PLANNING AND PERFORMANCE OF AN ECO-EFFICIENT DORMATORY IN COLD CLIMATE AREA

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Summary

A public company, Senate Properties, is contracting multi-purpose dormitory building in the shore of Lake Inari in Lapland, Finland. The area is one of the coldest areas in the country. The building project will be realized in accordance with strict energy- and ecological requirements. In this paper the set requirements and planned actions to meet the requirements are presented.

Keywords: Eco efficiency, passive house, cold-climate building, demand controlled operations

1. Introduction

Senate Properties is a state enterprise with nationwide operations and a role as government-internal premises expert provides the central government premises with associated services. One of those premises is the Sámi Education Institute, a secondary degree school, which provides a variety of vocational training both in Finnish and Sámi, as well as promotes Sámi culture in the whole Sámi region. The Institute is located in the shore of Lake Inari in Lapland (figures 1[1] and 2[2]). Currently, Senate Properties is contracting a multi-purpose dormitory building for the students of Sami Education Institute in connection with the existing property. Due to Northern location and relatively hard weather conditions caused by the open Lake Inari as well as due to increased energy efficiency demand and fragile nature, Senate properties decided to realize the building project in accordance with strict energy- and ecological requirements. In addition, the environment as a part of Sámi culture adapted centuries with surrounding nature sets special demands for the project. During the seasons the dormitory is occupied by students and in summer times it can be used as summer hostel. Consequently, Senate properties decided to implement the project by using special commissioning procedures, in co-operation with VTT Technical Research Centre of Finland and subcontractors. This means systematic verification of the key performance indicators and owner´s project requirements in each stage of the building process.

Figure 1. Location of Inari community (source: Discovering Finland)

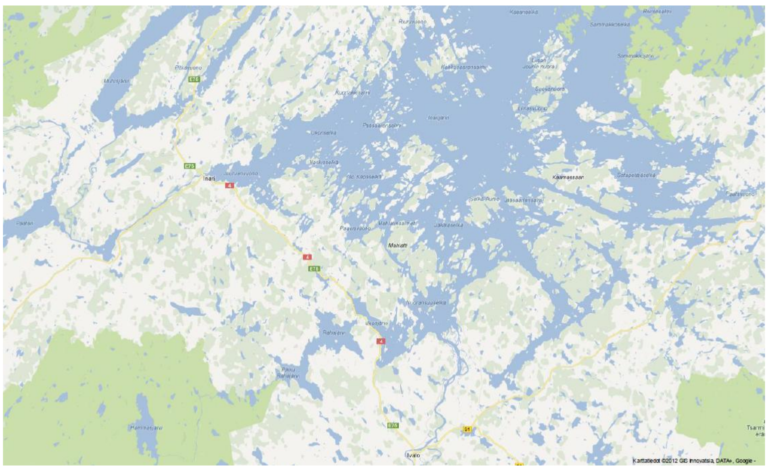

Figure 2. Lake Inari area (source: Google Maps)

In this paper we present the set requirements and different stages from pre-design phase to the construction stage. The building is due to be completed in 2013. The main idea of the paper is, anyway, to introduce requirements for energy, Eco technical efficiency and performance, as well as the design procedure and quality control steps to confirm the imposed goals. The HVAC-system will be based on geothermal heat pumps, but also solar panels and wind turbine will be installed. Insulation of the building envelope will be better than required. A special attention will also be paid to air-tightness. The building will be equipped with a detailed metering and control system in order to control the performance on-line. The nearby education center is heated by oil burner, and in the same connection the heating system of that building will also be renewed.

This kind of solution is very rare especially so in northern region in Finland. The goal of the contractor´s premises was to have an energy- and eco-efficient building equipped with an advanced monitoring and metering installation. The purpose of the extensive metering is 1) to verify the performance of the building (as designed) and 2) to be “a showcase” for possible similar buildings in the future. Because of a unique type of project there are no other reference buildings in the area or in the region available. The contractor´s aim is that a neutral research organization will verify the performance of the building. Due to the type of the contract, there was no possibility to study extensively other possible cases in semi-arctic region.

The implementation of the project has delayed compared with the original schedule, so no results are not in use at the moment.

2. Thermal conditions in the region

2.1 Background information

The municipality of Inari is the largest one in Finland (2012), area > 15 000 km^2. The water area is > 2000 km^2, of which the share of Lake Inari is approximately the half of it. The population of Inari is 6700 (31.12.2011) [3]. Inari is one of the strongest tourist areas in Lapland.

2.2 Thermal seasons

Thermal seasons [4] are determined on the grounds of daily mean temperatures. In Finland the longest thermal season is winter and the spring is the shortest. The change of thermal season is defined as follows:

- Spring begins when the daily mean temperature exceeds constantly > 0 °C
- Summer begins when the daily mean temperature exceeds constantly > + 10 °C
- Autumn begins when the daily mean temperature lowers constantly < +10 °C
- Winter begins when the daily mean temperature lowers constantly < 0 °C

In Finland the mean temperature may vary on both sides of the limits and the exact moment of the season is not always unambiguous. Nowadays the change of thermal seasons is based on the heat summation calculated of previous weeks/month. Traditionally, the winter begins when the average day temperature decreases constantly below 0 °C. For instance, winter begins from the next day, when the sum of mean temperatures, calculated from the beginning of September, reaches its highest value. Then one can see that temperature is constantly below zero even in single days the temperature could be above zero degrees. Winter started in Inari 17.11.2012.

2.3 Vegetation zones

Inari-area belongs to slow-growing forests zone [4]. In this north-boreal area the forests are sparse, slow growing and renewable only in the best summers (figure 3) [4].

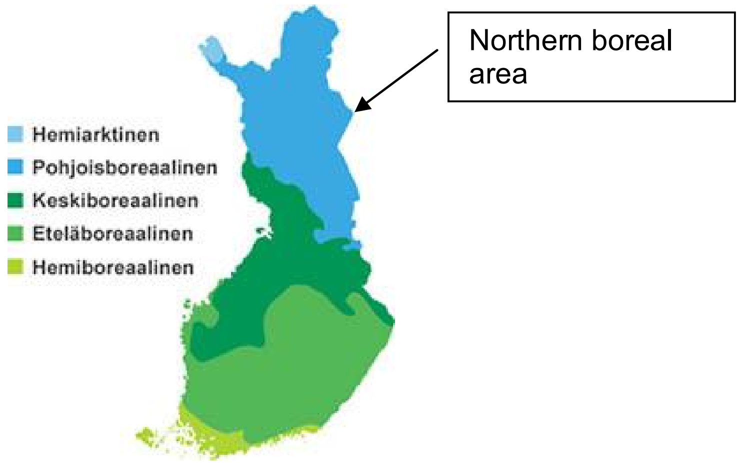

Figure 3. Vegetation zones

2.4 Building stock

The building stock in Inari region has mainly built after the war period and it is relatively new. There is nothing exceptional to build in northern areas of Finland; only outdoor temperatures have to be taken into account in the design criteria. There are not so many buildings in the community, anyway, which has been design based on sustainability and very high energy efficiency. Climate conditions due to the open lake and northern location will set some challenges for design, or, one must be very careful in planning details in order to meet set requirements.

According to the statistics of Association of Finnish local and regional Authorities [5], the volume of public building stock in Inari municipality is 136 500 m^3 (18 buildings), the average heating energy consumption is 53,4 kWh/m^3 and weather corrected consumption 45,2 kWh/m^3. The consumption of electricity is 17, 8 kWh/m^3 and water 118, 3 l/m^3. Savings of 5 % in energy consumption would mean 19 900 €/year and reduction of 2, 2 tons of CO_2.

3. General planning principles

3.1 Design intents

Finland has divided into 4 weather zones in terms of energy use in building design (figure 4) [6]. Inari region belongs to the zone IV. The monthly mean outdoor temperatures and sun radiation energies are based on four weather stations and on the test year 1979, the reference weather station for zone IV is in Sodankylä, south from Inari community. The normalized heating needs value based on degree days S17 is used by comparing the heating need with the heating need to other years or locations. Table 1 shows the weather data in weather zone IV (Sodankylä 1979). The heating need value for the whole year (used in calculations) is in zone IV 6317, when it is in zone I (e.g. in Helsinki) 4447. In case of Inari, the heating need values (degree days number) will be calculated using the local weather and heating need data which are represented in public sources.

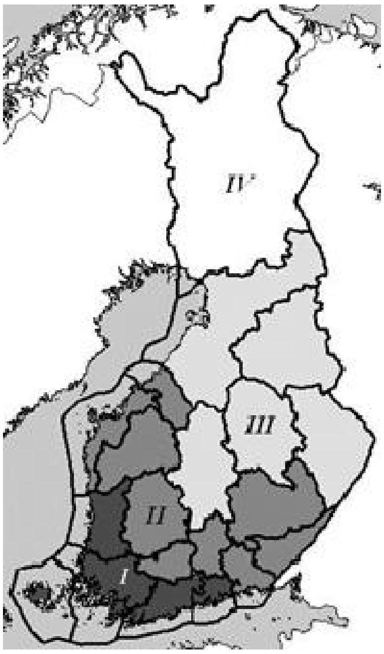

Figure 4. Weather zones for construction design

Table 1	Weather data	Sodankylä observation site	
	Zone IV	The total radiation energy of the sun, Grad, horizontal plane	Heating need value for normalizing the data
Month	Mean outdoor temp. °C	kWh/m²	S17, Kd
January	-18,3	1,5	1 094
February	-14,9	11,1	893
March	-7,03	43,8	745
April	-3,62	97,7	619
May	5,79	130,1	315
June	12,2	143,2	62
July	14,7	157,8	24
August	12,6	103,6	111
September	6,25	48,5	323
October	-3,1	19,7	623
March	-5,44	3,1	673
December	-9,97	0,3	836
Whole year	0,81	760	6 317

Table 1. Weather data used in energy calculations and design

3.2. Eco-efficient goals of the project

The goal of the construction project was to design and build an eco-efficient accommodation building in cold climate area, in Inari Finland. Additional focus of the building project was on energy efficiency and performance by pursuing passive house efficiency. Also life-cycle economy viewpoint for the entire project was adapted to guideline the planning process. The design complied with the Finnish building code regulations and guidelines. Passive house energy efficiency goals were set to as follows:

- E- ratio target value for purchased energy < 140 kWh / m^2,a (space program)
- Demand for heating energy < 30 kWh / m^2
- Demand for specific fan power for AHU < 2,0 kW/ m^3/s, (SFP-ratio)
- Annual heat recovery efficiency of AHU > 70 %
- Indoor conditions class S3
- CO_2 maximum value 1200 ppm in living rooms

Indoor classification is set according to indoor air classification ranges in Finland. S3 is the best range.

3.3. Method (process to achieve the goals)

During the planning phase analysis of eco efficiency and performance were made as performed and different solutions for fulfilling the objectives set by the client were evaluated. Already at the beginning of the project it was told to the whole design team that after the construction verification measurements will be used to evaluate the implementation.

In the design phase the life-cycle related guidance containing renovations and replacements, maintenance and energy efficiency was given to the designers. In the structural engineering attention was paid to placing the building services and to preparing for changing of HVAC equipment and piping (openings, enclosures etc. to facilitate operations) from the viewpoint of maintenance, repair and replacements. In the building envelope design phase the goal was to avoid high windows in low energy houses – to avoid the feeling of draft, to pay attention to routings and spaces for building services in order to avoid feed-through connections in the envelope and to reserve enough space for renovation of the building services. Also the goal was to avoid feed-through connections in electricity and ICT wirings.

The main focus was in selecting the energy supply and building services. Geothermal heating was selected as the main renewable energy sources after comparison it to pellet energy since pellet is unfavorable in low consumptions. In dimensioning of the geothermal energy 100% capacity was used instead of usually used 80 %. Boiler dimensioning and control, prevention of boiling and need for solar thermal collectors were also considered as were the use of photovoltaic panels and wind generator. Attention was also drawn to access to power grid and how to arrange power generation possibilities when disconnected. It was also realized if basic consumption is low then the investment payback time is longer.

3.4. Simulations

The main idea in building services is demand controlled operation (presence information) based on CO_2, temperature and humidity contents. Need for displays and controls in rooms, sub metering for lighting, air conditioning and water were seen important from the viewpoint of consumption. Five design cases were simulated with IDA Indoor Climate Energy simulator, namely:

- Accommodation according to Finnish Building Codes, parts D3/D5 (dealing with air exchange and energy efficiency, 2012) airflow and other regulations
- Apartment house airflows, loads and other regulations
- Reduced lightning energy consumption (LED)
- Reduced effect of structural cold bridges to one third according to the instructions as well as other system losses
- Target calculated including all changes by using Helsinki weather

Simulations showed that planning and implementation of air conditioning and equipment is crucial because of high energy consumption due to air flows in accommodations. If apartment house specifications are applied instead of accommodation ones the consumption falls to less than half. The same is also true with respect to the energy required by the illumination. Significant savings can be achieved with demand controlled ventilation and lighting. As a result energy consumption exceeds slightly the passive house consumption.

The challenge is that the passive energy level for the heating is difficult to achieve if the ventilation rate of accommodation buildings (dormitories belong to this category according to building code) is used. In real conditions it may be possible to use demand-controlled ventilation and hence decrease energy consumption.

3.5. Solutions

Focus was paid to large windows, feed-troughs, life-cycle viewpoint for renovations and replacements and verification by measuring the goals by giving a notice in the planning phase. It is important already from the beginning of the construction process to focus on eco efficiency, life-cycle use of the building and to verify the efficiency goals by measuring. Also it is important to pay attention to eco-efficiency from the structural engineering phase to avoid high windows and feed-through connections in the envelope especially in low energy houses. In the structural engineering attention has to be paid to placing the building services and to prepare for changing of HVAC equipment and piping (openings, enclosures etc. to facilitate operations) from the viewpoint of maintenance, repair and replacements. It is important also to reserve enough space for renovation of the building services. Also the goal was to avoid feed-through connections in electricity and ICT wirings.

As a result demand controlled lighting and air conditioning will be used (compare hotels). Part of lighting and electric sockets and room air conditioning will be connected to electric lock systems to switch them off when the occupant leaves and takes his/ her key card with. Building will also be equipped with information screen to show building energy consumption.

3.6. Planned measurements

3.6.1. Background

Indoor class 3 is accepted for indoor conditions. It means e.g.:

- Indoor air temperature in the summer +21 … +27 °C
- If mean outdoor temperature during 5 hrs. maximum period is higher than +20 °C, the indoor temperature can exceed it by 5 °C at most
- The air velocity in occupational zone in winter 0,19 m/s and in summer 0,3 m/s at most. During the boosted ventilation exceeding not more than +0, 1 m/s.
- Sound level of ventilation in the rooms must be not more than 28 dB (A). During the boosted ventilation exceeding not more than -10 dB compared with the reference value.
- Maximum concentration of carbon dioxide (CO_2) 1200 ppm in living rooms.
- The goal is the common automatism of electrical and HVAC-systems. The system must recognize the exceptional or wrong use of the building and prevent energy spending (e.g. open windows with simultaneous heating). By absence function one can switch off the ventilation in living rooms and control the temperature drops. The main goal is to create a developed and innovative system using the newest technology by reliable and energy-saving way.

Project will apply the Cx (building commission)-procedure (figure 5) [7]

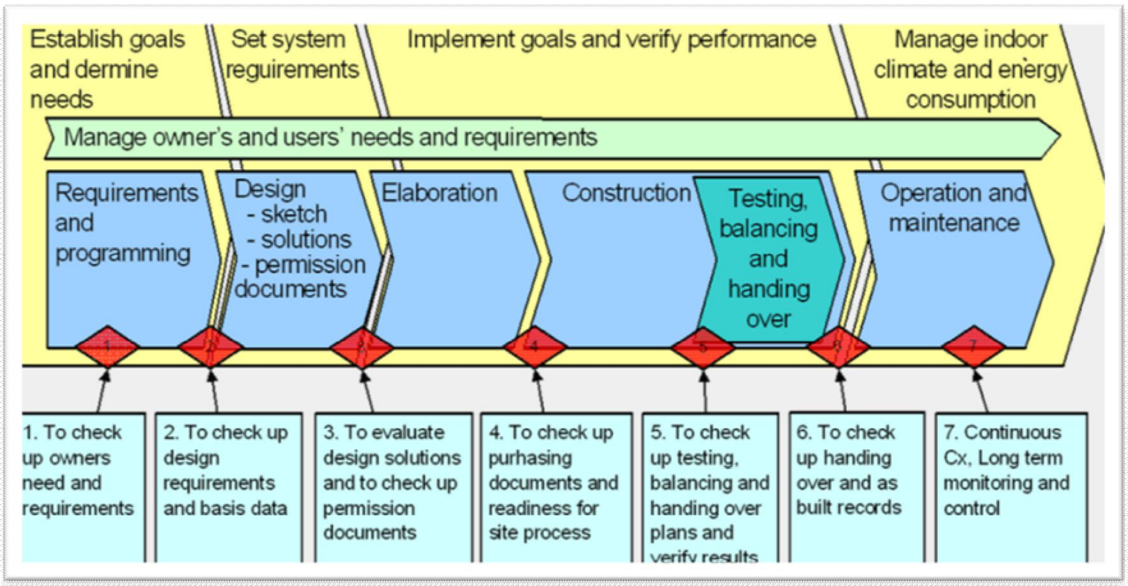

Figure 5. The schematic presentation of building commissioning procedure [7]

3.6.2. The aim of measurements

There are two main goals for the measurements:

1. To ensure the performance of the building and building systems and the proper use of them
2. To collect and analyze the data in that way that the performance of the building can be compared with the set requirements and goals

Except the basic instrumentation some additional fitted metering has been suggested (some of the measurements could be included in the basic instrumentation).

3.6.3. Structures

In customary solutions the temperatures of the structures are normally not measured. Because of pilot project, there is an opportunity to measure the soil temperature under frost protection (outside insulation) outside in both facades against the foundations. Also the corner temperatures in the joints of the wall and floor (inside) and across the wall structure (outside) can be measured. By these measurements one can see the real effect of thermal bridges and can also evaluate the heat flows from/to the ground. The local weather station to monitor outdoor temperature, wind speed and direction and relative humidity is suggested.

3.6.4. Indoor environment

The RH-concentration and CO_2-concentration of the exhaust air will be measured. Depending on the owners interest CO_2 could be measured also in some rooms. The indoor air temperature measurements belong to basic instrumentation.

Depending on HVAC-solution the exhaust air flows will be measured, too. The efficiency of heat exchanger (heat recovery) is a necessary measurement. The measurements of main supplied air and exhaust air belong to basic instrumentation. The pressure conditions will be measured separately in the connection of balancing of ventilation system. Draft measurements will be carried out if there is a need to do so.

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3.6.5. Heating system

The heating energy consumption of ventilation, heating and hot water is measured separately. The instrumentation of heat pump will be realized according to manufacturer´s basic instrumentation model.

3.6.6. Electricity

The electricity used by ventilation, heating system and lighting will be separately measured. The total consumption of electricity covers besides electricity consumed by ventilation, heating and lighting also other objects of use – the difference tells the distribution of other use. The consumption measurement of electricity should be realized in that way, that the evaluation of daily distribution of electricity consumption would be possible (an hourly average value is too sparse).

3.6.7. Building automation system and reporting

The realization of target values and key performance indicators (KPIs) will be verified by energy- and facility management software, which is based on the installed metering. The reporting model will be created separately. The orderer will determine the factors presented in reporting. The goal is a reporting system which serves users, owner and other stakeholders.

4. Lessons learned

It is important already from the beginning of the construction process to focus on eco efficiency, and life-cycle use of the building and to verify the efficiency goals by measuring. Make clear already in the design phase the goals and keep focus all the time on those goals. By running comparing design solutions in the simulator impact can be demonstrated clearly. Continuous focus on design goals resulted in several changes compared to ordinary design practices used. It was rather evident that passive house target and its verification by measurements caused a bigger rise in costs than it was expected. It must emphasize that the commissioning procedure should be started from pre-design phase and verify the owner´s project requirements in each stage very strictly, because in recent projects there are many subcontractors and actors, and in normal daily routine work the goals can stay for a secondary position for instance because of generally used technical solutions.

5. The recent stage of the project

The construction works are now in the skeleton stage. The builder is waiting the permission for ground heat pump system and acceptance for wind turbine. According to the original schedule the building should have been completed in the turn of 2012-2013 and the first measurements should be done in the spring season 2013. As a summary of the recent stage one can say:

- Rise in costs resulted in cost cuttings and delays.
- Finalizing of the planning still going on.
- Delay in construction close to one year.

This situation is not so unusual, especially if it is question about a little bit diverging projects compared with business-as-usual-type building projects. Also the requirements in proportion to the budget frame will cause some limitations.

6. Conclusions

The preliminary set requirements are not very different compared with the ongoing and planned passive house/near zero energy building projects. Special attention has been paid the performance of the building envelope, thermal bridges and air tightness which is also communicated to the design team. The structural details needed must be shown also in the working site and be presented in site meetings; even they are described in the design documents.

As a result of demand controlled lighting and air conditioning will be used (compare hotels). Part of lighting and electric sockets and room air conditioning will be connected to electric lock systems to switch them off when the occupant leaves and takes his/ her key card with. Building will also be equipped with information screen to show building energy consumption.

The systematic commissioning approach will be used during the building project. Cx (building commissioning)-procedure should ensure that the building performance and indoor conditions are "as designed".

References

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