance on fossil fuels. The United Nations Global Commission for Environment and Development emphasized, back in 1986, that because of the pollution of air, water and the soil, as well as global warming, all countries, and the industrialized nations in particular, will have to raise their levels of energy efficiency and change to renewable energy sources if the world is to move to a sustainable development track. The same commission has recommended making energy conservation a core aspect of national energy policy.

Interest in questions and problems of energy consumption has developed in the course of time. The history books tell the problems of deforestation around the Mediterranean and in Central Europe, and of air pollution caused by excessive coal burning in London. However, these were typical regional phenomena. The global way of thinking has developed in the course of the past three decades. As a result of the first oil crisis in 1974, conserving energy became an important part of the energy policy of most western countries. By the end of the 80s, awareness of the environmental consequences of burning fossil fuels had reawakened interest in energy policy, energy efficiency and energy conservation.

The Norwegian State’s interest in energy conservation closely followed international trends in this area. The first Norwegian White Paper to deal with energy conservation appeared in 1979, and for the first time, National Budget included items earmarked for energy conservation. Since then, no fewer than five White Papers on energy conservation have appeared, the last in 1998. In 1992, a completely new Energy Act introduced the power of the market to electricity sales. This was intended to guarantee that energy resources would be managed rationally and for the benefit of society as a whole. The “balance clause” in the Energy Act also required energy conservation to be regarded as a means of meeting energy demand on an equal footing with new development and purchases of energy on the market.

The aim of public sector interest in energy conservation in Norway is to help ensure that energy resources are utilized in a macro-economically efficient way and that the harmful environmental effects of energy consumption are reduced.

Awareness of energy and environmental questions has also meant that buildings with technical installations are facing more stringent requirements for efficient use of energy and cuts in environmental contamination. In an international context, Norwegian buildings are of reasonably good standard in energy terms, and about 70 - 75% of energy consumption in our buildings is electricity, which is almost completely generated by renewable hydropower. However, this does not mean that we can relax. Our philosophy for putting greater effort into efficient energy consumption in buildings is based on the fact that energy consumption in building cannot be considered isolated from other areas of application or from other parts of the world. We must all pull together if we are to make a better future for everyone.

Until 1990, national energy conservation activities basically consisted of information, training and development of know-how. Research, prototype and demonstration projects were also given support. The latter item refers to the development and dissemination of new, energy-friendly technologies. The authorities have also allocated funds for the implementation of energy conservation measures in their own buildings.

Since 1990, funds have been allocated for the implementation of energy conservation measures in industrial and commercial buildings, and as well in local authority and county council buildings. In 1992, a subsidy scheme for private dwellings was also introduced.

Many refurbishment and renovation projects have been initiated and conducted during the few years of the regime of subsidies. Some projects were success stories others were not. It became obvious that motivated operation staff, and close follow-up of energy consumption and conditions of the equipment is crucial for a persistent efficiency. The concept of energy audit was developed and implemented. Lots of important practical experience was gained. In many cases it was observed that the comprehensive energy audits were curried out, but not followed by implementation of measures. The building owner was motivated just enough to conduct the audit, but not enough to go for implementation. A further experience gained was that many projects were implemented just for the sake of the subsidy. The renovation was the prime issue for the owner and not necessarily improved energy efficiency.

During the second half of the 90s, Norwegian authorities appointed special operators for public information, for energy efficiency in industry and for energy efficiency in buildings. Regional centers for energy efficiency were established in Norway’s nineteen counties. These centers got the responsibility for introduction of simple energy surveys and for motivation of building owners for further investment in complete energy audits and in subsequent energy efficiency measures. Energy monitoring became mandatory part of the measures. The operator for energy efficiency in buildings initiated dedicated energy efficiency networks connecting building owners for particular types of building. Importance of energy management deeply rooted in management of the whole building and real involvement of the owner was pinpointed.

A public enterprise Enova SF, owned by the Royal Norwegian Ministry of Petroleum and Energy was established in 2002. Enova`s mission is to contribute to environmentally sound and rational use and production of energy, relying on financial instruments and incentives to stimulate market actors and mechanisms to achieve national energy policy goals.

The establishment of Enova SF signals a shift in Norway’s organization and implementation of its energy efficiency and renewable energy policy. By gathering strategic policy responsibilities in a small, flexible and market oriented organization, Norway wanted to create a pro-active agency that has the capacity to stimulate energy efficiency by motivating cost-effective and environmentally sound investment decisions. Enova SF enjoys considerable freedom with regard to the choice and composition of its strategic foci and policy measures. Enova SF advises the Ministry in questions relating to energy efficiency and new renewable energy.

To achieve its goals, Enova SF has organized its activities into main programme areas. In the field of energy efficiency in buildings many of previous activities are pursued but adapted according to gained experience and further developed. Currently, organizations are invited to apply for funding within programmes in the following areas:

- *Energy management in large commercial buildings:* The goal is to reduce the level of energy use by 100 GWh/year. The programme is aimed at projects and networking among building owners with a total floor area over 20.000 m². Project activities that qualify for funding are energy management, training, dissemination of information, energy monitoring and energy and environmental analyses.

- *Energy management in small commercial buildings:* The goal of the program is to reduce the need for energy by 70 GWh/year. The program is aimed at buildings with a total floor space under 20.000 m². Projects where more than five building owners cooperate are preferred. Activities that are funded are training, information, energy management and monitoring and energy and environmental analyses. 40 to 50 % of total project costs qualify for funding, exclusive of investment costs.

- *Residential buildings:* The program is aimed at both new homes and rehabilitation of the existing building stock in the residential sector. Enova SF is particularly looking for best practice examples where best available climate adjusted technology is being used that will minimize the need for heating, reduce heat loss and improve heat recovery.

ENERGY EFFICIENCY PRACTICE IN BUILDINGS IN NORWAY

Current energy efficiency practice in Norway contains four closely connected areas:

- Energy survey
- Energy audit
- Energy monitoring
- Energy management

These four activities reflect the experience gained trough implementation and development of the methods during the period of approximately twenty years. As earlier explained, during the first period with focus on simple energy efficiency, the concept of energy audits was established. Later it was divided into a simple energy survey and a thorough energy audit. The next step was energy monitoring and the last extension is the development of the concept of energy management that actually comprises all mentioned stages and actively involves both the building owner and the manager.

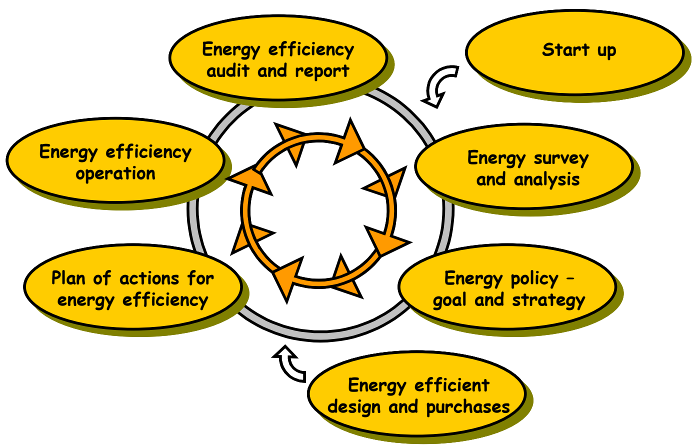

Figure 1. The good cycle of energy management

Energy audit

The energy audit process is described in /1/:

1. Collect all relevant information about building and facilities
2. Obtain information about current energy use, and cost for energy
3. Identify obvious profitable projects
4. Detailed building inspection, including: performance measurement, inspection of control system, interview with operating staff and occupants.
5. Identify other savings than energy (water, sewage)
6. Consider the projects influence on indoor climate
7. Identify other maintenance projects that could be implemented in the same operation
8. Make decision basis with savings and investments based estimates

9. Consider energy prices and tariffs before and after the project
10. Suggest separate or prime/principal contracting, call for tenders, and enter into a contract
11. Procure financing possibilities
12. Inspect the project during implementation
13. Undertake performance measurements of the project and compare the results with the expectations
14. Establish energy monitoring systems and training of operational staff
15. Document energy savings

As we can see, the Energy audit will lead to the establishment of an energy monitoring system to demonstrate the energy savings.

Energy monitoring system

Establishment of the energy monitoring system can be introduced in several ways but a typical process can include the following steps:

1. Collect all relevant information about the energy supply system, existing energy consumption, building and facilities
2. Subdivide the building according to different use of the building or according to building condition etc.
3. Consider subdividing energy consumption according to different end-uses of energy
4. Identify the necessary energy meters and other instrumentation needs to accomplish the measurement according to subdivision in building areas and different end-uses of energy
5. Decide necessary extent of measurement
6. Make decision basis with savings and investments based estimates
7. Decide type of system for monitoring: manual, by dedicated computer, by building energy management system (BEMS) or by separate data logger.

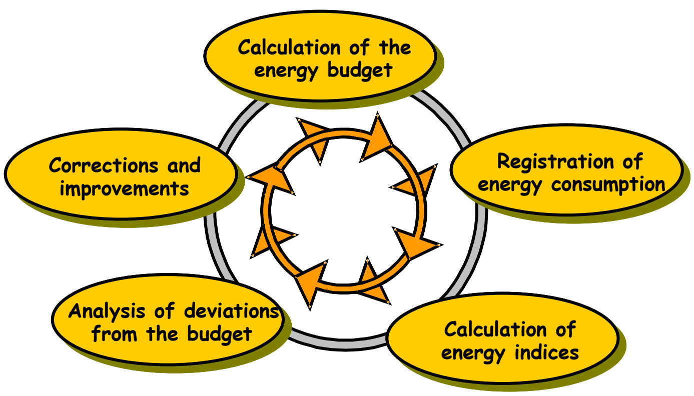

Figure 2. The good cycle of Energy Monitoring

Energy management

The energy management method has come in to the energy efficiency methods due to experiences with the process during the years. Energy efficiency projects initiated by the operational staff or others further down in the organization have less possibility to be executed. This is explained by the fact that the management has traditionally had a little interest in energy consumption and energy efficiency. To change this behavior a process called energy management, that actively involves both the building owner and the manager, has been introduced.

COMPARISON BETWEEN CC^{SM} AND NORWEGIAN ENERGY EFFICIENCY METHODS

The method called Continuous Commissioning^{SM} (CC^{SM}) has its origin from the Texas A & M University and is developed under the direction of the U.S. Department of Energy's Federal Energy Management Program (FEMP). CC^{SM} is defined as 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. The CC^{SM} method described in the CC^{SM} Guidebook /2/ is used for comparison of equivalent Norwegian energy efficiency methods. The two main phases in CC^{SM} are Project Development (Phase 1) and Implementation and Verification (Phase 2). A thorough audit, with system measurement and involvement from the technical staff as important parts, should lead to implementation of the CC^{SM}-measures. Documentation of the improvements and keeping the commissioning continuous are the final steps.

The CC^{SM} method is described step by step and each step is compared to the corresponding Norwegian energy efficiency methods.

Phase 1: Project Development

Step 1: Identify Buildings or Facilities
In the CC^{SM} process the first step is to identify building and facilities that will be included in the CC^{SM} audit.

This is equivalent to the first step in both the Energy Audit and the Energy Monitoring. This activity is therefore well included in the methods used for energy efficiency in Norway.

Step 2: Perform CC^{SM} Audit and Develop Project Scope
In this step the scope of the project is developed. This involves defining the owner's requirements; identify available technical support and major CC^{SM} measures. At the end of Phase 1, the scope of the project shall be clearly defined and a contract regarding the CC^{SM} project shall be signed. This is established through a meeting between CC^{SM} project manager, CC^{SM} engineer and a representative from the building owner. After the meeting, a walkthrough must be conducted to verify that it is possible to meet the owner's expectations regarding energy measures and indoor climate. This step also involves collecting all available documentations from design to latest measurement.

This step is also included in the Norwegian methods, but it is carried out in several steps. The involvement of the building owner at managerial level is the key issue in the energy management. The other actions are covered in The Energy audit in various steps. The main difference between the methods is that in the Norwegian Energy Audit the scope of the project is not developed before a detailed analysis has taken place. The obvious profitable projects are identified during the energy survey.

Phase 2: CC^{SM} Implementation and Verification

Step 1: Develop CC^{SM} Plan and Form the Project Team
The CC^{SM} project manager and CC^{SM} project engineer establish a complete work plan for the project that includes major tasks, their sequence, time and technical requirements. This plan is then presented to the building owner or his representative.

This is one area where there is a difference between the traditional Norwegian methods and the CC^{SM} methods. In the CC^{SM} methods the involvement from the in-house technical staff is clearly defined. Even if the involvement of in-house technical staff is a part of the energy management method, their role and task is not precisely described. The detailed plan for the whole project is covered in the energy audit method.

Step 2: Develop Performance Baselines
In this step in the CC^{SM} method all the existing conditions connected to indoor air climate, technical systems and energy performance should be documented.

If the energy savings should be documented after the project is completed, it is necessary to develop an energy baseline for the building. The energy baseline model could be developed with:

- Short term measured data
- Long term (hourly or 15-minute) energy data for the entire building
- Utility bill for electricity, gas etc.

The whole building energy baseline models normally include whole building electricity, cooling and heating models. These models are generally expressed as functions of outside air temperature.

In the Norwegian methods the documentation of energy savings are required in the energy audit. There are no requirements for a baseline model in the Norwegian methods. Usually correlations for heating degree-days or hours are made for the heat energy savings.

Step 3: Conduct System Measurements and Develop Proposed CC^{SM} Measures
Step 3 starts with a detailed survey of all current operating schedules, set points and problems. Further, the CC^{SM} team must develop solutions to existing problems, develop improved operation and control schedules and set points, and identify potential cost effective energy retrofit measures.

The CC^{SM} engineer should develop a full measurement plan for each major system. The measurement plan should list all parameters to be measured and all mechanical and electrical parts to be checked.

The measurements shall be implemented according to the plan. On basis of the results from the measurements results the CC^{SM} team shall propose solutions to problem areas and energy measures.

The Norwegian energy monitoring will contain most of the measurements and a measurement plan. The difference is maybe that the energy monitoring systems are most focused on energy use and less on operational problems regarding indoor climate. The tasks connected to energy measures are also covered in the Norwegian methods. In the energy audit a set of energy measures are suggested.

Step 4: Implement CC^{SM} Measures Objectives
For the CC^{SM} measures suggested in Step 3 one shall obtain approval for each CC^{SM} measure from the building owner's representative prior to implementation. Solutions to existing operational and comfort problems should be implemented together with refined and improved operation and control schedules.

This step is equivalent to the Norwegian Energy Audit where the building owner is the decision maker. A representative for the building owner must approve all energy measures. When the approval is given, all the energy efficiency measures that are agreed upon are implemented.

Step 5: Document Comfort Improvements and Energy Savings
In Step 5 all improvements regarding indoor climate, system conditions and energy performance should be documented. This is done by measurements of indoor climate and energy use under comparable conditions as they where measured in Step 2, Phase 2.

The only difference from the Norwegian Energy Audit is the emphasis on indoor climate in the documentation.

Step 6: Keep the Commissioning Continuous
The goal is to maintain improved comfort and energy performance over time, and provide measured annual energy savings. The CC^{SM} engineers should review the system operation periodically to identify any operating problems and continuously develop improved operation and control schedules.

The goal with the Norwegian Energy Monitoring process is also to maintain the energy performance over time. The difference in this step is also that the CC^{SM} method has more emphasis on the indoor climate than the Norwegian methods.

CONCLUSION FROM THE COMPARISON BETWEEN CC^{SM} AND NORWEGIAN METHODS

There are only small differences between the CC^{SM} method and the traditional Norwegian energy efficiency methods. The development of the Norwegian methods over time has been motivated by problems obtained in different phases of energy efficiency scheme. It seems that the CC^{SM} is more extensive than the Norwegian methods.

The main benefits in the CC^{SM} method compared to the Norwegian methods are:

- The whole process is covered in one method
- The involvement of the in-house technicians are better described throughout the process
- The emphasis on indoor climate is consistent throughout the whole process.

CASE STUDY

To test Continuous Commissioning^{SM} as a tool, in Norway, a limited case study has been carried out /3/. The method was implemented on a small primary school building "Okstad skole" in Trondheim in Middle of Norway. The school was built in 1997 with 1600 m^2, 134 occupants, hydronic heating and 3 air-handling units. The building has had increasing energy consumption over the last four years, and there has been complaints regarding low temperatures during the winter.

Figure 3. Primary school building "Okstad skole", Trondheim, Middle Norway

Analyzing the building energy performance and documenting the existing conditions has been the primary objective of the project. Three different software programs have been used for energy calculation. The real energy consumption in the school building is somewhat high compared to the calculated results from "Encon Key numbers"/4/. The calculation indicates that heating, ventilation and domestic hot water heating should require 75 kWh/m^2, while calculations based on the corresponding utility bills for the last two years, show 118 kWh/m^2. Calculations done with the tools "NS 3031" /5/ and "Energy in buildings" /6/ also shows that the real consumption is a bit higher than simulated, although not as high as the first estimate. The estimate here is 107 kWh/m^2. A total assessment of these results indicates that there are no faults in the system, but that the conditions, under which the building is operated, can be improved. The electricity demand has been evaluated using basic preferred figures, because no other data was available. This evaluation implies that the electricity consumption is too high, but a better basis is necessary before this can be concluded.

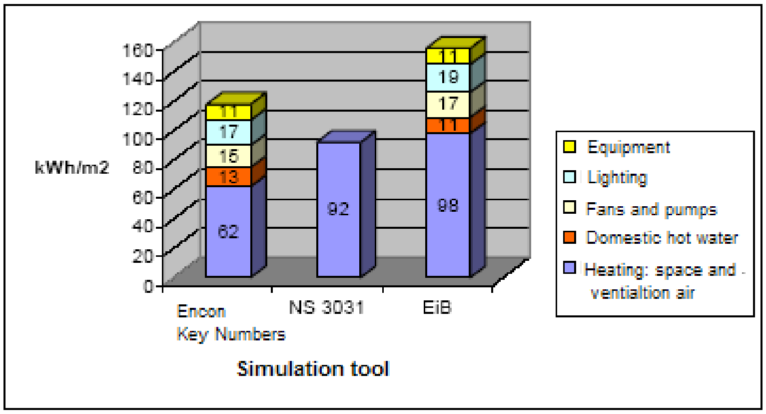

Figure 4. Comparison of results from different energy calculation codes

Analysis of the existing comfort conditions in the building, show that the air quality in the classroom zone is good. This is based on the fact that there are no complaints and that the measured carbon dioxide level is far below the recommended value of 1000 ppm. In the teachers' lounge, the comfort seems to be poorer. With complaints regarding high temperature and bad air quality, and measurements that suggest that the airflow rate is too low, this should be investigated more closely. In the winter it seems to be too cold in the classroom farthest away of the plant.

The case study was conducted as a master thesis study and was limited in time and comprehensiveness due to restrictions of the assignment. Further work is necessary to draw any final conclusions.

ACKNOWLEDGMENT

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