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Integration of Technical Installations in Hospitals Allows Flexibility to Adapt for Changing Usage During Lifetime

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Abstract

A large university hospital uses twice as much energy per square meter compared to other commercial buildings. Large university hospitals recently built in Norway have annual energy consumption between 300-400 kWh/m2.

Flexible buildings are needed for adapt opportunities to change patient care and treatment methods during the buildings lifetime. Technical innovation proceeds very fast within healthcare, so the need is urgent for built-in flexibility in new and future-oriented hospitals. Rapid change in the usage of different function areas, without too much rebuilding or retrofitting, is possible by integrating the various technical installations through common bus systems. This integration enables the building to adapt changes in new and future-oriented hospitals. In most cases, a simple reprogramming is all that is required to reconfigure the technical systems to new demands.

We recommend demand control as the design philosophy for flexible building systems, including ventilation, window shading, lighting, heating and cooling. To achieve its full potential, demand control functionality should be integrated in the centralized management and control system of the building. One immediate benefit of integrated systems is a reduction in the total energy consumption, estimated at 20-50% for a new hospital.

Keywords – Energy savings, control systems, system integrations, technical solutions, bus system

1. Introduction

Buildings account for about 40 % of national energy consumption, and hospitals represent about 6 % of the total energy consumption of public buildings in Norway. A large university hospital uses twice as much energy per square meter compared to other commercial buildings. Large university hospitals recently built in Norway have annual energy consumption between 300-400 kWh/m2. Hospitals have a wide variety of functional requirements, usage patterns and other operational challenges that determine the suitability of different technical solutions.

The authors are key members of a research project funded by The Research Council of Norway to examine energy design of new hospital buildings, known as “Low Energy Hospitals” project (www.lavenergisykehus.no). The main goal of the project is to discover and describe a collection of best-practices which can achieve a 50 % reduction of the total delivered energy to new hospitals.

A breakdown of energy consumption in a typical large hospital is shown in Figure 1. The "Other" category in this Figure represents electricity consumption by medical and office equipment.

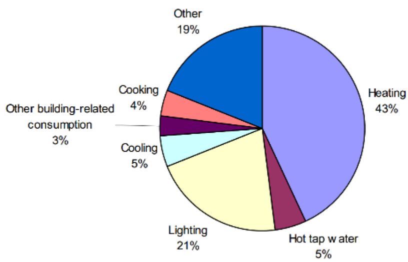

Figure 1. Breakdown of the energy flows in a large hospital

Hospitals are in changing mode during the hole lifetime. Our experience is that 5-10 % of the total hospital area for new university hospitals are in continious changing. This means that the function in the different areas are changing from time to time, depending of the hospitals different needs.

In order to optimize flexibility and total energy consumption, it is important that the various communication systems (bus systems) can communicate with each other (integrated communication). Building systems such as lighting, ventilation, cooling and heating, can then respond in a unified way to a common set of external demands such as presence detection, room reservation, fire/smoke detection, solar flux and so on. This approach allows customized management of each configuration. Integrating as many technical systems as are feasible within a building automation system is also likely to reduce the amount of cabling and the total investment cost for the installations.

Technical integration has four main categories that will be described in this paper:

- Communication related to specifications in hospitals
- Safety (secure) systems
- Centralized technical systems
- Specific functional area technical systems

Although our recommendations are aimed at hospitals in northern Europe, they have a general applicability to other types of health facilities worldwide and for other complex building categories.

2. Methods

During the project we studied several hospitals built in Norway over the last 10-15 years, looking for examples of typical and best practice with respect to energy performance. The research and knowledge emerge from literature studies, excisting hospitals, measurements, experiences and knowledge, demands and regulations, technical considerations, energy simulations in models and system integrations.

In our research project we used a reference hospital which was divided in 10 different departments as listed:

- Bed ward
- Public area
- Day treatment area
- Surgical Operation area
- Office and administration area
- Polyclinic area
- Imaging area
- Lab area
- Patient hotel
- Acute area

The areas listed above have all different use and different technical installation that have different needs of control system.

An interdisciplinary integration process early in the planning phase is important to ensure that most systems communicate on the same platform (bus-system). This will make it easier and overall less expensive to achieve good energy efficient solutions. To get the right level of integration, it is important to analyse all the positive and negative aspect of integrating one system with another. And further we need to study close which technical systems and installations are to be integrated in the specific hospital. Some integration will be of great use and we will achieve energy savings and more efficient management 24/7. But of course it is not possible to say that integration of all technical installations gives the same flexibility and energy savings in all hospitals in general. This must be an individual process in each project. However we have some lessons learned through this research-project that is to be recommended for all planning-processes.

At last, decisions of integration for different technical systems should be analysed by life-cycle cost calculations. Investment and cost for management in total are important issues to take into account for choosing technical solutions.

Design criteria have no easy recipe! We start by dividing as listed:

- Good hospital logistics and patient flow will generally enable good demand control
- Similar functions are usually grouped together
- Enables better zonal control, especially for corridors and other connecting areas in hospitals
- Easier to maintain correct pressure relationships for ventilation.
- Challenge to maintain flexibility
- Functions in the different areas depends of treatment methods, patient groups and medical speciality fields

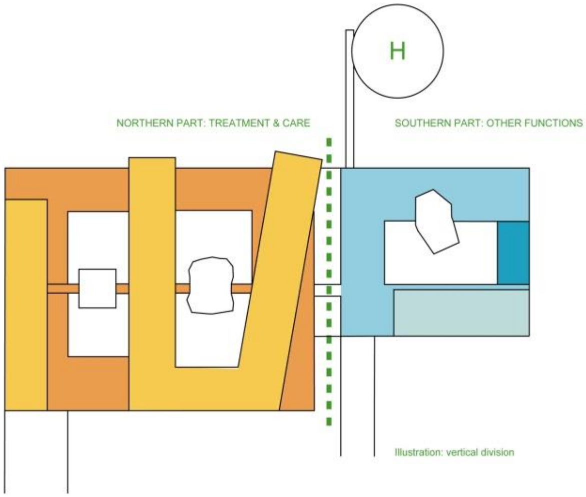

Figure 2, Example of different functional area in hospital

It is important to identify the smallest spaces for room demand control:

- Room categories as patient rooms, bathrooms, treatment rooms, meeting room
- Suggestion: attach a schedule for occupancy and equipment usage for each room in the room program; this will help the designers

Further, choose optimal control strategy for each room/space:

- Room type will determine control variables: time of day, CO_2, or presence detection
- Patient rooms and other small rooms controlled by presence detector, with modulating temperature on top
- Sensing of CO_2 not for treatment rooms or OP rooms due to high ventilation rates

A patient room is an example of an area with many different activities and needs for illumination throughout the day. The lighting requirements are different during normal stay, relaxation, examination, cleaning and recovery.

In an operating room the current procedure's clinical requirements will determine the kind of medical equipment and other installations, the use of X-rays and monitors, the number of staff, and their task locations. All of the different cases must be considered when planning the optimal integrated system for an all-purpose operating room, including also the cases for cleaning and preparation of the rooms before the arrival of medical personnel and the patient.

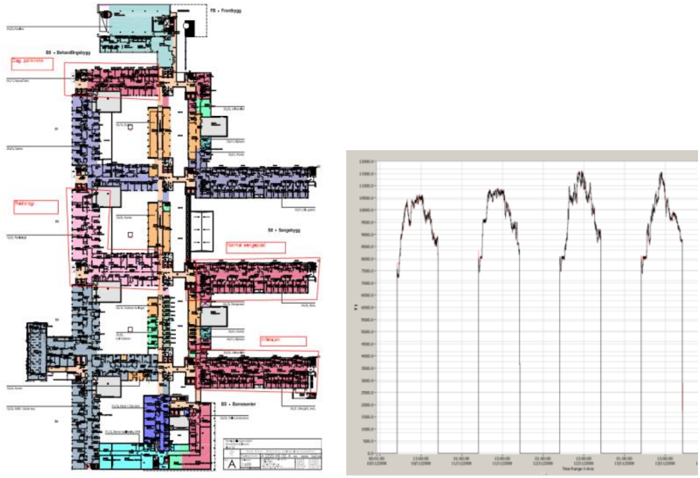

Figure 3 University hospital in Oslo divided in different functional areas

Technical integration has four main categories:

• Communication related to specifications in hospitals
• Safety (secure) systems
• Centralized technical systems
• Specific functional area technical systems

Communication

- Hospitals signals
- Patient journals
- Alarm systems
- Call system
- Booking system

Safety

- Access control
- Fire detection
- Fire alarm
- Emergency lighting

- TV signals
- TCP/IP Ethernet
- Video monitoring
- Elevator signals / alarm
- IP – telephone

Centralized technical system

- Ventilation
- Heating
- Cooling
- Technical sub-processes
- Energy systems
- Electrical installations

Specific functional area technical systems

- Zone technical systems
- Lighting control
- Blinding control
- Temperature control
- Demand ventilation control

These are to be considered integrated in the centralized management and control system of the building, and has to communicate on the same level. It is important and a success factor that the systems and installations can understand each other and be at the same platform (communicate at the same level). Different systems can with very good results be integrated and communicate and cooperate for the best technical solutions – achieve flexibility and energy savings.

3. Results

An interdisciplinary integration process during the planning phase will help us to optimize the combinations of integrated energy systems.

Rapid change in the usage of different function areas, without too much rebuilding or retrofitting, is possible by integrating the various technical installations. This integration enables the building to quickly adapt changes in new and future-oriented hospitals. In most cases, a simple reprogramming is all that is required to reconfigure the technical systems to the new demands.

In each project we recommend to discuss what it is possible to integrate, what should be integrated and what should not be integrated of all technical systems divided into functional and physical areas.

We recommend that the following systems and areas **should** be integrated:

- Ventilation systems in all areas including demand control ventilation.
- Heating system, local and central
- Cooling system, local and central
- Lighting system for all areas
- External and inside blinding

We recommend **considering** the following systems and areas to be integrated:

- Presence detection
- Hospital signals
- Emergency Lighting

We recommend the following systems and areas **not** to be integrated:

- Boundary protection
- Access control
- Elevator signal and alarms

We analysed energy savings potential in four different hospitals in Norway over a period of 24 months. In table 1 we have listed the calculated reduction with use of demand control in different installations. This is a consequence of integrated solutions.

Table 1 Energy consumption and possible reductions as result of demand-control

Today's energy consumption (kWh/m^2)		**Demand-controlled (kWh/m^2)**	**Reduction**
1a Local room heating	55	47	
1b Ventilation heating	**110**	**22**	**80%**
2 Hot water	20	20	
3a Ventilation fan	**50**	**25**	**50 %**
4 Artificial lighting	**50**	**40**	**20 %**
5 Techn. equipment	65	65	
6 a Room cooling	35	26	
6b Ventilation cooling	**15**	**15**	**25 %**
Total net energy	**400**	**260**	**35 %**

In general we find that ventilation and lighting have highest potential for demand-control.

- Energy saving potential for demand control at room level is up to 50 %
- Decouples heating from air handling

- Large ventilation air flows have a cooling effect; room heater starts to counteract
- Important side-effects of lower airflows:
  - Lower Specific Fan Power
  - Higher effectiveness of heat recovery
- Local room heating (1a) is more difficult to demand-control due to time lag
- Domestic hot water (2) already on demand, and water-saving taps installed
- Most hospital technical equipment (5) is already on-demand
- Room cooling (6a) is fixed by continuous process and IT equipment demands

4. Conclusions

We recommend an interdisciplinary integration process early in the planning phase to ensure that most systems communicate on the same platform (bus-system); this will make it easier and overall less expensive to achieve good energy efficient solutions. To get the right level of integration, it is important to analyze all the positive and negative aspect of integrating one system with another. Integration decisions for different technical systems should be guided by life-cycle cost considerations.

We also recommend using demand control (DC) principles in the design of systems for window shading, ventilation, lighting, heating and cooling to achieve the potential for energy and flexibility. To achieve its full potential, demand control functionality must be integrated with the centralized management and control system of the building.

Energy flows between outdoor climate, building envelope, local heating and cooling, ventilation and airborne heating and cooling are complex. These flows also interact with the building lighting, medical equipment, pumps and fans, and domestic hot water. Modern communications and integration technologies now allow us to regulate how all these technical systems combine in real-time to respond flexibly to current demand with the minimum amount of energy input. With this approach, reductions of total energy consumption of 20-50% in new hospitals are within reach.

Further we conclude that integrated systems that communicate on the same platform (bus-system) allow future hospitals to re-configure functional areas with a minimum of retrofitting and rebuilding. Simply re-programming the control system will give us the opportunity to change settings for airflow, lighting, security etc. In this way can all the technical systems adapt to a cost-effective future hospital.

Acknowledgment

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