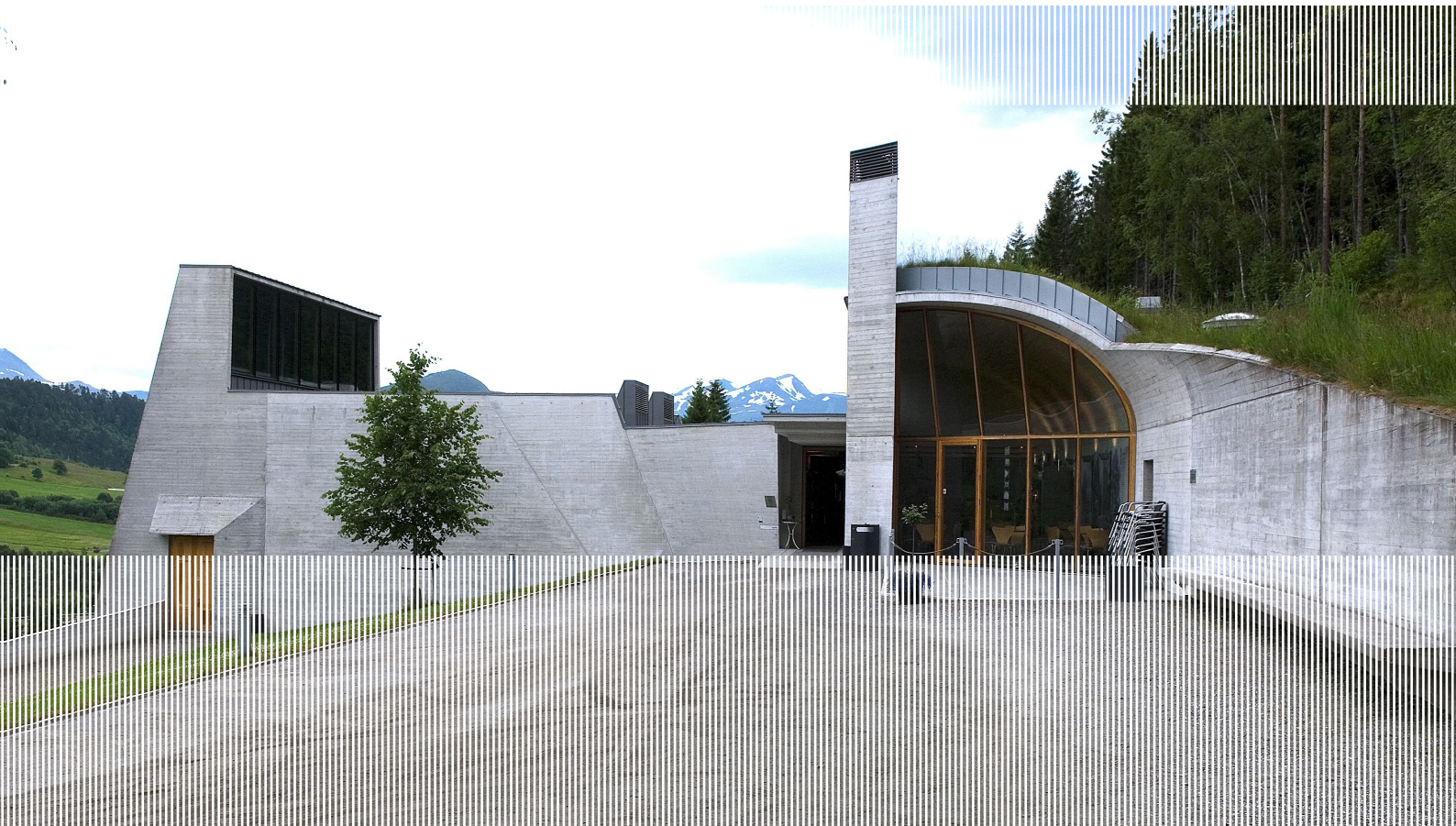


SINTEF Building and Infrastructure Catherine Grini

# Post-occupancy evaluation of a recent energy efficient office building

COIN Project report 30 – 2011



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FA 1 Environmentally friendly concrete

SP Insulating and energy preserving concrete

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## Preface

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This study has been carried out within COIN - Concrete Innovation Centre - one of presently 14 Centres for Research based Innovation (CRI), which is an initiative by the Research Council of Norway. The main objective for the CRIs is to enhance the capability of the business sector to innovate by focusing on long-term research based on forging close alliances between research-intensive enterprises and prominent research groups.

The vision of COIN is creation of more attractive concrete buildings and constructions. Attractiveness implies aesthetics, functionality, sustainability, energy efficiency, indoor climate, industrialized construction, improved work environment, and cost efficiency during the whole service life. The primary goal is to fulfil this vision by bringing the development a major leap forward by more fundamental understanding of the mechanisms in order to develop advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.

The corporate partners are leading multinational companies in the cement and building industry and the aim of COIN is to increase their value creation and strengthen their research activities in Norway. Our over-all ambition is to establish COIN as the display window for concrete innovation in Europe.

About 25 researchers from SINTEF (host), the Norwegian University of Science and Technology - NTNU (research partner) and industry partners, 15 - 20 PhD-students, 5 - 10 MSc-students every year and a number of international guest researchers, work on presently eight projects in three focus areas:

- Environmentally friendly concrete
- Economically competitive construction
- Aesthetic and technical performance

COIN has presently a budget of NOK 200 mill over 8 years (from 2007), and is financed by the Research Council of Norway (approx. 40 %), industrial partners (approx 45 %) and by SINTEF Building and Infrastructure and NTNU (in all approx 15 %).

For more information, see [www.coinweb.no](http://www.coinweb.no)

Tor Arne Hammer  
Centre Manager

## Summary

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This report is a post-occupancy evaluation of a recent energy efficient building. The building is located in Professor Brochs gate 2, in the city of Trondheim, the third largest Norwegian municipality. The building was erected in 2008-2009 and got partially moved in during September 2009. The building owner, KLP Eiendom, wanted to build an energy efficient office building. A target of 86 kWh/m<sup>2</sup>-yr for delivered energy (all electrical appliances included) was defined during the design stage. Among all energy efficient measures that have been taken, one consists of using fair-faced concrete ceilings instead of suspended ceilings to take advantage of the concrete's thermal inertia. The objective of the post-occupancy evaluation is to verify the energy target, to quantify the users' satisfaction rating and to get feedback on the use of fair-faced concrete ceilings.

Real conditions for operation differ often from the ones defined during the design stage. In our case, the main difference concerns the occupancy level of the whole building. The office building was put to use in September 2009 but wasn't rent in its entirety at that time. Some areas get rent in the course of 2010, others are not moved in yet. The real demand for delivered energy is then difficult to compare with the target, but is definitely lower than in newly built office buildings without focus on energy efficiency. There is no use of local cooling in the office areas of the building. The temperature isn't experienced too hot during summer, showing that carefully designed internal gains and controlled solar gains can be eliminated by ventilation cooling. The users' survey shows that a majority of the respondents experience too low indoor air temperature during summer. The users judge favourably the design of the ceiling, with fair-faced concrete slab and hanging acoustic insulation panels. After only 16 months of occupancy and a regular moving in of new tenants, the technical installations are not optimal operated yet, especially those producing cooling and distributing heating.

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## 1 Background

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The objective of this study is to analyse a recent energy efficient building after 16 months of use. The building is located in Professor Brochs gate 2, in the city of Trondheim, the third largest Norwegian municipality. The building was erected in 2008-2009 and got partially moved in during September 2009.

The building owner, KLP Eiendom, wanted to build an energy efficient office building. A target of 86kWh/m<sup>2</sup>·yr for delivered energy (all electrical appliances included) was defined during the design stage.

Among energy efficient measures that have been taken, one consists of using fair-faced concrete ceilings instead of suspended ceilings to take advantage of the concrete's thermal inertia. See photo 1. The building get then affiliated to COIN and became part of the pilot buildings in the focus area 1.2 *Utilisation of concrete in low energy building concepts*.

The post-occupancy evaluation has three goals:

1. to verify the energy target
2. to quantify the users' satisfaction rating
3. to get feedback on the use of fair-faced concrete ceilings



Photo 1. Office building in Prof. Brochs gt. 2 - Open space office area on the third floor, with fair-faced concrete ceilings, hanging acoustic boards and fair-faced concrete pillars (Photo: SINTEF Byggforsk)



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## 2 Method

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### 2.1 Energy target

#### 2.1.1 Energy demand budget

The energy demand budget has been calculated by SINTEF Building and Infrastructure at different stages of the building process. The latest calculation was performed in August 2009 after the completion of the building and with available results from the air-tightness measurement.

The energy budget calculated by SINTEF consists of eight budget items, as defined in the Norwegian Standard NS 3031:2007 *Calculation of energy performance of buildings – Method and data*. All calculations were performed with the Norwegian simulation tool SIMIEN which is validated according to the requirements defined in NS 3031:2007. The energy demand budget has been calculated with climatological data for Trondheim available in SIMIEN.

The result of the latest calculation could be used as reference when comparing the real energy consumption with the energy budget. Since the comparison is only based on one year and since the meteorological observations for the year 2010 (<http://eklima.met.no>) reveal significant differences between the observed temperatures and the normal temperatures available in SIMIEN, it has been necessary to rerun the latest calculation with real temperatures in order to ensure a valid comparison.

#### 2.1.2 Energy demand logging

The office building located in Professor Brochs gate 2 in Trondheim contains 61 private meters registering the electrical energy demand and 7 private meters registering the thermal energy demand, as well as one electrical and one thermal meter from the energy suppliers. All meters are connected to the energy demand logging from Entro. The logging has a web-based interface that is available via Internet (<http://www.entro.no>). The meters send time value to the logging. All registered time values since the building was put to use in September 2009 are saved in Entro's logging.

All figures showing energy demand in this report have been downloaded from Entro's logging, if any other information is mentioned.

Thunderstorm in Trondheim on August 6<sup>th</sup>, 2010 caused power failure in many areas of the city. The power failure results in an interruption of the communication between the building's private meters and Entro's logging. The data transmission got interrupted for two months, from August 6<sup>th</sup>, 2010 to October 6<sup>th</sup>, 2010. Another interruption occurred on December 2<sup>nd</sup>, 2010 and lasted until December 15<sup>th</sup>, 2010. Entro's logging comprises nine and half months of registering for 2010. The missing data have been stipulated by interpolation of the registered consumptions. For electrical meters, the average monthly consumption resulting from the nine and half months of registering has been multiplied by twelve months. For thermal meters, the consumption registered during the months/ days with similar outdoor air temperature has been used for the periods missing registering. The total consumption has also been controlled and corrected in accordance with the registrations performed by the energy suppliers.

In order to verify the energy target, the registration of the different meters has been summarized by energy item. Each item in the calculated energy budget has then been compared with its corresponding registering from Entro's logging for the year 2010. Since new tenants moved in at different time of the year 2010, the occupancy of the building and

the total heated area varied over the year. For that reason, the comparison is based on the absolute figures (kWh/yr), and not on specific ones (kWh/m<sup>2</sup>·yr).

The building is equipped with a Building Management System (BMS), a computer-based control system that controls, monitors and allows optimization of the building's mechanical and electrical equipment. In the present building, the BMS includes heating, cooling, ventilation, lighting and fire systems. It gives also the possibility to have instantaneous information on occupancy, room air temperature and supply ventilation volume for each room in the whole building.

## **2.2 Users' satisfaction**

Users' satisfaction has been rated by the mean of a questionnaires survey among users of the 3<sup>rd</sup> and 4<sup>th</sup> floor. The questionnaire, as presented for the users, is available in Appendix 2 (Norwegian).

The survey assesses the following issues relative to the indoor environment quality:

- Thermal comfort
- Indoor air quality
- Acoustics
- Lighting

The questionnaire has been distributed to all employees of Enova and Sweco Norge AS, the two companies renting respectively the 3<sup>rd</sup> and 4<sup>th</sup> floor. The questionnaire has been distributed and collected through internal post. The survey has been achieved at the end of August 2010 for the 4<sup>th</sup> floor (Sweco) and at the beginning of September 2010 for the 3<sup>rd</sup> floor (Enova). At the time the survey got realized, the users have experienced one winter and one summer in the new building.

The answering rate is approximately 45% and 55% for respectively Sweco and Enova. The results from the survey should then be interpreted warily.

The reason why the answering rate isn't higher is unknown. Some persons may be uninterested, or satisfied, by the office where they work, and don't find any reason to fill in the questionnaire. Others may be critical to the survey. They don't expect that it brings any changes or ameliorations, and found it useless. It is impossible to know to what extent the users that didn't answer are satisfied with the indoor environment quality of the building.

In order to have a quantitative reference when reading the results from the survey, a complementary registration of the indoor air temperature and relative humidity was performed during one month (from August 11<sup>th</sup>, to September 7<sup>th</sup> 2010).

## **2.3 Feedback on the use of fair-faced concrete ceilings**

### **2.3.1 Monitoring of temperature variation in the concrete slab**

The temperature in the concrete slab (ceiling) has been registered in two open space office areas on the 3<sup>rd</sup> floor. Two temperature sensors are mounted in the room 3.036. The first is on the edge of the slab, the other is placed inside the slab, two centimeters from the edge. In the room 3.259, both temperature sensors are mounted inside the slab, respectively two and four centimeters from the edge. All temperature sensors have been placed in a hole in the concrete slab. The holes were made only for this purpose. The slab got pierced, the temperature sensors were placed and the holes were filled again with a high thermal conductive mortar. The registering is based on a 6-minutes interval and started in September 2009. It is available from the Building Management System.

The temperature sensors require calibration after installation to guarantee the exactitude of the measurements (personal communication with Knut Ivar Grue, Gunnar Karlsen). The calibration of the temperature sensors has unfortunately not been done at the time of writing, making difficult to interpret the registered values.

### **2.3.2 Users' satisfaction questionnaire**

The questionnaire includes several questions about acoustics and one question about the aesthetic appearance of the ceiling.

### 3 Results

#### 3.1 Energy target

##### 3.1.1 Total energy demand

Table 1 consists of three columns. The first one shows the energy target calculated in August 2009. The second column shows how the results of the simulation performed in August 2009 vary when the normal outdoor temperatures available in SIMIEN are replaced by the meteorological observations for 2010. The third column shows the registered energy use. The measured values correspond to the registration performed by the energy supplier's meters.

*Table 1. Energy target as simulated in August 2009, temperature correction of the energy target and energy registration by the energy supplier for the whole year 2010. All figures refer to delivered energy as defined in NS3031:2007.*

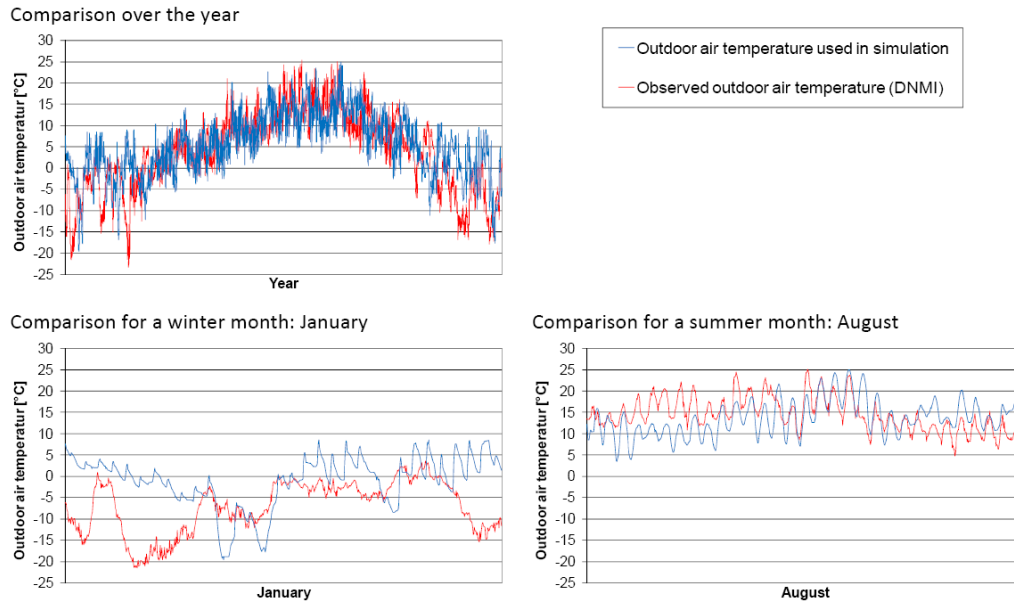
	Latest calculation August 2009	Latest calculation, temperature corrected	Measurement by energy suppliers Year 2010
Electricity [kWh/yr]	922 897	955 188	899 661
Heating <sup>1)</sup> [kWh/yr]	170 353	238 383	602 851
Total [kWh/yr]	1 093 250	1 193 571	1 502 512
Total [kWh/yr.m <sup>2</sup> ]	86	93	Not relevant (building only partially moved in)

<sup>1)</sup> Heating includes room heating, ventilation heating and heating of hot water.

The meteorological observations registered by the Norwegian Meteorological Institute, DNMI, show that outdoor temperature in Trondheim in 2010 differs substantially from SIMIEN's normal temperature for the same location. Winter and summer temperatures were respectively lower and higher than normal. See Figure 1.

The simulation based on observed meteorological data has a total energy demand that is about 100 000 kWh/yr (  $\approx 9\%$  ) higher than the latest calculation based on normal climatological data. Both electricity and heating demand increase when using the real outdoor temperatures instead of normal temperatures. The electricity demand increases by approximately 32 000 kWh/yr. This is due to the fact that electricity demand includes among other things electricity to operate cooling machines, pumps and ventilation fans, all depending on outdoor temperature. The heating demand goes up by approximately 68 000 kWh/yr (  $\approx 40\%$  ), when using real outdoor temperatures instead of normal temperatures. The augmentation of the heating demand points out that winter months in 2010 have had much cooler temperatures than the normal used by SIMIEN for the city of Trondheim. It looks like the normal temperatures used by SIMIEN differ both from the observations in 2010 and from the normal defined by the Norwegian Meteorological Institute. Standardized climatological data to use for the calculation of buildings' energy performance exist only for the city of Oslo (NS 3031:2007). It should be interesting to compare the climatological data available in SIMIEN with observations made by the Norwegian Meteorological Institute in order to validate them and permit refined simulation results in the future, but the topic is out of our scope.

Figure 1. Outdoor air temperature, comparison of the temperatures used in simulation (City of Trondheim in SIMIENS' database) with the observations made by the Norwegian Meteorological Institute DNMI in 2010.



When comparing the temperature corrected calculation with the measurement, the real total energy demand is around 300 000 kWh/yr ( $\approx 26\%$ ) higher than calculated. When regarding only the use of electricity during 2010, the figure from the simulation is lower than the measured one and differ by approximately 55 500 kWh/yr ( $\approx 6\%$ ). Regarding the heating demand, the real consumption is almost three times bigger than simulated.

The comparison is quiet rough, but it already points out two moments:

- The total energy demand is about 26% higher than calculated, despite the fact that the simulation is based on a full-occupied building, while the building was not entirely in use in 2010.
- The real heating demand is much higher than calculated, even after outdoor temperature correction.

### 3.1.2 Energy demand by energy item

A more refined comparison, considering each energy item, is shown in table 2.

Table 2 reveals highest divergence between calculation and measurement for the following energy items, ranged by order of importance:

- Cooling
- Room heating
- Electrical equipment
- Fans

Table 2. Comparison of calculated and measured energy demand. The simulation performed in 2009 are temperature corrected according to the meteorological data recorded in 2010. All figures refer to delivered energy as defined in NS3031:2007.

Energy item	Latest calculation, temperature corrected [kWh/yr]	Measurement by energy item – private meters [kWh/yr]
1.Room heating	93 038	385 257
2.Ventilation heating	142 923	171 487
3.Hot water	68 980	46 305
4.Fans	157 188	79 985
5.Pumps	14 921	18 575
6.Lighting	283 640	294 355
7.Electrical equipment <i>divided in 4 sub-items</i>	417 067	286 073
<i>Electrical appliances</i>		190 352
<i>Electrical cars</i>		996
<i>Data servers</i>		89 954
<i>Elevators</i>		4 771
8.Cooling <i>divided in 2 sub-items</i>	15 816	219 119
<i>Room cooling</i>	844	
<i>Ventilation cooling</i>	14 972	
Total <sup>1)</sup>	1 193 571	1 501 156

1) The total from the private meters is not exactly equal to the registration done by the energy suppliers as shown in table 1. Figures in table 2 have been stipulated to compensate for missing data, as explained in paragraph 2.1.2. The extrapolation based on existing data explains the marginal difference between totals in table 1 and table 2.

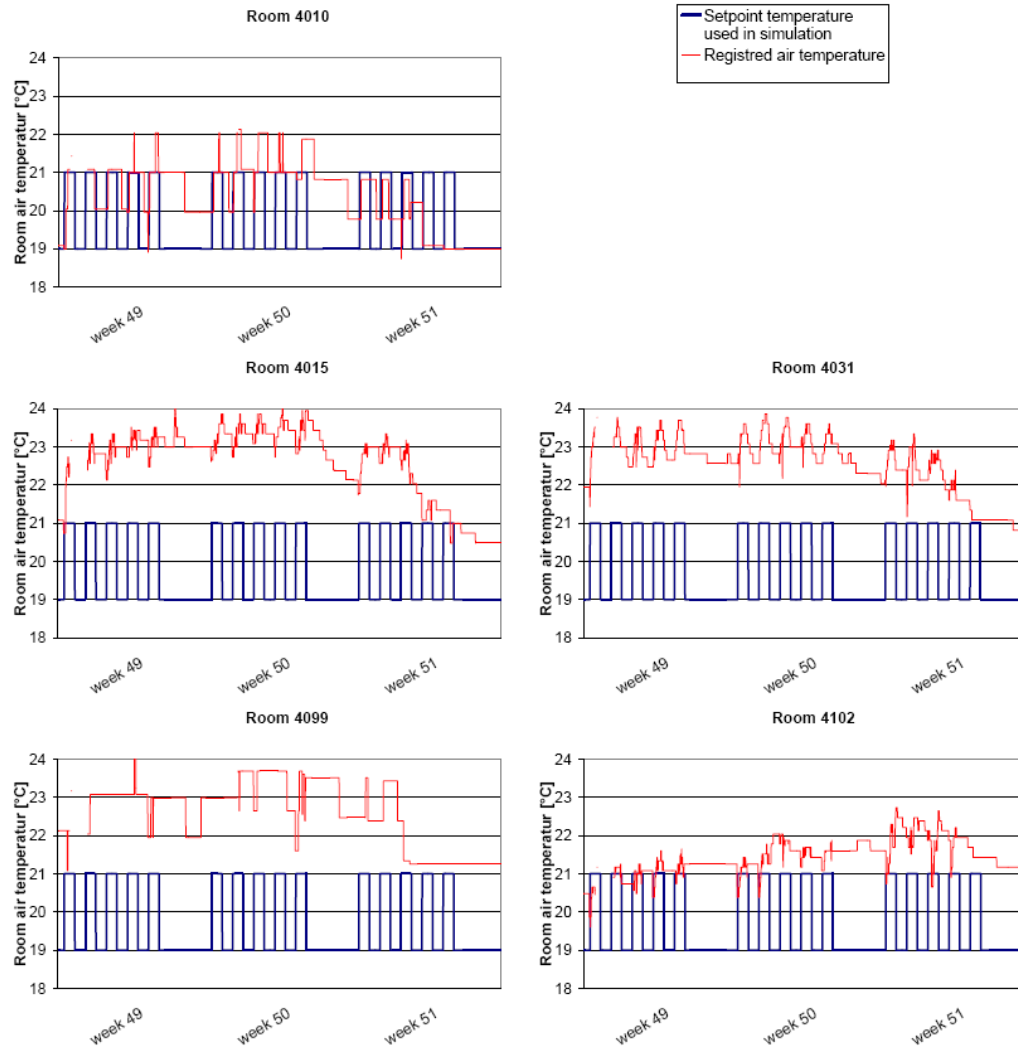
Comments on the difference between the calculation and the measurement are made by energy item in separate tables on the following pages.

Each item is commented separately with indication of the difference between the calculated and measured energy use. Comments explaining differences are based on cross-comparison between the different energy items and on registrations available in the Building Management System.

Table 3. Item 1, room heating

<b>Item 1. Room heating</b>
<b>Difference</b> +414%
<p><b>Comments</b></p> <p>The heating demand is the most important measured energy item. It counts for about 25% of the total measured energy demand. Even after temperature correction, the gap between the simulated and the measured value stays extremely large.</p> <p>There are four reasons that explain the difference:</p> <ol style="list-style-type: none"> <li>1. Internal gains, i.e. lighting and electrical equipment                     <p>When the internal gains go down, the heating demand goes up. The internal gains considered in the simulation are much higher than the real ones. The measurements show that the energy use for electrical equipment is lower than half of the value used in calculation. The energy use for lighting is also lower than calculated in certain areas. See Table 2, and comments in table 8 and 9. The low internal gains are partially due to the low occupancy rate of the building, but also to the use of energy efficient lighting and computers. Another relevant issue is related to the fact that internal gains are considered as an average over the whole building area in the simulation, but will in reality occur locally and influence the energy balance locally. The heating demand became 184 363 kWh/yr when recalculated with real internal gains.</p> </li> <li>2. Setpoint temperature for heating wintertime                     <p>The setpoint temperature for heating seems to be higher in real life than the value used in the calculation. The simulation was performed with setpoint temperatures like 21°C during the day and 19°C at night and during week-ends. The setpoint temperature is in reality continuously calculated by the Building Management System, depending on the exhaust air temperature and the occupancy of the room. The room air temperature recorded for five rooms on the 4<sup>th</sup> floor show indoor air temperature wintertime varying from 21°C to 24°C during the day and from 19°C to 23°C during the night. See Figure 2. Regarding the registered values on the 4th floor, it may be a better assumption to use an average setpoint temperature equal to 22°C during the day and 21°C at night in the simulation. The heating demand became 316 623 kWh/yr when recalculated with real internal gains and corrected setpoint temperature.</p> </li> <li>3. Summer operation                     <p>According to the simulation, there is no heating demand during the five summer months: May, Juni, July, August and September. For the same period, the energy demand logging registered around 50 000 kWh for heating purpose in connection with radiators. See Figure 3. The Building Management System confirms this fact. The registration of the status for the circulation pump show that the pump is switch on each night in summer. See Figure 4. The heating demand became approximately 366 500 kWh/yr when recalculated with real internal gains, corrected setpoint temperature for heating and no energy demand during summer, quiet close to the measured value of 385 257 kWh/yr.</p> </li> <li>4. Energy efficiency of heating system                     <p>It is assumed that the entire room heating demand is covered by district heating, with a supposed energy efficiency of 88% according to NS3031 (88% energy efficiency correspond to 12% losses in the system). The energy efficiency includes heat losses from the heat exchanger, from non-insulated distribution pipes and non-optimal regulation, and may in reality be poorer than assumed.</p> </li> </ol> <p>It may be inadequate to make any change with internal gains and with the setpoint temperature for heating during the occupancy time. Low internal gains have a positive effect on energy efficient buildings and have to stay as low as possible. The setpoint temperature is often decided by the end-user, depending on their expectation of acceptable thermal comfort. Nevertheless it should be possible to change the setpoint temperature for heating at night and it seems necessary to shut down all radiators during the summer months. An energy use of 50 000 kWh (summer consumption in 2010) represents 3,33% of the total measured energy demand for the whole building. The logging shows that the radiant floor heating circuit is shut down during the summer months. The radiator circuit should be shut down as well.</p>

Figure 2. Registered air temperature in five rooms on the 4<sup>th</sup> floor in December 2010 (week 49, 50 and 51)

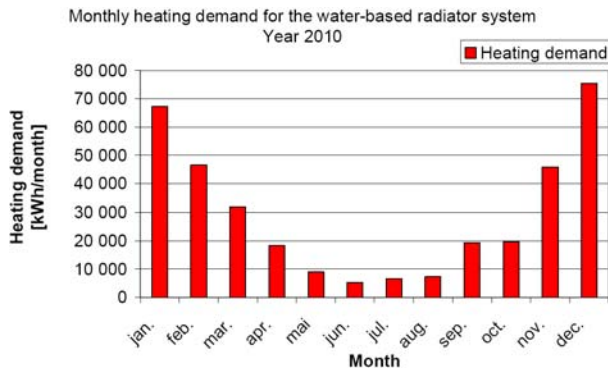


Thermal comfort is a question of personal feeling and preferences. The preferred room air temperature will vary from person to person, which is confirmed by the diagrams on Figure 2. The lowest room air temperatures are registered in room 4010, staying close to 21°C during working hours, down to 20°C at night and down to 19°C during week-ends/ holidays. The last weekday of week 51 in 2010 was Christmas Eve where usually office workers are on holidays. The highest room air temperatures are registered in rooms 4015, reaching 24°C during working hours and staying higher than 22.5 / 23°C at night. During holidays, the temperature falls to 20.5°C.

The calculated heating demand increase from 184 363 to 316 623 kWh/yr ( $\approx 72\%$ ) when the setpoint temperature for heating wintertime get corrected from 21°C during the day and 19°C at night to respectively 22°C and 21°C. This parameter has a major importance on the heating demand.

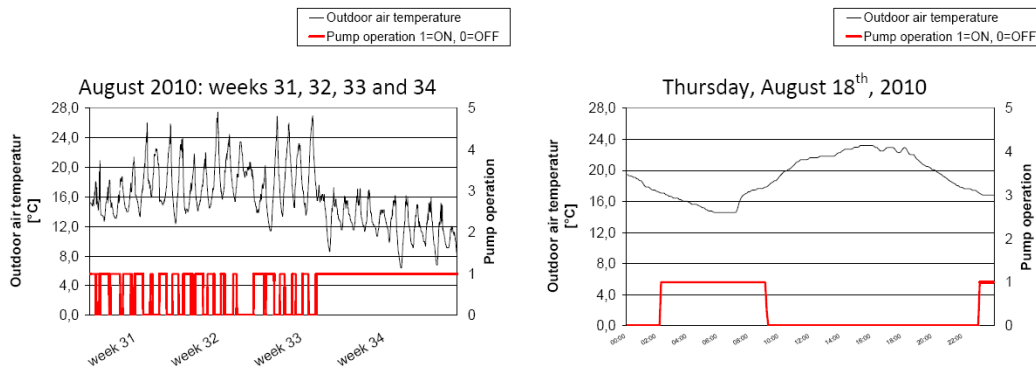


Figure 3. Monthly heating demand for the water-based radiator system during 2010, registered values from the energy demand logging



The profile of the heating demand for the water-based radiator system is typical for an office building located in Trondheim, with highest heating demand during the coldest winter months and lower heating demand when the outdoor air temperature increases. Figure 3 reveals a heating demand during all summer months. This demand shouldn't be necessary according to the insulation level of the building.

Figure 4. Operation of circulation pump in the water-based radiator system in correlation with the outdoor air temperature, overview for weeks 31 to 34 in August 2010 (figure on the left) and detailed figure for Thursday August 18<sup>th</sup>, 2010 (figure on the right)



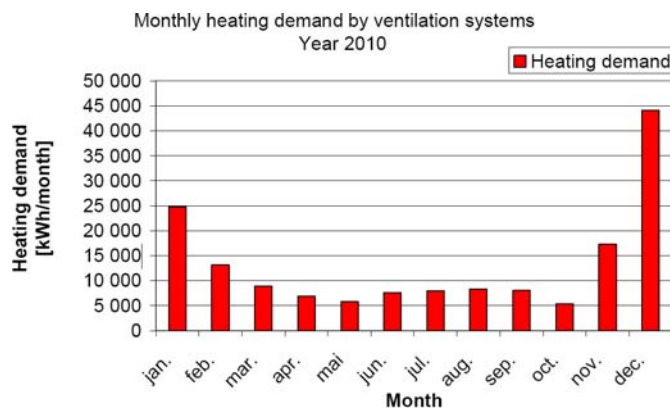
The circulation pump is always switched on during the week 34, even if the outdoor air temperature never falls under 6°C. The calculation is run with lower outdoor air temperature than observed for this week (see Figure 1, last week of August) and still don't reveal any heating demand for the period.

On Thursday, August 18<sup>th</sup>, 2010 the circulation pump got switch on at night when the outdoor air temperature passed under 17°C.

Table 4. Item 2, ventilation heating

<b>Item 2. Ventilation heating</b>
<b>Difference +20%</b>
<b>Comments</b>
<p>Ventilation heating is the fifth largest measured energy item. It tells for 11.4% of the whole energy demand in 2010.</p> <p>The measured energy demand for ventilation heating is 20% higher than the simulated value. Both values have the same order of magnitude and the difference is not alarming. Nevertheless, it should be noticed that the energy use for fan operation is lower than calculated, which means that it has been heated less air than expected and that the real ventilation heating demand per m<sup>3</sup> heated air is in fact more than 20% higher than calculated.</p> <p>The difference doesn't come from the inlet air setpoint temperature in the ventilation plant, which is assumed constant in the calculation (19°C during the winter, all day long) and is recorded to approximately the same value in the Building Management System.</p> <p>The energy demand logging shows a registered energy demand for ventilation heating equal to 29.672 kWh for the summer months (from May to August). See Figure 5. The registered ventilation heating for the other months (January to April + September to December) is equal to 141 815 kWh/yr and is close to calculated value of 142 923 kWh/yr.</p> <p>The energy source used for ventilation heating may also explain the difference between the calculated and the measured value. In the calculation, one third on the ventilation heating demand is covered by district heating, while two thirds are covered by the heat pump. The real ratio between the two energy sources may differ and the energy efficiency rates are probably poorer than assumed. Heat losses in the distribution circuit may be higher than calculated.</p> <p>The logging shows that the radiant floor heating circuit is shut down during the summer months. The ventilation heating circuit should be shut down as well. The heat recovery wheel in each ventilation plants is able to raise the inlet air temperature to the desired supply air temperature during those months.</p>

Figure 5. Monthly heating demand for all ventilation systems during 2010, registered values from the energy demand logging



The heating demand for the ventilation systems is almost constant from March to October, regardless of the outdoor air temperature. The heating demand during the hottest months of the year shouldn't be necessary.

Table 5. Item 3, hot water

<b>Item 3. Hot water</b>
<b>Difference</b> -33%
<p><b>Comments</b></p> <p>The measured energy demand for hot water is 33% lower than the simulated value. The simulated value is based on normalized assumption from NS 3031:2007. Demand for hot water varies greatly from office building to office building, depending on users habits (training, showering) and utilization of the canteen/kitchen and is difficult to assess during the design stage of a building. The difference is probably due to the fact that the building was only partially occupied during 2010.</p> <p>The heating demand for hot water is higher at the end of the year than at the beginning. The new tenants that moved in during the autumn 2010 influence the energy use related to hot water.</p>

Table 6. Item 4, fans

<b>Item 4. Fans</b>
<b>Difference</b> -49%
<p><b>Comments</b></p> <p>The measured energy demand for the fans is 49% lower than the simulated value.</p> <p>The building is partially occupied, which means that the ventilation fans don't need to run as much as simulated. All ventilation supply and exhaust devices in the whole building are using demand controlled ventilation. The operation of the demand controlled ventilation seems to work as well as planned.</p>

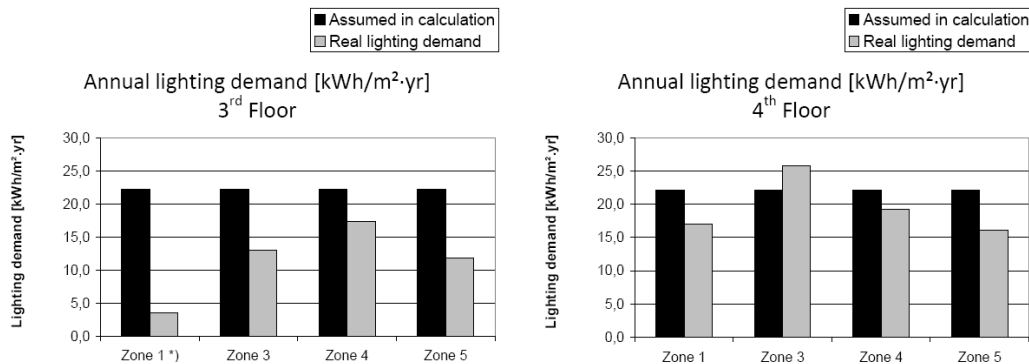
Table 7. Item 5, pumps

<b>Item 5. Pumps</b>
<b>Difference</b> +24%
<p><b>Comments</b></p> <p>The measured energy demand for the pumps is 24% higher than the simulated value.</p> <p>The simulated value is based on normalized assumption from NS 3031:2007 that are not detailed enough for different pump regulation principles or different types of pumps.</p>

Table 8. Item 6, lighting

Item 6. Lighting
<b>Difference +4%</b>
<p><b>Comments</b></p> <p>Lighting is the second largest measured energy item. It tells for 19.6% of the whole energy demand in 2010.</p> <p>The measured energy demand for lighting is 4% higher than the simulated value.</p> <p>The measurements vary greatly from floor to floor and from zone to zone. The measured value is lower than the value assumed in the calculation for true office areas (except for zone 3 on 4th floor). See Figure 6. The areas that are not moved in have unfortunately an electrical demand for lighting all year long, which shouldn't be necessary.</p> <p>The lighting demand on the first floor and on the basement (areas that are not dedicated to office functions, but used as canteen, meeting rooms, parking and technical rooms) represents 42% of the whole lighting demand. On the first floor, the lighting is always running, using 6kW continuously at night and during weekend. On the basement, a continuously power demand of 5kW is registered in the energy demand logging.</p> <p>The measured value in true office areas is in accordance with the occupancy rate of the building and much lower than the simulated one. It should be even lower since unused areas are partially lightened without any reason. The measured lighting consumptions on the first floor and on the basement are much higher than assumed. The lighting demand at night and during weekends seems unnecessary. The electrical lighting should be shut down in periods of unoccupancy.</p>

Figure 6. Annual lighting demand, comparison of the value assumed in calculation with the registered lighting demand. Comparison by zone for 3<sup>rd</sup> floor (left) and 4<sup>th</sup> floor (right).



\*) Zone 1 is not moved in.

Table 9. Item 7, electrical equipment

Item 7. Electrical equipment
<b>Difference -54%</b>
<p><b>Comments</b>                      Electrical equipment is the third largest measured energy item. It tells for 19% of the whole energy demand in 2010.</p> <p>The measured energy demand for electrical equipment is 54% lower than the simulated value, when considering only electrical equipment in the office areas.</p> <p>The measured value is lower than calculated, even after considering the reduced occupancy rate of the building. Some office areas are equipped with energy efficient appliances, which results in a lower annual energy demand for electrical appliances than assumed in the calculation. See Figure 7. The lower energy demand for electrical appliances in the office areas results in lower heat release from the appliances and higher demand for room heating.</p>
Item 7 + 7bis. Electrical cars / Data server / Elevators
<b>Difference -31%</b>
<p><b>Comments</b>                      When considering electrical equipment that doesn't influence the energy balance in the office areas (electrical cars, data servers and elevators), the difference between the measured energy demand and the simulated became 31% instead of the 54% shown earlier.</p>

Figure 7. Annual energy demand for electrical appliances, comparison of the value assumed in calculation with the registered electrical demand. Comparison by zone for 3<sup>rd</sup> floor (left) and 4<sup>th</sup> floor (right).

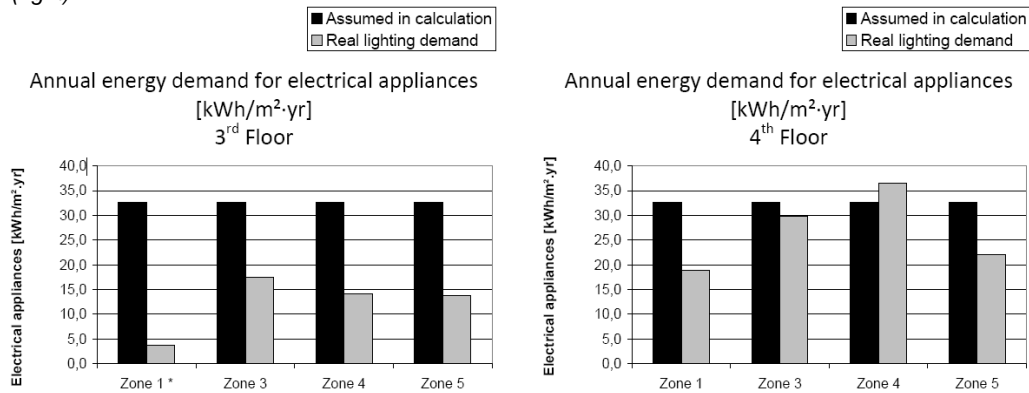


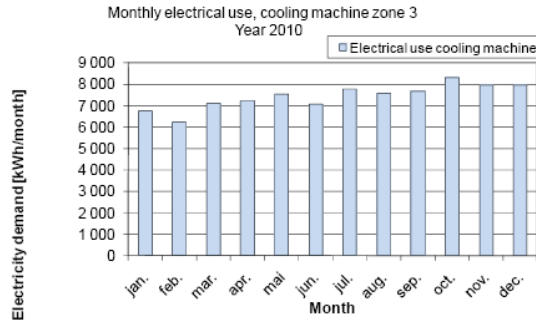
Table 10. Item 8, cooling

<p><b>Item 8. Cooling</b></p>
<p><b>Difference</b> +1385%</p>
<p><b>Comments</b></p> <p>Cooling is the fourth largest measured energy item. It counts for about 14% of the total measured energy demand.</p> <p>The measured energy demand for cooling is more than thirteen times higher than the simulated value. The building has three cooling machines: one dedicated to the data servers room and two dedicated to ventilation plants.</p> <p>Several reasons explain the difference:</p> <ol style="list-style-type: none"> <li>1. Room cooling Office areas aren't equipped with room cooling. The office areas are served by ventilation cooling only.</li> <p>The data server room is equipped with room cooling, which was taken in account in the calculation and result in a cooling demand of 844 kWh/yr. The internal gains were like 22 425 kWh/yr in the calculation, much lower than 89 954 kWh/yr registered by energy meters. Furthermore, the room cooling was supposed to be in used only 12 hours per day, 5 days per week. It runs in reality all day long, all year round. Supposing that the cooling demand for data servers is equal to the electrical use needed by the servers and supposing a coefficient of performance of 1 for the cooling machine, a cooling demand of 89 954 kWh/yr is required by the server room. The registered electrical use for the cooling machine in the basement equals 89 171 kWh/yr. See Figure 8, diagram on the top.</p> <li>2. Coefficient of performance (COP) The coefficient of performance (COP) for the cooling machines is equal to 2.5 in the calculation. A COP of 2.5 is the default value defined in NS3031:2007. The real COP may be lower.</li> <li>3. Abnormal operation of the little cooling machine dedicated to ventilation plants The little cooling machine has a yearly energy use of 33 442 kWh. The electricity demand for this cooling machine is unstable during the three first months of the year, probably due to tuning procedures. From April to November, the electricity demand is almost constant, regardless of the outdoor air temperature. The operation of the machine is not yet optimized.</li> <li>4. Abnormal operation of the cooling machine 1 The cooling machine 1 has a yearly energy use of 93 269 kWh. The profile of the electricity demand for the cooling machine 1 looks like the profile of a heating system, with highest demand wintertime and lowest demand during summer months. See Figure 8, diagram at the bottom. This profile is difficult to understand and explain. It seems simply wrong. The operation of this cooling machine has to be verified.</li> </ol>

Figure 8. Monthly electrical use for the operation of the cooling machines during 2010, registered values from the energy demand logging. Note that the y-scale varies from diagram to diagram.

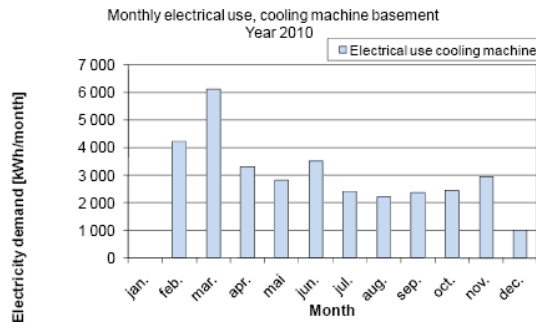
Cooling machine dedicated to data server room

Yearly electricity use: 89 171kWh/yr



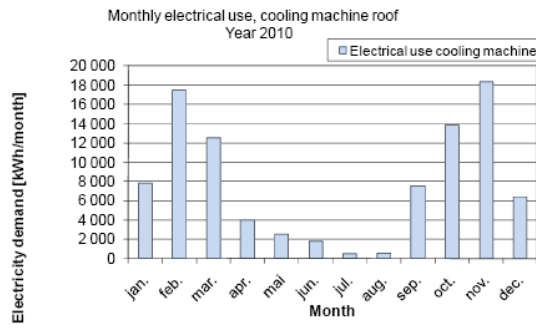
Little cooling machine dedicated to ventilation plants

Yearly electricity use: 33 442kWh/yr



Cooling machine 1 dedicated to ventilation plants

Yearly electricity use: 93 269kWh/yr



### 3.2 Users' satisfaction

Results of the questionnaire that has been submitted to all employees of the 3<sup>rd</sup> and 4<sup>th</sup> floor are presented on the following pages. The results are presented per floor and per topic: general comfort, temperature, acoustics, indoor air quality, and lighting.

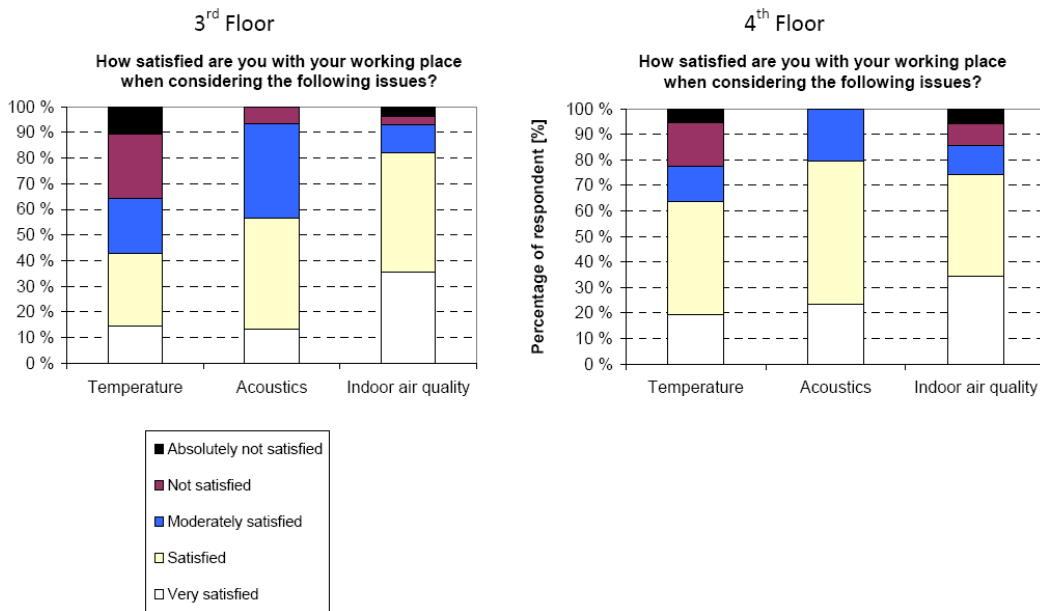
#### 3.2.1 General comfort

When asked about their satisfaction level regarding temperature, acoustics and indoor air quality, the respondents refer to temperature as the major issue of complaint. Almost 40% respondents are not satisfied or absolutely not satisfied on 3<sup>rd</sup> floor and around 20% are not satisfied or absolutely not satisfied on 4<sup>th</sup> floor.

The indoor air quality is the second issue of complaint, especially on the 4<sup>th</sup> floor, with about 15% respondents that are not satisfied or absolutely not satisfied. On the 3<sup>rd</sup> floor, less than 10% respondents say that they are not satisfied or absolutely not satisfied with the indoor air quality.

Acoustics is a minor issue of complaint, with only 7% respondents that are not satisfied on 3<sup>rd</sup> floor and none unsatisfied respondent on the 4<sup>th</sup> floor.

Figure 9. General comfort - How satisfied are you with your working place when considering the following issues? Results for 3<sup>rd</sup> floor (left) and 4<sup>th</sup> floor (right).

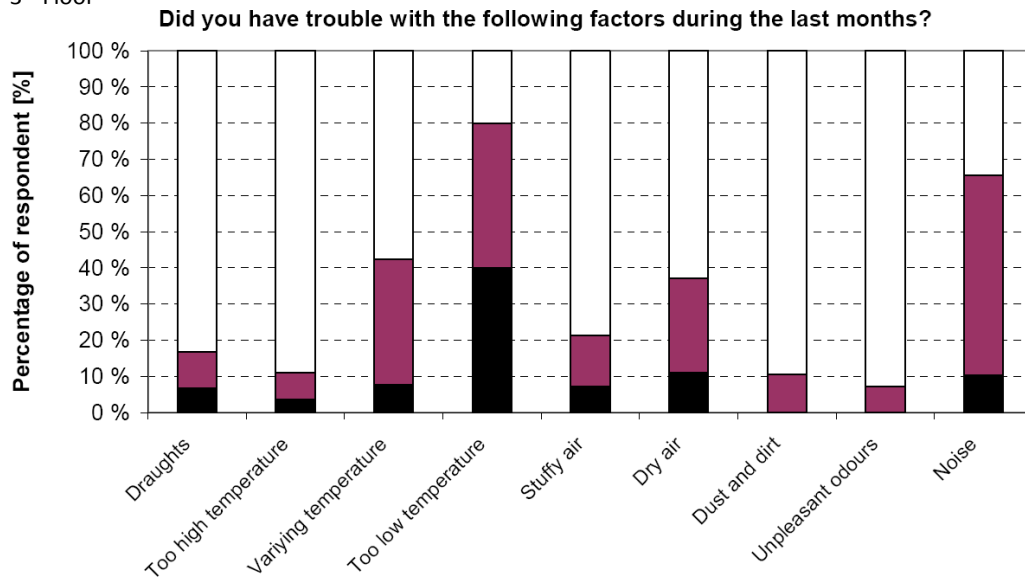


When asked about the general comfort and about problematic factors that may have occurred during the last months, it appears that a majority of respondents have experienced too low temperature. For the 3<sup>rd</sup> and 4<sup>th</sup> floor, respectively 80% and 60% respondents answered that they have had trouble with too low temperature often or sometimes during the last months. Half of them, respectively 40% and 30% respondents for the 3<sup>rd</sup> and 4<sup>th</sup> floor, said that they often experienced too low temperature.

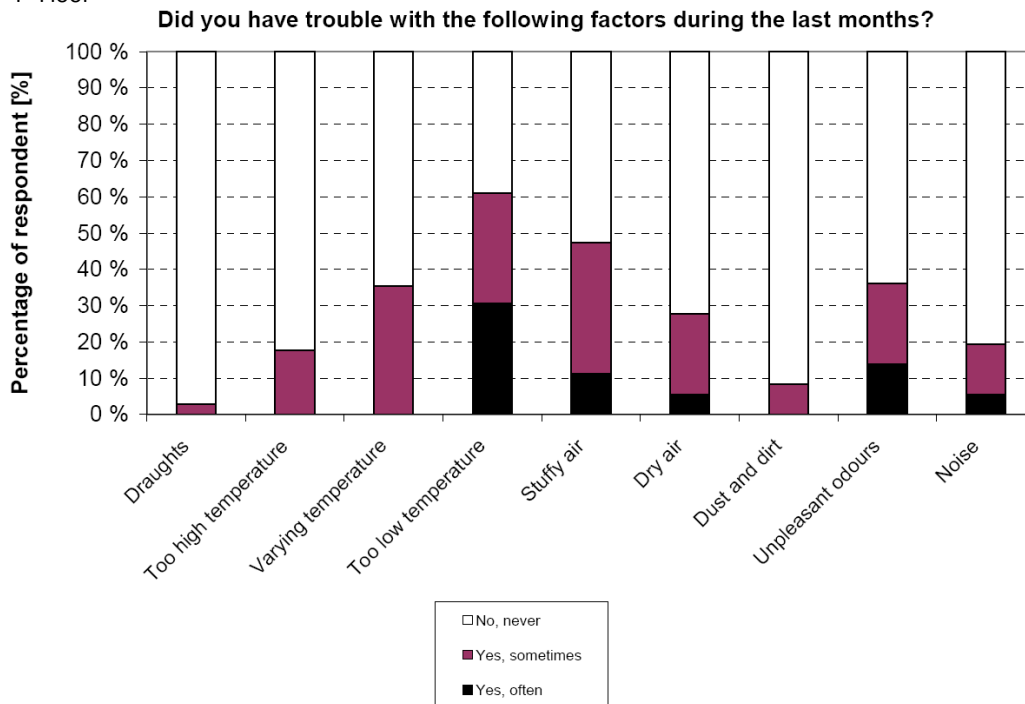


Figure 10. General comfort - Did you have trouble with the following factors during the last months?  
Results for 3<sup>rd</sup> floor (top) and 4<sup>th</sup> floor (bottom).

3<sup>rd</sup> Floor



4<sup>th</sup> Floor



If we consider that the most important factors of discomfort are the factors where more than 10% respondents answered *Yes, often* or *Yes, sometimes*, we note six factors of discomfort on the 3<sup>rd</sup> floor and seven factors of discomfort on the 4<sup>th</sup> floor.

On the 3<sup>rd</sup> floor, the factors of discomfort are, sorted by importance:

- Too low temperature
- Noise
- Varying temperature
- Dry air
- Stuffy air
- Draughts

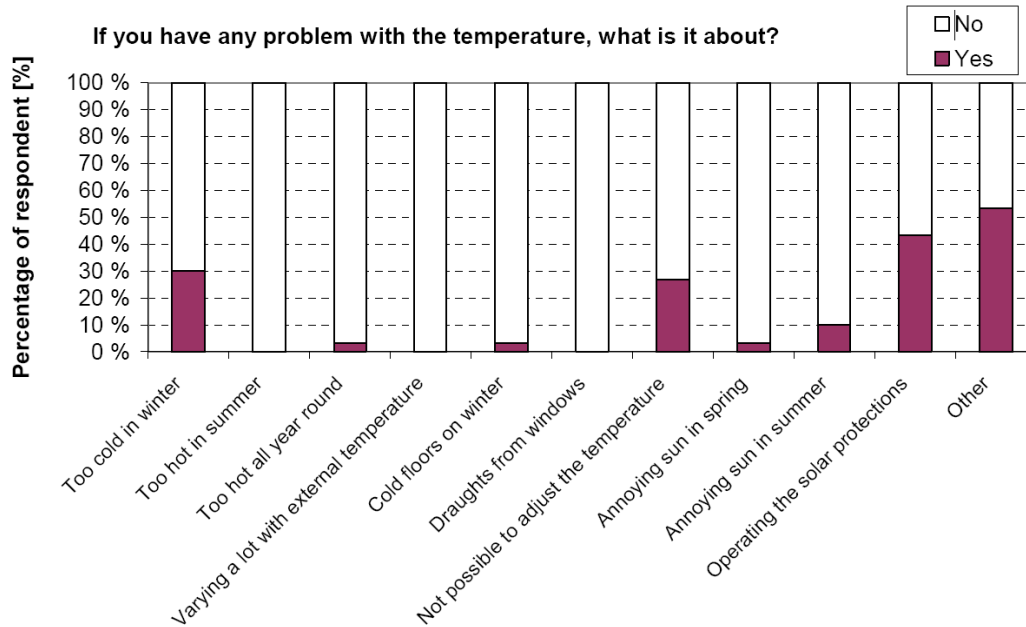
On the 4<sup>th</sup> floor, the factors of discomfort are, sorted by importance:

- Too low temperature
- Stuffy air
- Unpleasant odours
- Varying temperature
- Dry air
- Noise
- Too high temperature

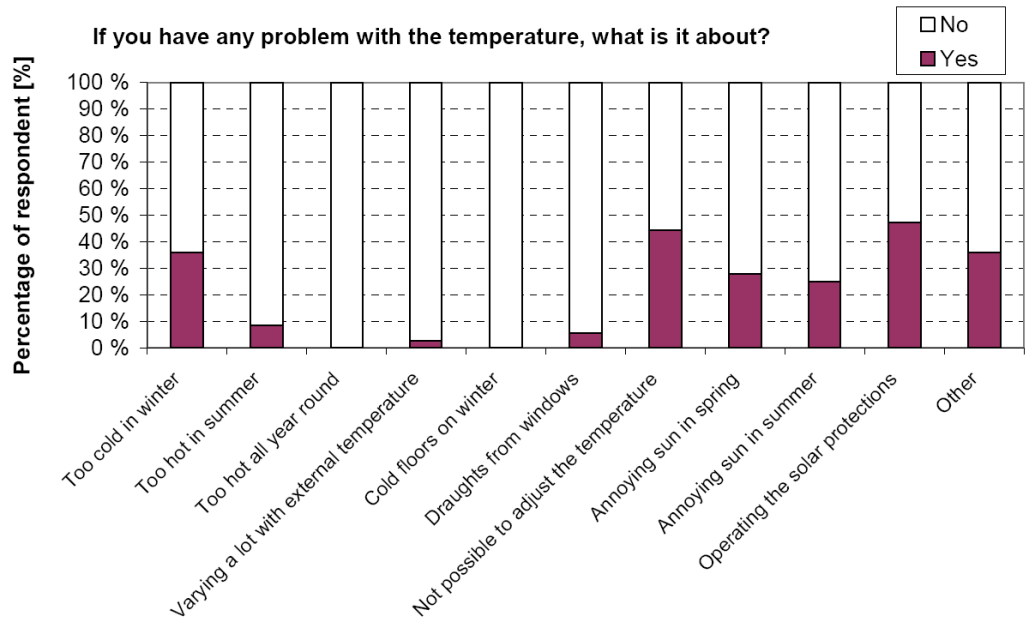
### 3.2.2 Temperature

Figure 11. If you have any problem with the temperature, what is it about?  
Results for 3<sup>rd</sup> floor (top) and 4<sup>th</sup> floor (bottom).

3<sup>rd</sup> Floor



4<sup>th</sup> Floor



On the 3<sup>rd</sup> floor, relevant problems experienced with temperature conditions are:

- Other, 53%  
All respondents commented the problem defined as "Other" with the same remarks: *Too cold in summer* and/or *Too cold all year round*.
- Operating the solar protections, 43%
- Too cold in winter, 30 %
- Not possible to adjust the temperature, 27 %
- Annoying sun in summer, 10 %

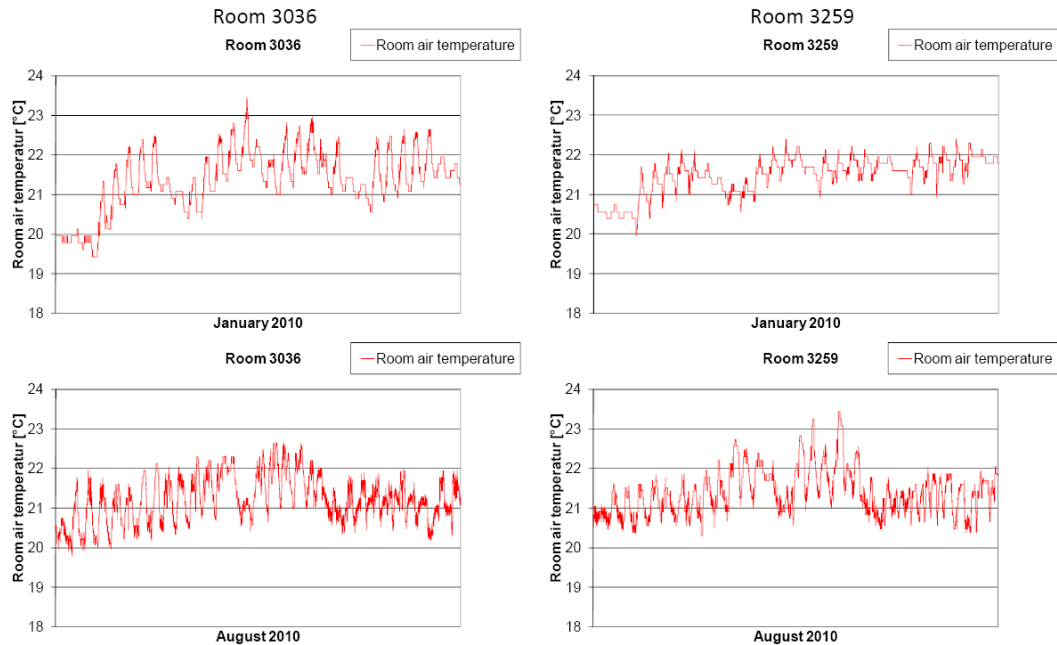
On the 4<sup>th</sup> floor, relevant problems experienced with temperature conditions are:

- Operating the solar protections, 47%
- Not possible to adjust the temperature, 44 %
- Too cold in winter, 36 %
- Other, 36%

Respondents had various comments to the problem defined as "Other", but several respondents have the following remarks: *Too cold in summer, Too cold all year round, Not satisfying solar protection, Too cold in the meeting room called cheery.*

- Annoying sun in spring, 28 %
- Annoying sun in summer, 25 %
- Too hot in summer, 8 %

Figure 12. Registered room air temperature in January 2010 and August 2010 for two rooms on the 3<sup>rd</sup> floor



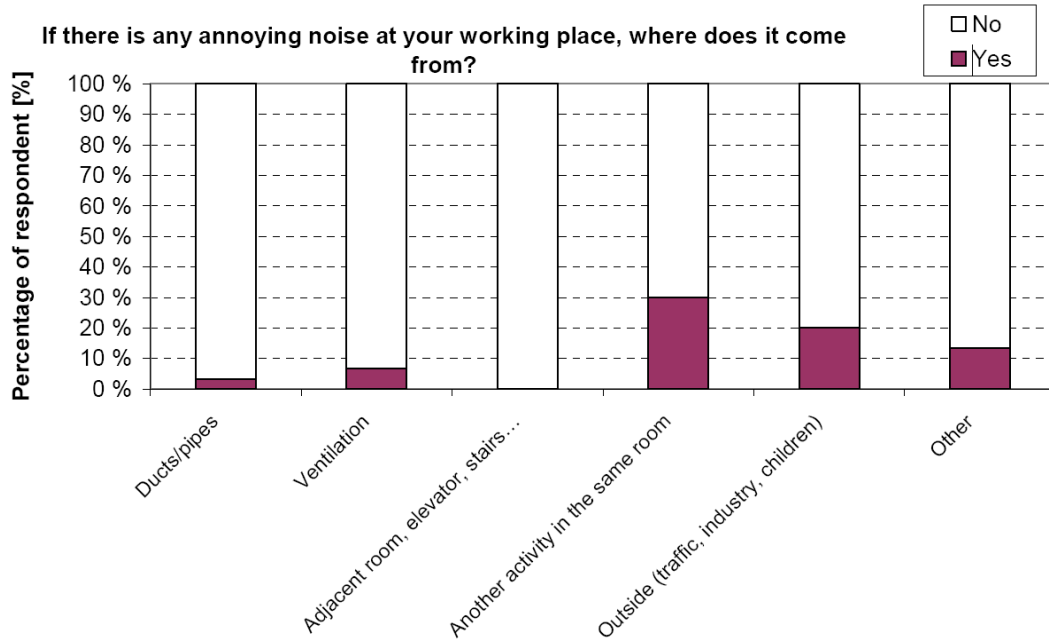
Registered room air temperature for room 3036 is comprised between 19.5°C and 23.4°C in January. In August, the room air temperature waves between 19.9°C and 22.8°C. For room 3259, the temperature in January stays between 20°C and 22.4°C. In August, it varies from 20.3°C to 23.4°C.

In room 3036, the registered room air temperatures during working hours in August 2010 are similar, and sometimes lower, than the registration performed for January 2010. In room 3259, the temperature in January is quiet close to the temperature in August. The minor variation of temperature from January to August may explain the users' feed-back on too low temperatures during summer.

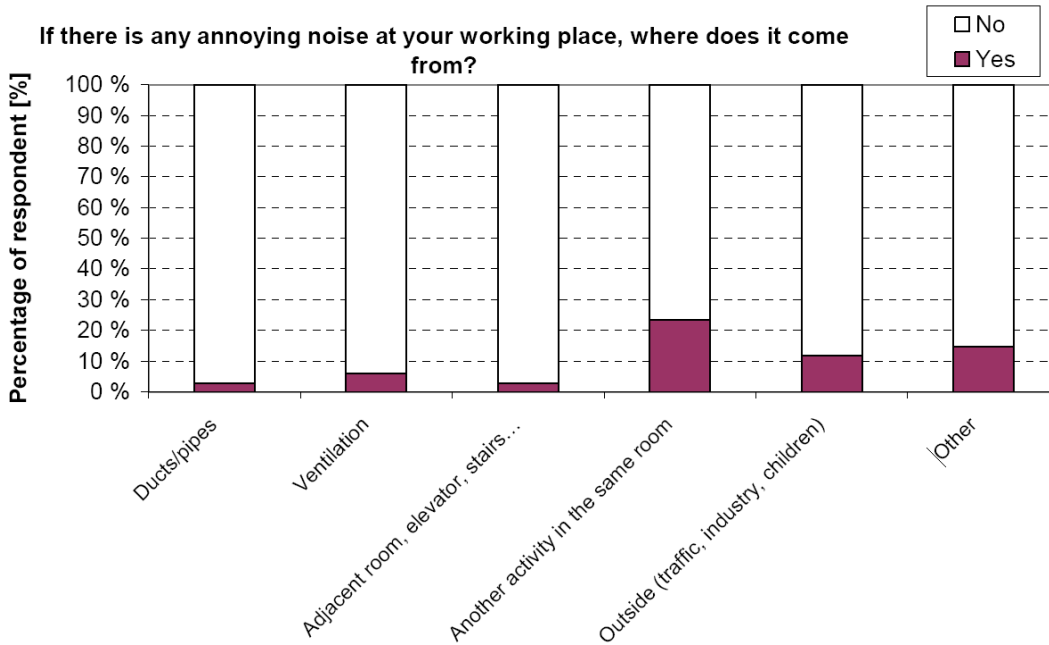
### 3.2.3 Acoustics

Figure 13. If there is any annoying noise at your working place, where does it come from? Results for 3<sup>rd</sup> floor (top) and 4<sup>th</sup> floor (bottom).

3<sup>rd</sup> Floor



4<sup>th</sup> Floor



On the 3<sup>rd</sup> floor, respondents experienced annoying noise due to:

- Another activity in the same room, 30%
- Outside, 20%
- Other, 13%

All respondents commented the problem defined as "Other" with the same remarks:  
*Poor acoustics in the meeting rooms*

On the 4<sup>th</sup> floor, respondents experienced annoying noise due to:

- Another activity in the same room, 22%
- Other, 14%  
Respondents had all different comments to "Other".
- Outside, 11%

The most common reasons for annoying noise at the working station are related to other activities in the same room and to noise coming from surroundings outside of the building. Several respondents worked in private office before moving in Professor Brochs gate 2. They don't feel comfortable when working in the open space. They feel they loss their privacy and that tasks that require concentration are more demanding to achieve than earlier, when they work in private office.

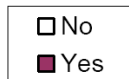
A little proportion of respondents, respectively 17% and 18% for the 3<sup>rd</sup> and 4<sup>th</sup> floor, have a bad opinion of the acoustics in the room.

Figure 14. If you experience noise problems, is it due to poor acoustics in the room? Results for 3<sup>rd</sup> floor (left) and 4<sup>th</sup> floor (right).

If you experience noise problems, is it due to poor acoustics in the room / is the understanding of other's speech difficult?



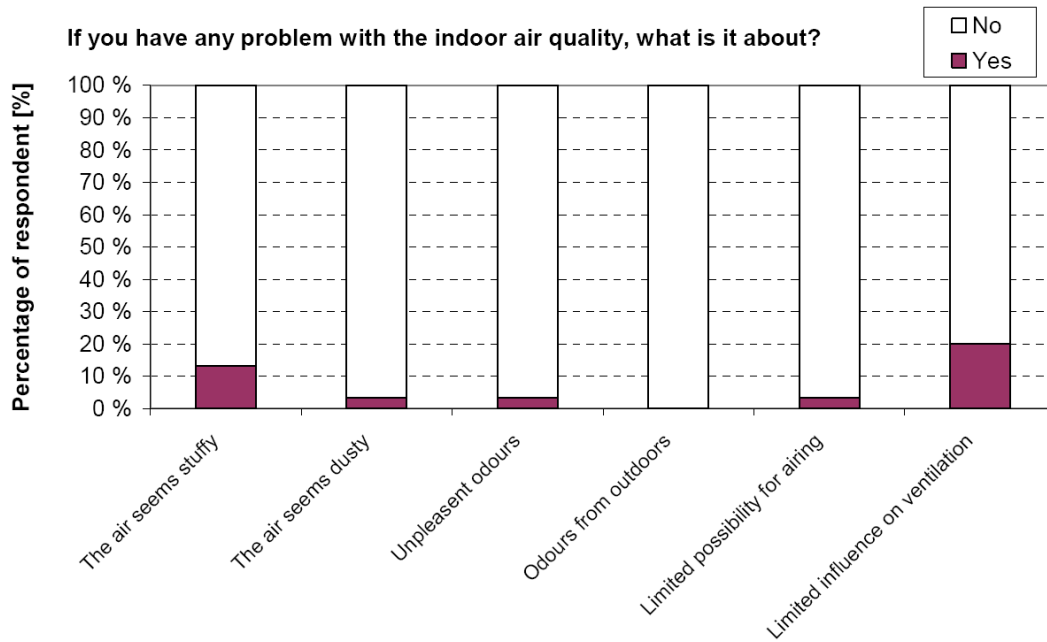
One respondent comments "Extremely poor acoustics. When I make phone calls, people on the other side can't hear me."



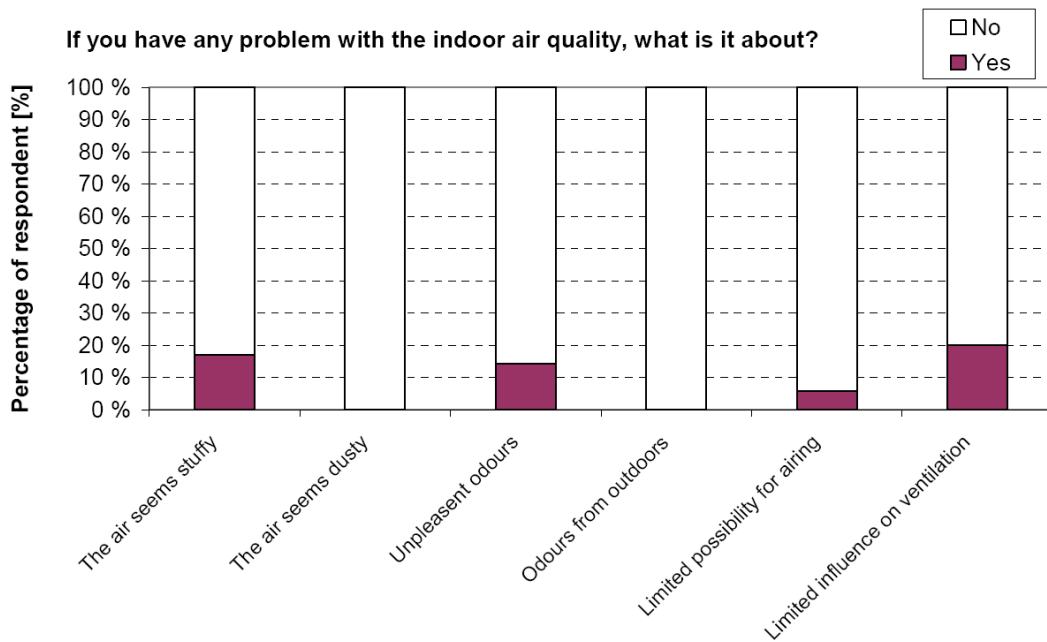
### 3.2.4 Indoor air quality

Figure 15. If you have any problem with the indoor air quality, what is it about? Results for 3<sup>rd</sup> floor (top) and 4<sup>th</sup> floor (bottom).

3<sup>rd</sup> Floor



4<sup>th</sup> Floor



Two problems connected to indoor air quality are pointed out on both 3<sup>rd</sup> and 4<sup>th</sup> floor

- Limited influence on ventilation, for respectively 20% and 19% respondents
- The air seems stuffy, for respectively 13% and 17% respondents

On the 4<sup>th</sup> floor, the factor *Unpleasant odours* are mentioned by 14% respondents. The complaint was specific to the reception area. The source of the odours has then been identified and removed.

Compared with complaints on temperature, the answering percentages on dissatisfaction due to poor indoor air quality are much lower.

Dry air isn't mentioned among the possible problems relative to indoor air quality. Nevertheless, the issue is included in the questions relative to the general feeling of comfort in the building. See Figure 9. About 30% of respondent complain about dry air (both floors) and 20/48% (3<sup>rd</sup> / 4<sup>th</sup> floor) complain about stuffy air. Figure 10 and 15 don't report the same level of complaint for stuffy air. There is no explanation to this difference. The respondent may have thought that they already tick once for this factor and don't care of ticking in second time later in the same survey.

The European Standard EN 15251:2007 *Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics* specifies the indoor environmental parameters which have an impact on the energy performance of buildings. But the standard does not include criteria for local discomfort factors like relative humidity rate.

The Building Research Design Guide 421.501 published by SINTEF Building and Infrastructure handles conditions for thermal comfort and contains recommendations for relative humidity rate. It says "*Under normal conditions, variations of the relative humidity rate between 20 to 60% RH have little influence on indoor environment. The relative humidity rate may be lower than 40% RH during the two or three coldest winter months and lower than 70% RH during the hottest summer months. Extreme low relative humidity rate, lower than 20% RH, may be avoided.*"

Figure 14 presents the measurements of relative humidity performed during three summer weeks in 2010 in two different rooms on the 3<sup>rd</sup> floor. The diagrams show two points of measurement in each room, at 30 cm and 90 cm from the ceiling. The measurements in the rooms are compared with the outdoor relative humidity level corrected for indoor air temperature.

The two points of measurement in each room show similar level of relative humidity rate, which should be acceptable as a proof of validity for the measurements.

During the weeks 33 and 34, the relative humidity rate indoor is always maintained between 40 and 60%. During the week 35, the relative humidity indoor is lower than earlier. It stays higher than 30% but waves between 30 and 40%.

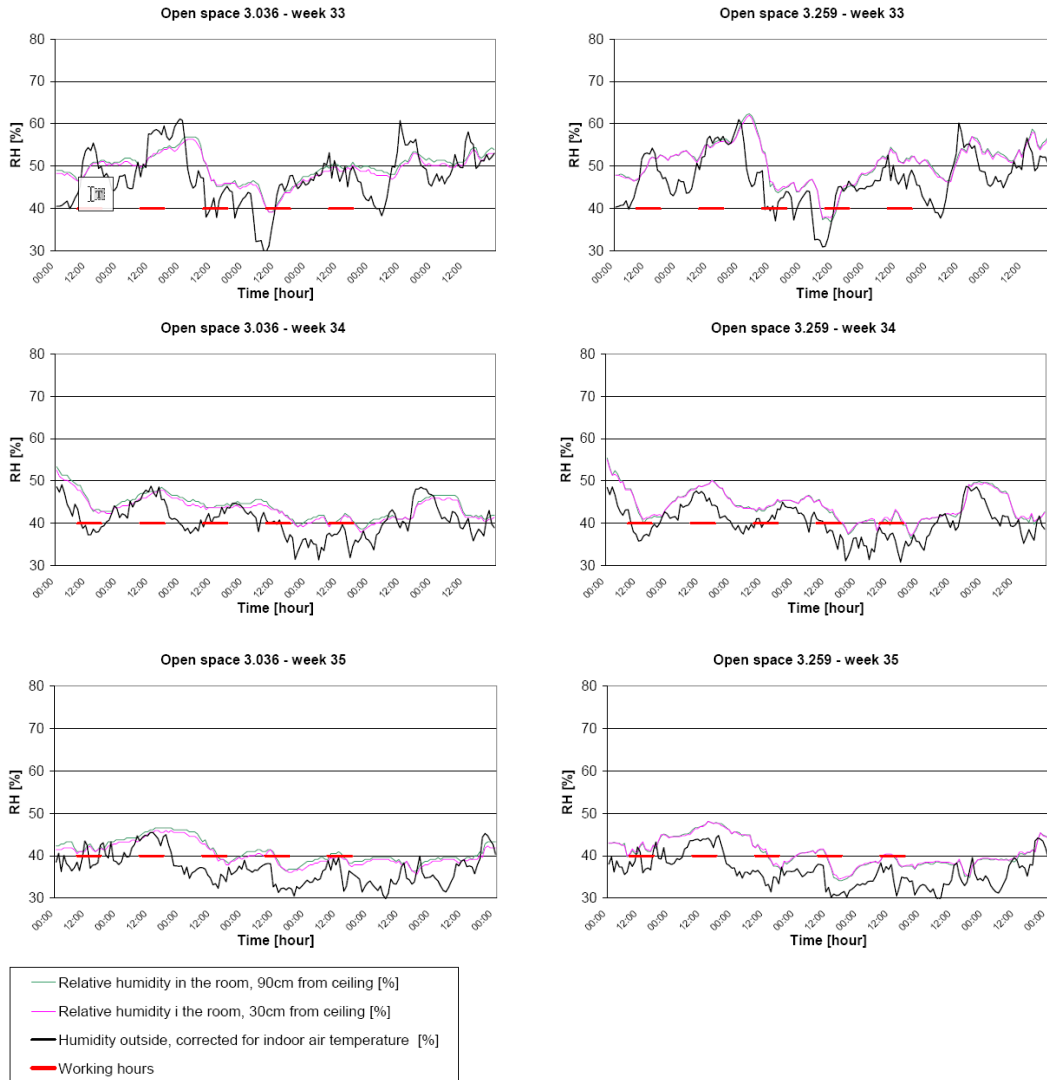
Regarding the recommendation from the Building Research Design Guide 421.501 which says relative humidity rate lower than 40% may be acceptable during the coldest winter months, the registered levels during the week 35 may be some low. The measurements of relative humidity rate can explain the feed-back from the respondents that complain about dry air.

Nevertheless, the indoor relative humidity rate varies in step with the outdoors level and the indoor level is always higher than outdoors during week 35. Office buildings shouldn't require humidifier. In buildings without humidifier, the fact that the indoor relative humidity rate lays over the outdoor relative humidity rate is often judged as acceptable.

For practical reasons, the measurements were performed in August. We have unfortunately no measurement during winter, the time of the year where the relative humidity rate uses to reach its lowest level.

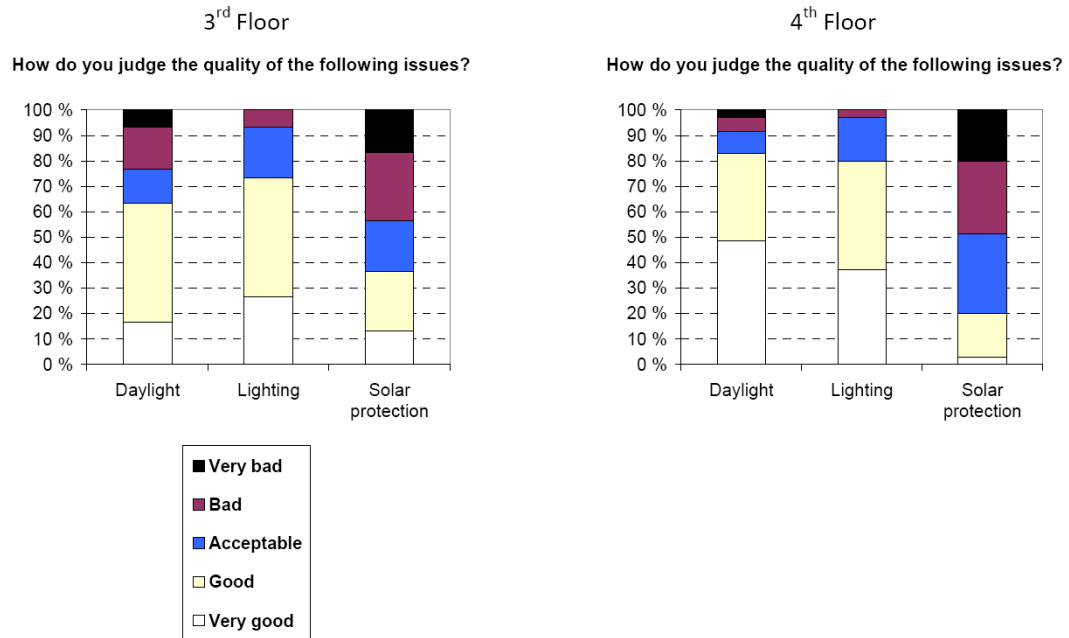


Figure 16. Comparison of indoor and outdoor humidity levels during three weeks (33, 34 and 35) in two rooms (room 3.036 and 3.259). Relative humidity indoor measured on two points of the room (pink and turquoise lines), Relative humidity indoor measured (black line)



### 3.2.5 Lighting

Figure 17. How do you judge the quality of the following issues: daylight, lighting and solar protection. Results for 3<sup>rd</sup> floor (left) and 4<sup>th</sup> floor (right).



When asked about daylight, lighting and solar protection, the respondents points out the solar protection as unacceptable. For both floors, almost 50% respondents judge the quality of the solar protection bad or very bad.

Daylight is poorly judge by 23% respondents and 9% respondents for respectively the 3<sup>rd</sup> and 4<sup>th</sup> floor. None respondent judge the lighting very bad. Only 7% and 3% respondents, for respectively the 3<sup>rd</sup> and 4<sup>th</sup> floor, don't judge the lighting positively.

### 3.3 Feedback on the use of fair-faced concrete ceilings

#### 3.3.1 Monitoring of temperature variation in the concrete slab

Figure 18 shows the variation of temperature in the concrete slab (ceiling) during August 2010 for two rooms on the 3<sup>rd</sup> floor, room 3036 and 3259.

In room 3036, the temperature on the surface of the concrete slab is always higher than the room air temperature by 0.5 to 2°C. The temperature inside the slab, 2 cm from the edge, follows the surface temperature but is always 0.3°C lower than on the surface. In room 3259, the difference between the two sensors that are placed inside the slab with a distance of 2 cm, is always around 0.8°C. The sensor placed deepest in the slab has the lowest temperature. On Figure 18, the concrete slabs have always a higher temperature than the room, working as radiant heating all day long. The daily cycle where the thermal inertia of the concrete slab gets charged during the day and discharged at night is missing.

The calibration required by the temperature sensors placed in the concrete slab has not been realized at the time of writing. Supposing a calibration error of 1°C, new diagrams were made. See Figure 19. On the new diagrams, the temperature in the slab moves according to the room air temperature but with a much smaller amplitude. The diagrams are in adequation with the expected activation of the concrete slab's thermal inertia. Since the diagrams are only supposed, they can't be used to draw any conclusion.

Figure 18. Registered room air temperature and concrete slab temperature in August 2010 for two rooms on the 3<sup>rd</sup> floor

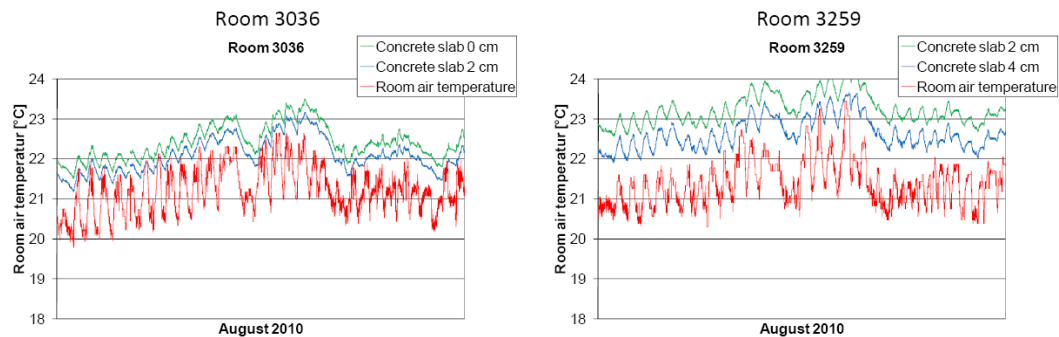
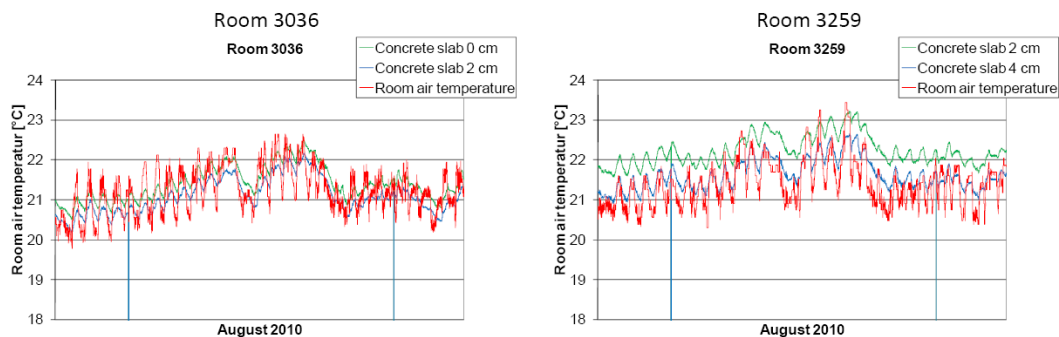


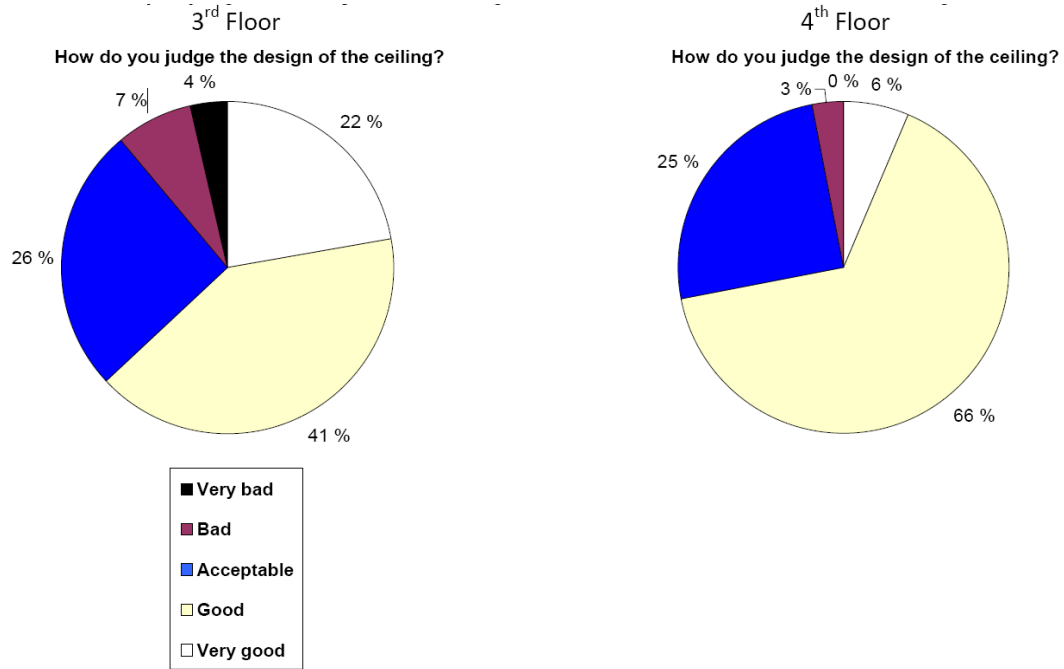
Figure 19. Registered room air temperature and supposed correction of concrete slab temperature in August 2010 for two rooms on the 3<sup>rd</sup> floor



### 3.3.2 Users' satisfaction questionnaire

When asked about the design of the ceiling, a majority of respondents answered that they judge it good, with 41% respondents and 66% respondents for respectively the 3<sup>rd</sup> and 4<sup>th</sup> floor. The design of the ceiling is poorly judge by 11% respondents and 3% respondents for respectively the 3<sup>rd</sup> and 4<sup>th</sup> floor. Only 4% respondents on 3<sup>rd</sup> floor judged it very bad. None respondent on 4<sup>th</sup> floor judged the design of the ceiling very bad.

Figure 20. How do you judge the design of the ceiling? Results for 3<sup>rd</sup> floor (left) and 4<sup>th</sup> floor (right).



## 4 Conclusion

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The total energy demand is about 26% higher than calculated, despite the fact that the simulation is based on a full-occupied building, while the building was not entirely in use in 2010. An augmentation by 26% of the energy target (86kWh/m<sup>2</sup>·yr) results in 108kWh/m<sup>2</sup>·yr, which is much lower than usually measured in modern office buildings in Norway.

The highest divergence between calculation and measurement is due to cooling. The difference is partially understood when looking at the real internal gains in the data server room, and their resulting cooling demand. But the difference remains partially unexplained, especially regarding the operation of the cooling machine 1, that seems irrational. The cooling machine 1 has the highest energy consumption of the three cooling machines in the building and the highest energy demand during winter. The operation of the cooling machine has to be verified.

There is no use of local cooling in the office areas of the building. The temperature isn't experienced too hot during summer, showing that carefully designed internal gains and controlled solar gains can be eliminated by ventilation cooling. On the contrary, the room air temperature is judged too low on summer months.

The questionnaires survey among users of the 3<sup>rd</sup> and 4<sup>th</sup> floor reveals major complaints relative to the room air temperature and operation of the solar protection. The room air temperature is experienced as too low during summertime by a majority of respondents. A large part of respondents judge the temperature too low all year round. The measurements realized on room air temperature show summer temperatures that are equal or lower than winter temperatures, explaining the feed-back from the respondents.

The respondents feel they can't control the temperature. One of the respondent is fully satisfied with the thermal comfort in the building, but added a comment at the end of the survey "My own electrical radiator is plug-in under my desk".

The respondents feel they can't control the solar protection. They are not satisfied by the inclination of the venetians blinds. The blinds are shut down in a vertical position most of the time on sunny days. This inclination doesn't allow sight on the outdoor environment and is commented as depressing.

The registration of the temperature inside the concrete slabs may confirm the expected activation of thermal inertia. Without calibration of the sensors placed in the concrete slab, it remains difficult to conclude on this point.

The users judge positively the design of the ceiling, with fair-faced concrete slab and hanging acoustic insulation panels.

## Appendix 1 – Complementary information of the office building (in Norwegian)

### Beskrivelse av kontorbygget kontorbygget i Professor Brochs gate 2, Trondheim

#### Generell beskrivelse

Kontorbygget i Professor Brochs gate 2 i Trondheim, også kalt ”Miljøbygget” sto ferdig i september 2009. Bygget er en del av Teknobyen som ligger mellom Nidelva (i vest) og Gløshaugen (i øst).



Oversikt over Teknobyen med Nidelva i bakgrunnen – Det nye kontorbygget i Professor Brochs gt.2 synes i nedre venstre hjørnet (innenfor rødt omriss). Bildet er tatt fra nord-øst. (Foto: KLP Eiendom)



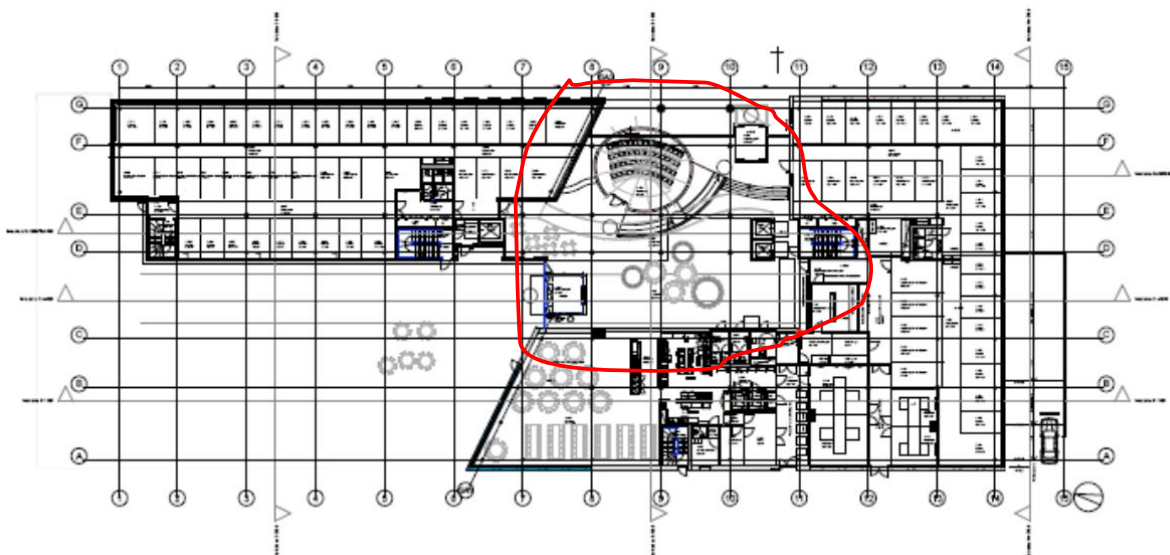
Professor Brochs gt.2 sett fra nord-vest. Den lave fløyen synes til høyre. Vestfasaden for den høye fløyen synes til venstre (Foto: KLP Eiendom)



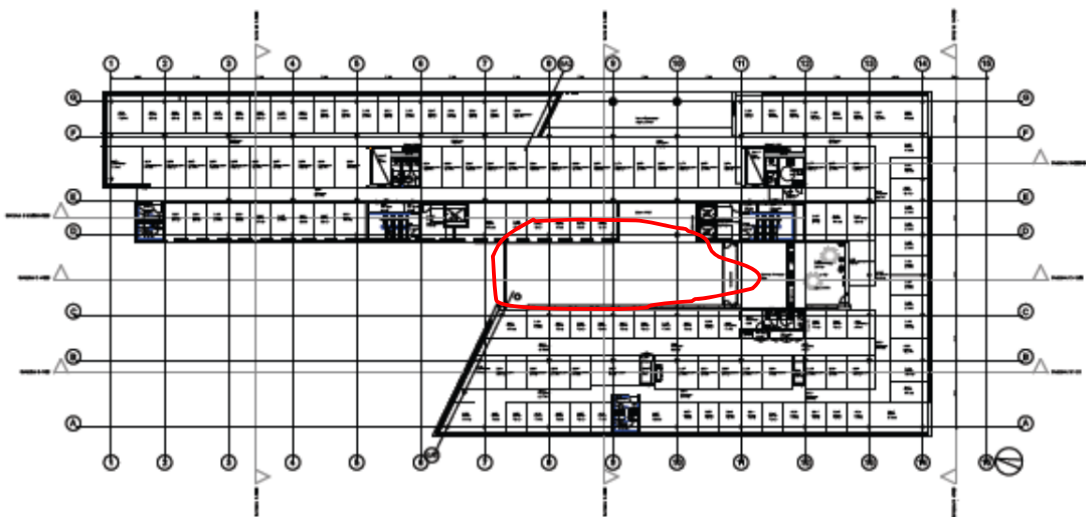
Professor Brochs gt.2 sett fra nord-øst. Bildet viser østfasaden for den høye fløyen (Foto: KLP Eiendom)

Figur 1. Oversiktbilder for Professor Brochs gate 2 i Trondheim

Bygget består av to parallelle rektangulære fløyer på hhv. 4 og 6 etasjer over bakkeplan. De to fløyene er koblet sammen med en glassgård. Glassgården rommer et inngangsparti med vrimlearealer, et auditorium og to heiser. Kjellerplan består av parkeringsplasser, lagerrom og teknisk rom. Ventilasjonsaggregatene ligger i teknisk rom på kjellerplan og på tak. Brutto gulvareal for hele bygget er ca. 16.300 m<sup>2</sup>. Bygget består hovedsakelig av kontorer, med en kantine på plan 1. Deler av bygget er foreløpig ikke tatt i bruk (ca. 7.700 m<sup>2</sup> i september 2010, ca. 3.550 m<sup>2</sup> ved utgangen av desember 2010).



Plantegning 1.etasje (Arkitekttegning datert 25.08.2008)



Plantegning 3.etasje (Arkitekttegning datert 25.08.2008)

← N

Figur 2. Plantegninger ved detaljprosjektering for 1. og 3.etasje, Professor Brochs gate 2 i Trondheim. Glassgård vises i midten (innenfor rødt omriss). Den korte lave fløyen vises på nedre del av plantegningene. Den lange høye fløyen ligger på øvre del av plantegningene.

## Adresse

Professor Brochs gate2  
N-7030 Trondheim

## Beliggenhet

### Orientering

Hovedfasadene til bygget er orientert mot øst og vest.

### Terrenngskjerming

Kontorbygget i Professor Brochs gate 2 står fritt langs Holtermannsveg på et flatt område. Bebyggelsen rundt bygget skjermer litt fasadene som vender mot syd, vest og nord for horisonten. Øst fasaden er i veldig lite grad skjermet for horisonten på grunn av omkringliggende bebyggelse. Skråningen mot Gløshaugen ligger 150m unna øst fasaden og utgjør en skjerming i forhold til vind men ikke i forhold til sol.

## Eie- og driftsforhold

Eier: KLP Eiendom

Ansvarlig for forvaltning og drift: KLP Eiendom

Leietager plan 3: ENOVA

Leietager plan 4: SWECO

Leverandør av SD-anlegg (Sentral Driftskontroll): Gunnar Karlsen Norge AS

Leverandør av EØS (Energi Oppfølging System): Entro AS

Elektroentreprenør: Fjeldseth AS

### Kontaktpersoner i forbindelse med COIN

Firma	Navn	e-post	Telefon
KLP Eiendom	Leif Fossum	leif.fossum@klpeiendom.no	95 03 65 00
KLP Eiendom	Snorre Almås	Snorre.Almaas@klp.no	90 12 48 40
KLP Eiendom	Roger Dahl	roger.dahl@klpeiendom.no	
ENOVA	Jan P. Amundal	jan.peter.amundal@enova.no	92 85 95 09
SWECO	Per Stig Solbakken	PerStig.Solbakken@sweco.no	92 26 24 13
Gunnar Karlsen	Tor Hjalmar Knudsen	Tor.Knudsen@gk.no	93 23 36 87
Entro AS	Erlend Moen	Erlend.Moen@entro.no	91 38 53 00
Fjeldseth AS	Roger Johnsen	roger.j@fjeldseth.no	93 25 41 15

## Byggets historikk

### Byggeår

2009

### Endringer etter ferdigstillelse

Ingen bygningstekniske endringer

### Brukerorganisasjon per i dag

På plan 1 er ca. en tredje del av arealet brukt til inngangs- og vrimleareal, kantine og et større møterom ("kirkebær"). Resterende areal brukes til kontorvirksomhet.

Plan 2 til 6 består hovedsakelig av kontorplasser, både cellekontorer og kontorlandskap, med tilhørende fasiliteter som møterom, stillerom, teamrom, kopirom, garderobe, tekjokken og toaletter.

### Eksisterende tegninger

Følgende digitale tegninger er oversendt:

ARK-tegninger fra august 2008 (plan og fasade)

VVS-tegninger som bygget fra oktober 2009



## Byggeteknisk

Isolasjonsnivået for hver enkel bygningsdel er gitt i tabellen under.

Parameter	Enhet	Verdi
U-verdi vegg	[W/(m <sup>2</sup> ·K)]	0,17-0,21
U-verdi gulv	[W/(m <sup>2</sup> ·K)]	Mot parkeringsplan
U-verdi yttertak	[W/(m <sup>2</sup> ·K)]	0,13
Vindu: U-verdi	[W/(m <sup>2</sup> ·K)]	0,80
Glasstak: U-verdi	[W/(m <sup>2</sup> ·K)]	1,20
Lekkasjetall Ve 50 Pa, n <sub>50</sub>	[h <sup>-1</sup> ]	0,4

## Appendix 2 – Questionnaire submitted to users (in Norwegian)

Hei!

Dette skjemaet er en del av et forskningsprosjekt ledet av SINTEF Byggforsk vedrørende energieffektive bygg med betong (*Concrete Innovation Centre COIN*, se også <http://www.coinweb.no>). Kan du besvare spørsmålene under ut fra dine egne vurderinger. Du vil være anonym, og svarene vil bli behandlet fortrolig. På forhånd, takk for hjelpen!

Med vennlig hilsen

Catherine Grini - forsker ved SINTEF Byggforsk

Tlf. 22 96 58 65

e-post: [catherine.grini@sintef.no](mailto:catherine.grini@sintef.no)

### Utfylt skjema leveres XXX innen fredag 10. september

#### Om arbeidsplassen din

Hvilke etasje sitter du i?	_____
Hvilke romtype sitter du i: cellekontor eller landskap?	_____
Hvilke fasade / himmelretning vender rommet ditt mot?	_____
Evt. romnummer (Obs! Ikke anonym hvis utfylt):	_____

#### Generelt om innemiljø i bygningen

Har du de seneste månedene hatt besvær med noen av de følgende faktorer:	Ja, ofte	Ja, iblant	Nei, aldri
Trekk	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
For høy romtemperatur	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Variierende romtemperatur	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
For lav romtemperatur	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Innestengt (dårlig) luft	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tørr luft	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Støv og smuss	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ubehagelig lukt	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Støy	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Annet, hva:			

### Lysforhold og romfølelse

Hvordan opplever du generelt bygningen når det gjelder:	Meget bra	Bra	Akseptabel	Dårlig	Meget dårlig
Dagslys	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Kunstig belysning	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Solavskjerming for å unngå blending	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hva synes du om himlingsløsningen? Evt. kommentarer om lysforhold og romfølelse:	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

### Temperaturforhold

	Meget bra	Bra	Akseptabel	Dårlig	Meget dårlig
Hva synes du om temperaturforholdene i bygningen?	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Om du opplever problemer med temperaturen: (Flere alternativ kan krysses av)					
				<input type="checkbox"/> for kaldt om vinteren	
				<input type="checkbox"/> for varmt om sommeren	
				<input type="checkbox"/> for varmt hele året	
				<input type="checkbox"/> varierer mye med utetemperaturen	
				<input type="checkbox"/> kalde gulv om vinteren	
				<input type="checkbox"/> trekk fra vinduer	
				<input type="checkbox"/> kan ikke selv påvirke temperaturen	
				<input type="checkbox"/> plagsom sol om våren	
				<input type="checkbox"/> plagsom sol om sommeren	
				<input type="checkbox"/> problemer med solavskjerming	
				<input type="checkbox"/> annet, hva:	



**Andre kommentarer (fylles ut ved behov)**

Hva er du mest fornøyd/misfornøyd med i bygget?

Er det noe du ville ha endret på og hvordan ville du gjort det?

**SINTEF Building and Infrastructure** is the third largest building research institute in Europe. Our objective is to promote environmentally friendly, cost-effective products and solutions within the built environment. SINTEF Building and Infrastructure is Norway's leading provider of research-based knowledge to the construction sector. Through our activity in research and development, we have established a unique platform for disseminating knowledge throughout a large part of the construction industry.

**COIN – Concrete Innovation Center** is a Center for Research based Innovation (CRI) initiated by the Research Council of Norway. The vision of COIN is creation of more attractive concrete buildings and constructions. The primary goal is to fulfill this vision by bringing the development a major leap forward by long-term research in close alliances with the industry regarding advanced materials, efficient construction techniques and new design concepts combined with more environmentally friendly material production.

