Synthesis Report on User Acceptability of Ventilation Technologies

2nd Draft

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Technical Report

Building AdVent – Work Package 3
Delivery D8

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P. Heiselberg

AALBORG UNIVERSITY

Aalborg University
Department of Civil Engineering
Indoor Environmental Engineering Research Group

DCE Technical Report No. 066

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by

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Contents

Introduction

1. INTRODUCTION

1.1 GENERAL

This report is prepared to summarise user satisfaction surveys available for 18 buildings in Building AdVent project. The results of user satisfaction survey are assembled in Building AdVent project D7 report for the Work Package 3. These serve a background for further discussions of acceptability of ventilation technologies by users.

1.2 QUESTIONNAIRE

Questionnaire survey is carried out for 18 buildings selected for a range of European climates. Some of the questionnaires are available from earlier studies and some questionnaire surveys were carried out within EU Building AdVent project. In Building AdVent surveys a common questionnaire format was agreed among the partners, with possibility for minor alterations of the questionnaires according to building use and occupant profile.

Questionnaire results available from earlier research were translated to fit format of Building AdVent questionnaire.

Building AdVent questionnaire is available in appendix and includes questions about:

- general comfort
- thermal comfort
- indoor air quality
- lightning
- noise
- possibilities for manual control

The occupants were asked to evaluate IAQ and comfort in building for summer and winter season separately. For some buildings, questionnaires were adapted acc. to building use, i.e. for museums and libraries questionnaires were reduced to fit user profile.

Occupants were asked to identify their sex, age, position in a company, the distance from their working space to a window, window orientation, etc.

Subjective scale

For most of the questionnaires, subjective scale of 7 points is used for evaluation, as for example thermal comfort was evaluated as following:

-3 *Absolutely unsatisfactory*	-2 *Unsatisfactory*	-1 *Slightly unsatisfactory*	0 *Neutral*	+1 *Just satisfactory*	+2 *Satisfactory*	+3 *Very satisfactory*
❑	❑	❑	❑	❑	❑	❑

Table 1-1. Subjective scale of 7 points, used for evaluation of IAQ and comfort in Building AdVent project.

This scale is used in EN 15251 standard, which is also used for overall evaluation of questionnaire surveys.

Evaluation of questionnaire surveys

An overall evaluation of questionnaires is carried out according to procedures recommended in EN 15251 standard for classification and certification of the indoor environment. The results of this overall evaluation are further discussed according to more detailed questionnaire responses.

In EN 15251 the evaluation of the indoor environment includes

- thermal criteria for winter
- thermal criteria for summer
- air quality and ventilation criteria
- lightning criteria
- acoustic criteria

For the overall evaluation, a comfort "footprint" is prepared for each building according to the results of questionnaire surveys. Occupants' votes for acceptable or neutral thermal environment and air quality are accounted as being satisfied.

1.3 APPROACH AND STRUCTURE

The report is organised so that, first of all, a reader is introduced to each case study building, specifics of its use and operation (chapter 2).

Next the overall results from questionnaire survey in each building are summarised and discussed (chapter 3). In the following chapter 4, all results are divided into groups according to ventilation principle in a building and user acceptability of these principles is examined. In this chapter, user responses are also grouped according to:

- General comfort
- Thermal comfort
- Air motion and draught
- IAQ
- Noise
- Lighting
- Control possibilities

In chapter 5, the main reasons for dissatisfaction with indoor air quality and comfort between the occupants in all building are investigated. Similar to chapter 4, the results are grouped according to ventilation principle in different buildings. As a result it is demonstrated whether the same ventilation principles in the buildings lead to the same reasons for dissatisfaction and complain between their occupants.

Finally, an overall summary of this work is organised in chapter 6.

1.4 LIMITATIONS IN SYNTHESIS REPORT

There is a number of limitations present in the synthesis report. The source of these limitations belongs to the quality of data from carried out questionnaire surveys.

As was mentioned, some questionnaire results are available from earlier studies, these were then translated to fit format of Building AdVent questionnaire. This means that occupants haven't received the same questions and their answers should not be rated equally. This limitation is disregarded in the report.

Another consequence of using different questionnaire format is the significant lack of data for some of the buildings.

Low response rate in several buildings does not allow accurate statistical treatment of data, as a consequence, some of the result can be misleading.

It is well known that user response to questionnaire will depend on relevance of questionnaire topic to user's needs and it will also depend on user's opinion about the topic. Therefore, dissatisfied users may use the questionnaire survey to express their strong negative feelings (dissatisfaction) with indoor air quality and comfort in the building. Meanwhile, users with neutral or positive perception will have a lower response rate. In that way, negative responses can become dominant and misleading, especially in the buildings with the low response rate. To be aware of that it is crucial to know total number of occupants who received the questionnaire.

Next limitation is seen in presenting the results, dividing them into the groups as:

- Satisfied
- Dissatisfied

In many cases the price of the comfort conditions in a building is the energy used for heating and ventilation of the building. Therefore it is important to discuss energy use issues along with the comfort conditions.

The above limitations will be mentioned in the discussions when it is relevant

18 Case studies

2. 18 CASE STUDIES

In this section each building is described in order to provide reader a short background information for synthesis and evaluation of the questionnaire survey results.

2.1.1 Aggelidis & Georgakopoulos building

Figure 2-1. Aggelidis & Georgakopoulos building

Aggelidis & Georgakopoulos is an office building and a paper storage, located in Greece.
There are three levels in the building: paper storage at ground floor, office areas at first floor, parking areas and mechanical installations in the basement. The building is mechanically ventilated in the office area and naturally ventilated in the storage area.

2.1.2 GSIS building

Figure 2-2. GSIS building

GSIS building is located in Greece. It has a rectangular shape with general dimensions 115mx39m. Its long axis runs along a South/Southeast to North/Northwest direction. The building consists of two basements with parking areas, ground floor and four floors with office areas.

2.1.3 Delfi museum

Figure 2-3. Delfi Museum.

Delfi Museum is located in Greece. It is ventilated using a HVAC system with heat recovery and demand control.

2.1.4 SOLAR XXI

Figure 2-4. Solar XXI.

Solar XXI building is located in Portugal.

There is a mechanical extract is used for the main spaces and the air supply is arranged through a set of buried pipes. An internal atrium allows communication with the main spaces via controllable air registers, and in this way promotes natural circulation of the air and air extraction at the top. Night ventilation can be used to promote summer cooling.

2.1.5 Edifício das Pós-graduações (EPG building)

Figure 2-5. Edifício das Pós-graduações (EPG building).

This is a university building, with traditional mechanical systems. There is a heat recovery unit installed and also the free-cooling strategy can be used during the suitable weather conditions. The displacement ventilation is used in the space with high internal loads such

2.1.6 Parque Expo HQ

Insert photo

Figure 2-6. Parque EXPO HQ.

Insert short description of the building

2.1.7 Nordea Bank Vallila

Figure 2-7. Investigation Nordea Bank Vallila.

The Nordea building is located in the city of Helsinki in the south coast of Finland.The building is 26 metres high and is located on a dense urban area just outside the city centre, about one kilometre from the shoreline.

Nordea Helsinki is a seven storey office building completed in 2001. All seven floors are almost identical in size and shape and contain mostly open-plan offices. The total heated floor area of the building is approximately 7000 m² and total volume is approximately 28000 m³. 450 regular office workers work permanently in the building.

The building is connected to the Helsinki area district heating distribution system. Customers receive heat from the hot water circulating in the heating distribution network. The temperature of the district heating water varies usually between 65 °C and 115 °C for the supply and between 40 °C and 60 °C for the returning water, depending on the heat demand. The heat demand depends mainly on the weather and is at its lowest in the summer when heat is needed only for the domestic hot water. Heat extracted from the district heating network is used in the building for domestic hot water and space heating through central air handling units and hot water radiators.

2.1.8 YIK Keskus Turku

Figure 2-8. YIK Keskus Turku.

This is a 5-storey rectangular building with heated basement. There is a large atrium space in the middle of the building. The offices are mainly open plan offices and also cellular offices.

Ventilation is mainly CAV system with active chilled beams. Outdoor air is filtered and heated in an airhandling unit and supplied to rooms. Ventilation air is heated partly with heat recovered from extract air and district heating. Room is heated with hot water radiators. The water is heated with district heating, and flow controlled with thermostatic radiator valves. The air flow is constant to normal office rooms, but is CO2 and temperature controlled to meeting rooms. Supply air flow is selected based on ventilation requirements but is heated or cooled depending on the requirements of the room. Major part of cooling and heating is supplied by the water systems (beams and radiators respectively).

2.1.9 Poikkilaakso School

Figure 2-9.The Poikkilaakso School.

This is an experimental school building, located in Finland, where some elements typical for hybrid systems are combined with mechanical ventilation. The ventilation system is fully mechanical low-pressure system, having central airhandling unit including filtering, heat recovery, etc.

The building serves as an airflow route and there are no suspended ceilings or visible ducts inside. Air handling unit on the top of the roof is connected to large supply air duct on the roof, from which two vertical ducts lead to each classroom having displacement diffusers. Central spaces of the building are ventilated with transfer air from classrooms (no ducts). Extract is from the central hall.

2.1.10 Kildare County Council

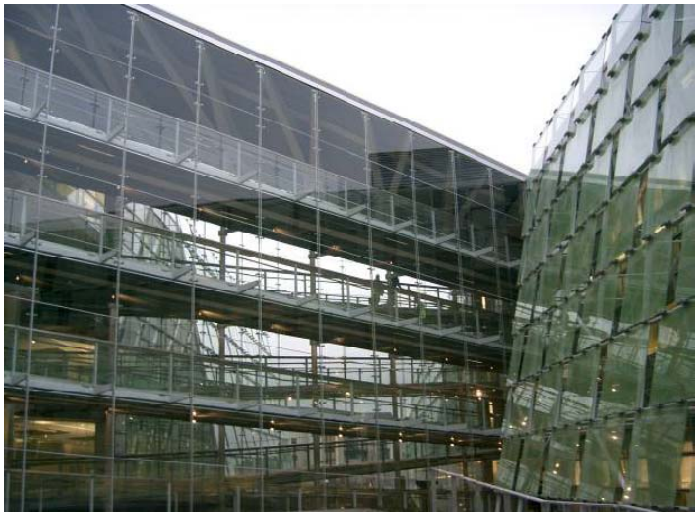


Figure 2-10.Kildare County Council.

Kildare County Council is located in Ireland.
The building is zoned into three areas – natural ventilation, mechanical ventilation, and comfort cooling/air-conditioning.

The total building area is 12,500 m2. The building is arranged in two wings, with a 3 and 4 storey height, connected by a central ramp. Facades are orientated to the East/West, with rain screen cladding applied to reduce solar gains.

2.1.11 Frederick Lanchester Library

The Frederick Lanchester Library is unusual in that it is a deep-plan building occupying a 50m by 50m footprint and is ventilated naturally with no artificial cooling, except for a separate basement storage area which is air-conditioned. In order to provide natural ventilation a tapering central lightwell provides extract ventilation, supplemented by 20 perimeter stacks with a 1.8m by 1.8m cross section. The stacks terminate 6m above roof levels with fittings to prevent reverse flow due to wind pressure. Air entry is via a plenum under the ground floor to the base of four 6m by 6m square corner lightwells. Under the influence of stack effect air is drawn via the four corner lightwells into each floor and extracted via the central lightwell and the smaller stacks. In winter the incoming air is warmed by pre-heating coils at the base of the supply lightwells and by trench heating at the point that the air from the lightwells enters each floor. Cooling is provided passively by thermally heavy-weight ceilings.

By its nature the building has a large number of transient occupants. At the design stage 2,500 entries per day were anticipated. In practice, this has increased to 5,000. In addition a number of staff work permanently in the building. The building is open for use for approximately 4,000 hours per year.

2.1.12 Red Kit House

Figure 2-11. Red Kite House.

Red Kite House is a three-storey building with a total floor area of 2,500 m2. Each floor is principally open-plan office accommodation but includes some enclosed rooms for meetings and special uses. In plan the long dimension is curved in the shape of an arc, with the concave façade facing south. The distance between the south and north facades is 16m. A brise-soleil is situated at roof level on the south façade to provide protection from direct solar gain in the summer months. The brise-soleil incorporates photovoltaic cells which reduce the building's electricity demand on conventional grid supply. Roof-mounted thermal solar collectors provide hot water for washrooms. The building is naturally ventilated by automatically controlled high-level windows on each floor of the main facades. Larger manually operated windows are also available. The ceiling of each storey is exposed concrete. This thermal mass is used in conjunction with night-time ventilation to reduce peak internal temperatures in summer.

2.1.13 Bristol Academy

Figure 2-12. Bristol Academy.

The school is arranged in five villages, each pupil is a member of one village throughout their secondary education. The orientation of classes are mainly NE/SW, however the geometry means that solar exposure occurs in most directions. The school has a sports specialism and has a separate sports centre onsite.

Hybrid Ventilation principle is applied in the building together with ventilation through windows and small supply and extract fans in the ground floor classrooms. Natural air supply is designed through windows in the first floor classrooms with the air extract through motorized openings at high level. Some classrooms have a natural air supply via a buried concrete pipe with a mechanical extract on the ground floor and natural extract on the first. For special rooms cooling is provided from split systems.

2.1.14 Kensington Academy

Figure 2-13. Kensington Academy.

The school had a specialism in the environment and it was the intention of the design team to demonstrate this through design. The school is orientated with main facades facing North/South. The school is organized over 5 levels, from the single level, ground floor Year 7 & 8 classrooms to the three storey full height atrium.

The halls in the basement of the school are mechanically ventilated, incorporating heat recovery and demand controlled ventilation based on carbon dioxide levels in the space. The ICT space, music practice rooms and server rooms have mechanical supply and extract with room Fan Coil Units. Cooling is supplied via a Variable Refrigerant Flow, heat-recovery air-source heat-pump. This allows heat to be effectively moved between zones and suits a simultaneous heating and cooling demand. Science and technology rooms on the ground and first floor teaching blocks are mechanically ventilated to reduce noise ingress, however the second and third floor classes are naturally ventilated due to a dispensation to save money. The ETFE atria is naturally ventilated on the South side and extracts at high-level on the North facade, through an external plant room.

2.1.15 Office Ministry of Transport

Figure 2-14. Office Ministry of Transport.

The building is built in Netherlands. It has a spherical triangular shape in which the floor levels rise like a snail-shell. In the centre of the building is an atrium with a glazed roof. The building houses 60 employees and has a gross area of about 1350 m^2.

An advanced natural ventilation system provides fresh air and controls the thermal comfort in summer. Opening of the inlet grills is constantly adjusted as function of the air velocity through the opening. From office rooms the airflow is led to the central atrium via overflow openings in the internal separation walls. Overflows are custom-made and acoustical absorption in the opening provides a good sound insulation. Air is exhausted through openings in the atrium roof.

2.1.16 Københavns Energi, Vejlandshuset

Figure 2-15. Københavns Energi, Vejlanshuset.

Københavns Energi is a cube-shaped building with an atria-space in the middle. This is 5-storey, open space office building with approximately 400 employees.

The building is naturally ventilated, except for the ground floor, which is mechanically ventilated. Natural ventilation is time, CO2 and temperature controlled. There is a possibility for the manual control of ventilation system in the building. The occupation density in the building varies from floor to floor and therefore the control over the IAQ and comfort conditions is carried out in each thermal zone separately.

2.1.17 CHH– Christophorus Haus MIVA

Figure 2-16. CHH– Christophorus Haus MIVA.

This project describes the new built office building of the Catholic Church association "MIVA". The association is active in development cooperation and mission work. One of their activities is to prepare all kinds of vehicles for developing countries. Therefore the building is of multifunctional use. Office building is combined with a logistics centre, there is also a warehouse for the aid shipments of BBM, a car-wash, premises for events and seminars, a world-shop, exhibition areas and a catering kitchen.

The office building with 1,215 m² is a work place for 40 persons. The remaining building area is used for parking of the company's cars (325 m²) and basement (550 m²). The building has a basement, a ground floor and two upper floors.

2.1.18 SFO Spirehuset

Figure 2-17. SFO Spirehuset

The building is located in a smaller town Hirtshals on the Northern coast of Denmark. In a neighbourhood of SFO Spirehuset, there are mainly one-storey buildings and some greeneries without any tall trees The distance from Spirehuset to the nearest buildings is quite long and therefore Spirehuset is well exposed to wind and sun. However there is a small artificial hill 150m away from South-West facade. The area around the building can be identified as suburban.

SFO Spirehuset is one storey building, which functions as an after- and before- school institution. At the peak hours the institution can be occupied maximum by 100 pupils and 5-6 adults. The age of pupils at the institution is from 6 to 12 years old.

The building is divided into several zones, which are connected by an open-space common room. 5 of these zones are directly connected to the common room, while 5 smaller rooms can be closed. Room height in the common room is significantly higher than in the other rooms.

The core part of the building is wooden construction, while all appendixes to the building made of brick.

The building is naturally ventilated, except for toilets and kitchen. According to Danish building regulations toilets and kitchen must have a mechanical exhaust.

Natural ventilation is automatically controlled, but users have a possibility for manual control (opening windows) and can change the control strategy in the building, if needed. The natural ventilation principle is combined with the night cooling strategy, which is activated during warmer seasons.

Due to the cross-stack ventilation principle used in the building, there is a number of roof windows designed for the exhaust air, but also to provide sufficient level of day lighting. Good level of the day lighting together with smooth automatic light control ensures minimal use of energy for lighting. This is especially relevant when dealing with children, who can often forget to turn off the light when leaving a room.

Roller blinds installed in the windows as an option for internal shading, however these are rarely used, as an actual shape of the building is shading the large glazing areas, serving as a protection from direct solar gains.

Special sound reducing finish is used at the internal surfaces in Spirehuset, to improve acoustical qualities of the building.

Results of questionnaire surveys for 18 buildings

3. OVERALL RESULTS

In this section the background for further synthesis of the results will be established using the overall results of questionnaire survey for 18 buildings.

The Table 3-1 presents a complete overview of user evaluation in each building. Graphically this information is presented in the following sections and it will be investigated whether there any correspondence between the control possibilities and the level

Control possibilities over the indoor air quality and comfort are evaluated only in 11 buildings and the level of satisfaction with these possibilities is low for the majority of those buildings. In the following sections it will be investigated whether there any correspondence between the control possibilities and the level of satisfaction with the indoor environment and comfort in the buildings.

The highest level of satisfaction between the occupants in the buildings is seen with regard to the artificial lighting and day light. The average level of satisfaction with the light conditions is 65%.

Good scores are also characteristic when the overall comfort conditions are evaluated.

In the Figure 3-2, one can observe distribution of votes of satisfied occupants by each building. It is seen that there is a number of buildings with relatively low overall level of satisfaction. However, buildings with low satisfaction votes were investigated in detail, together with reasons for dissatisfaction, pointed out by the occupants.

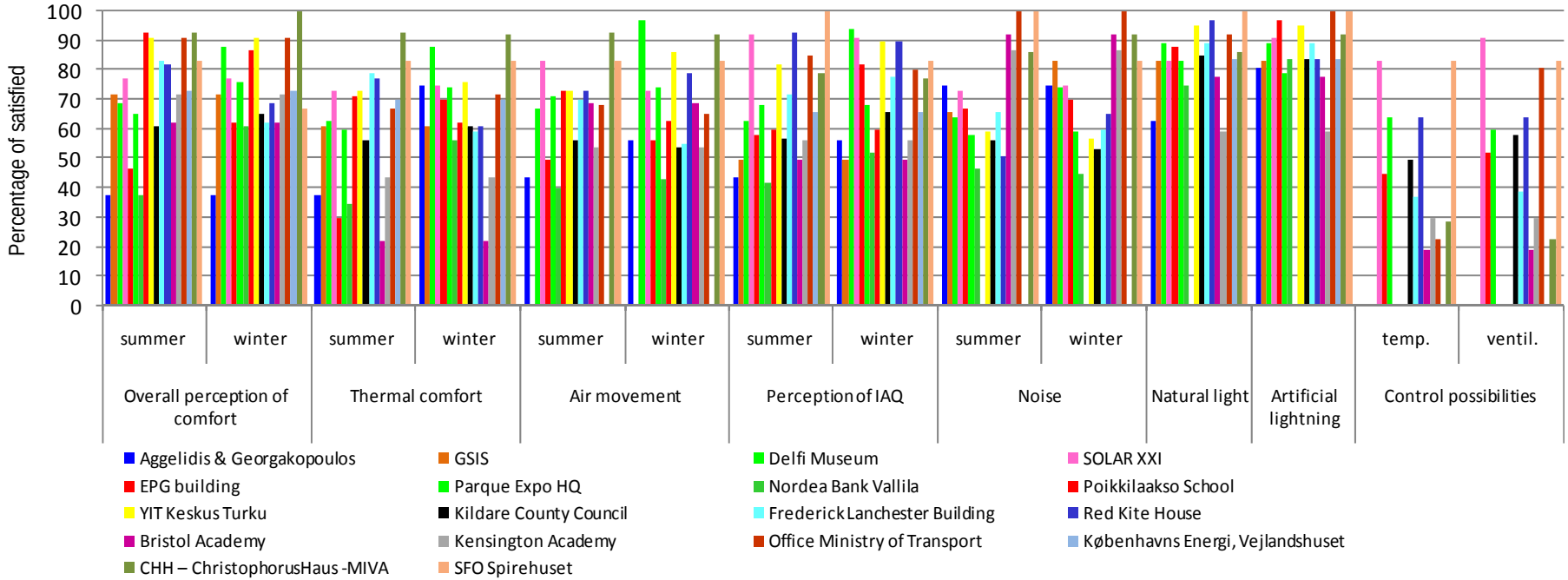


Figure 3-1. Summary over the results from occupant surveys by building.

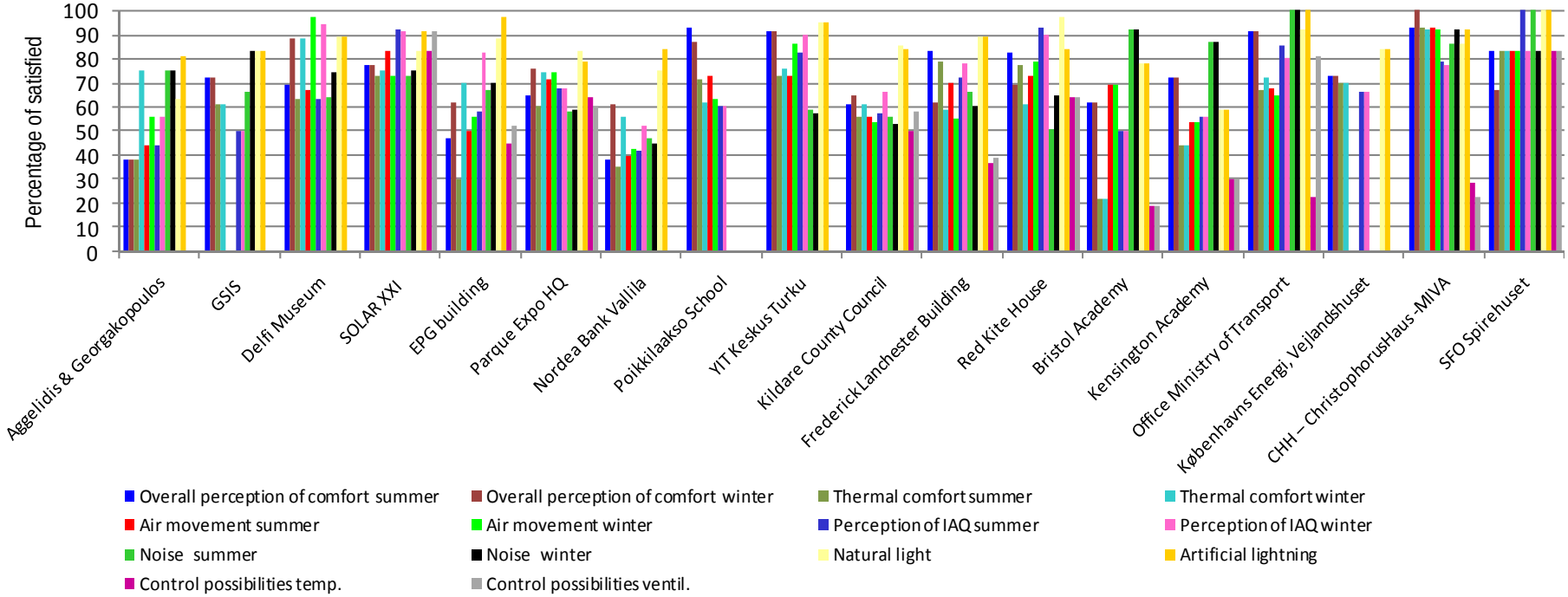


Figure 3-2. Summary over the results from occupant surveys by comfort parameter.

Building	Country	Number of responses received	Overall perception of comfort		Thermal comfort		Air movement		Perception of IAQ		Noise		Natural light	Artificial lighting	Control possibilities	
			summer	winter	summer	winter	summer	winter	summer	winter	summer	winter			temp.	ventil.
uropean Climates with High Cooling Load																
Aggelidis & Georgakopoulos	Greece	16	38	38	38	75	44	56	44	56	75	75	63	81		
GSIS	Greece	74	72	72	61	61			50	50	66	83	83	83		
Delfi Museum	Greece	33	69	88	63	88	67	97	63	94	64	74	89	89		
SOLAR XXI	Portugal	19	77	77	73	75	83	73	92	91	73	75	83	91	83	91
EPG building	Portugal	42	47	62	30	70	50	56	58	82	67	70	88	97	45	52
Parque Expo HQ	Portugal	75	65	76	60	74	71	74	68	68	58	59	83	79	64	60
European Climates with High Heating Load																
Nordea Bank Vallila	Finland	35	38	61	35	56	40	43	42	52	47	45	75	84		
Poikkilaakso School	Finland	16	93	87	71	62	73	63	60	60						
YIT Keskus Turku	Finland	22	91	91	73	76	73	86	82	90	59	57	95	95		
European Climates with Moderate Cooling Load and Heating Load																
Kildare County Council	Ireland	152	61	65	56	61	56	54	57	66	56	53	85	84	50	58
Frederick Lanchester Building	UK	47	83	62	79	59	70	55	72	78	66	60	89	89	37	39
Red Kite House	UK	143	82	69	77	61	73	79	93	90	51	65	97	84	64	64
Bristol Academy	UK	38	62	62	22	22	69	69	50	50	92	92	78	78	19	19
Kensington Academy	UK	39	72	72	44	44	54	54	56	56	87	87	59	59	30	30
Office Ministry of Transport	Netherlands	26	91	91	67	72	68	65	85	80	100	100	92	100	23	81
Københavns Energi, Vejlandshuset	Denmark	366	73	73	70	70			66	66			84	84		
CHH – ChristophorusHaus -MIVA	Austria	17	93	100	93	92	93	92	79	77	86	92	86	92	29	23
SFO Spirehuset	Denmark	6	83	67	83	83	83	83	100	83	100	83	100	100	83	83

Table 3-1. Summary over the results from occupant surveys.

4. PARAMETRIC STUDY

In this section all parameters evaluated in the questionnaire survey will be assessed quantitatively, by comparison with other buildings, their ventilation principles and building use.

In number of buildings the perception of indoor environment and comfort, thermal comfort and IAQ are evaluated for the whole year, without seasonal considerations i.e. summer/winter seasons. These buildings are:

- Aggelidis and Georgakopolous building
- GSIS building
- Vejlandshuset
- Bristol Academy
- Kensington Academy
- Office Ministry of Transport
- Københavns Energi, Vejlandshuset

In this chapter, in order to be able to compare between the buildings, all of survey results will be presented as an average value for the whole year, thus without seasonal separation to summer and winter conditions.

4.1 OVERALL PERCEPTION OF INDOOR ENVIRONMENT AND COMFORT

For all of the buildings, except for Nordea Bank, Aggelidis&Georgakopoulos building and EPG-building the satisfaction rate with overall comfort conditions is above 60%.

In general, it is seen that for moderate climates users are well satisfied with the naturally ventilated buildings (Figure 4-1). With regard to the mechanical ventilation, there are both cases (Figure 4-2): satisfied and dissatisfied. Rather good evaluation is received from the occupants for the hybrid ventilated buildings in moderate climates.

However, due to the limited data the above statements must be considered carefully.

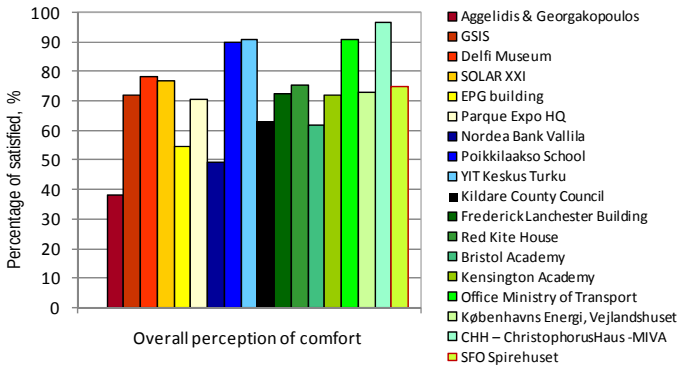


Figure 4-1. Overall perception of indoor environment and comfort from the questionnaire results for the whole year.

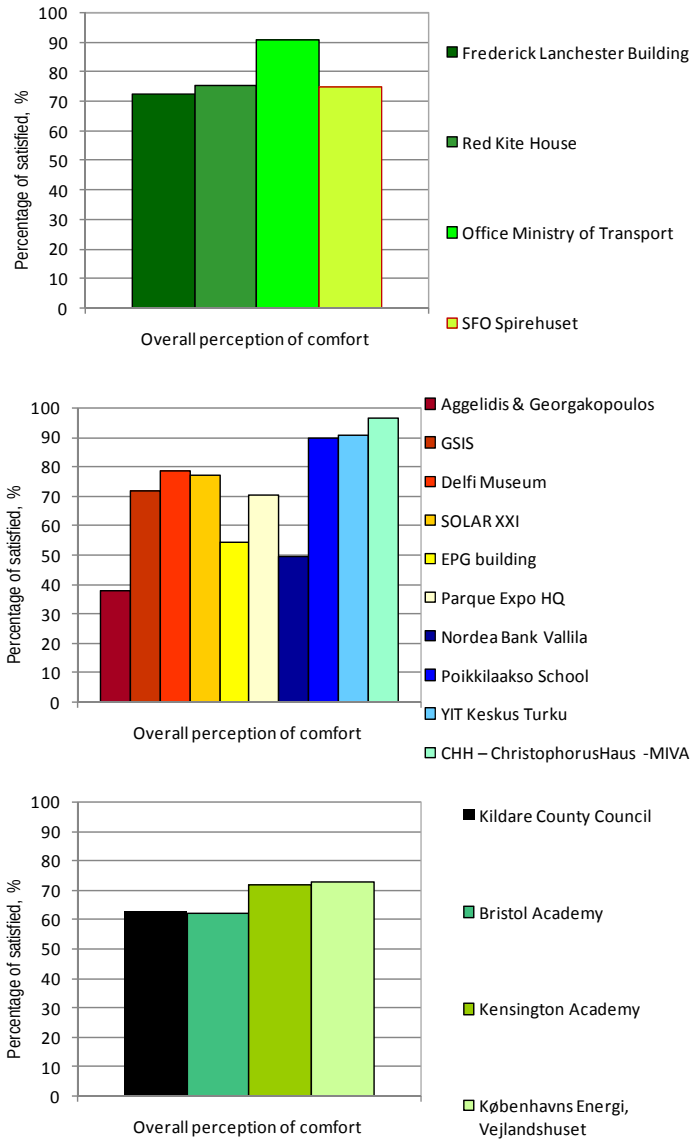


Figure 4-2. Overall perception of indoor environment and comfort as an average value for the whole year. 1- in naturally ventilated buildings. 2- in mechanically ventilated buildings. 3- hybrid ventilated buildings.

4.2 PERCEPTION OF IAQ

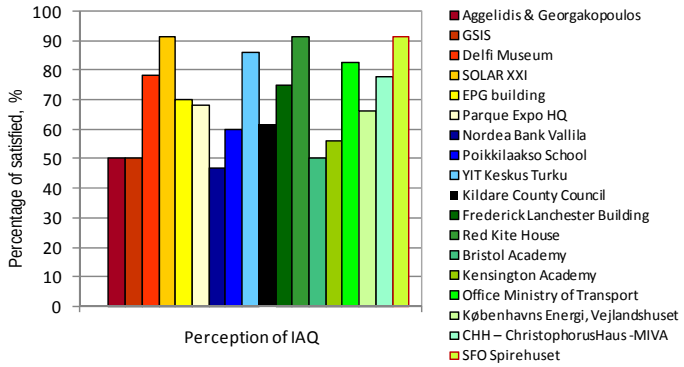
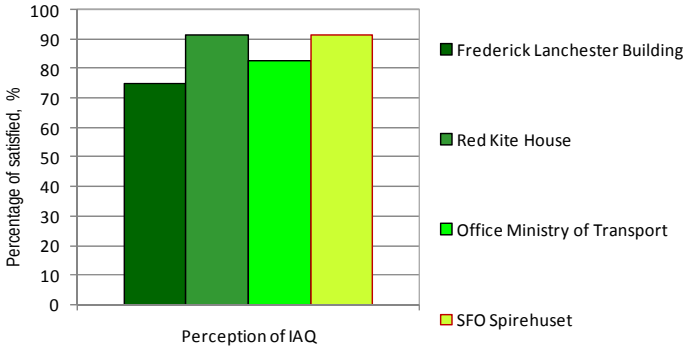
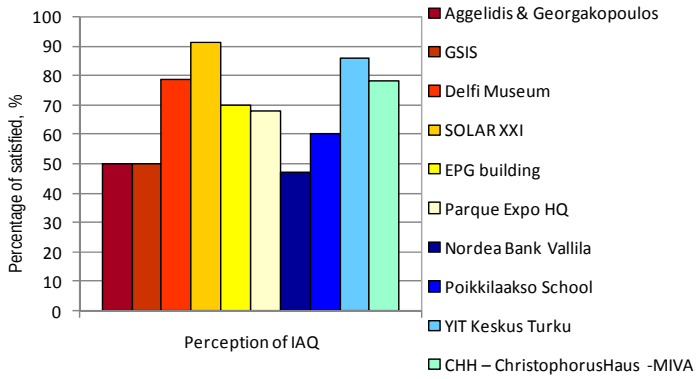


Figure 4-3. IAQ from the questionnaire results





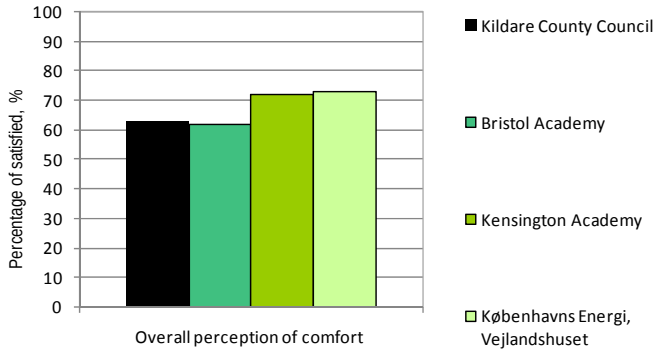


Figure 4-4. IAQ from the questionnaire results, divided into groups: 1- in naturally ventilated buildings. 2- in mechanically ventilated buildings. 3- hybrid ventilated buildings.

In the above Figure 4-4, it is seen that satisfaction with the indoor air quality is very good in the naturally ventilated buildings (above 71% of satisfied). In the mechanically ventilated buildings the level of satisfaction varies a lot between buildings. As it was explained earlier, low satisfaction rate is characteristic for the buildings with low response rate and can be misleading.

4.3 PERCEPTION OF THERMAL COMFORT

Perception of thermal comfort in the buildings is different from perception of IAQ. This time naturally ventilated buildings perform well (more than 62% of satisfied), but the level of satisfaction has been reduced if compare to IAQ score of above 70% of satisfied.

In the mechanically ventilated buildings the thermal comfort was evaluated as satisfactory in 7 out of 10 buildings with the vote above 60% of satisfied.

Finally in the hybrid ventilated buildings only Københavns Energi building exceeded 60% of satisfaction votes.

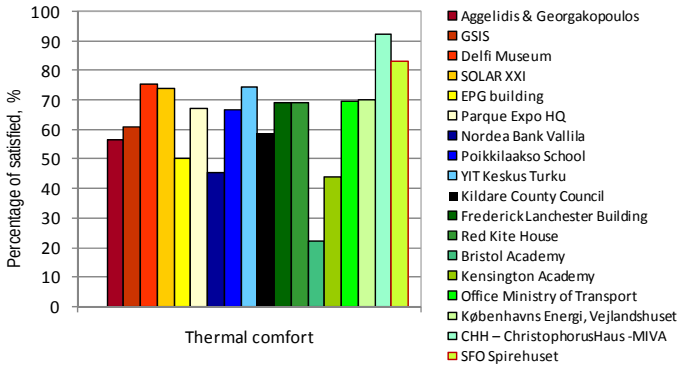


Figure 4-5. Perception of thermal comfort.

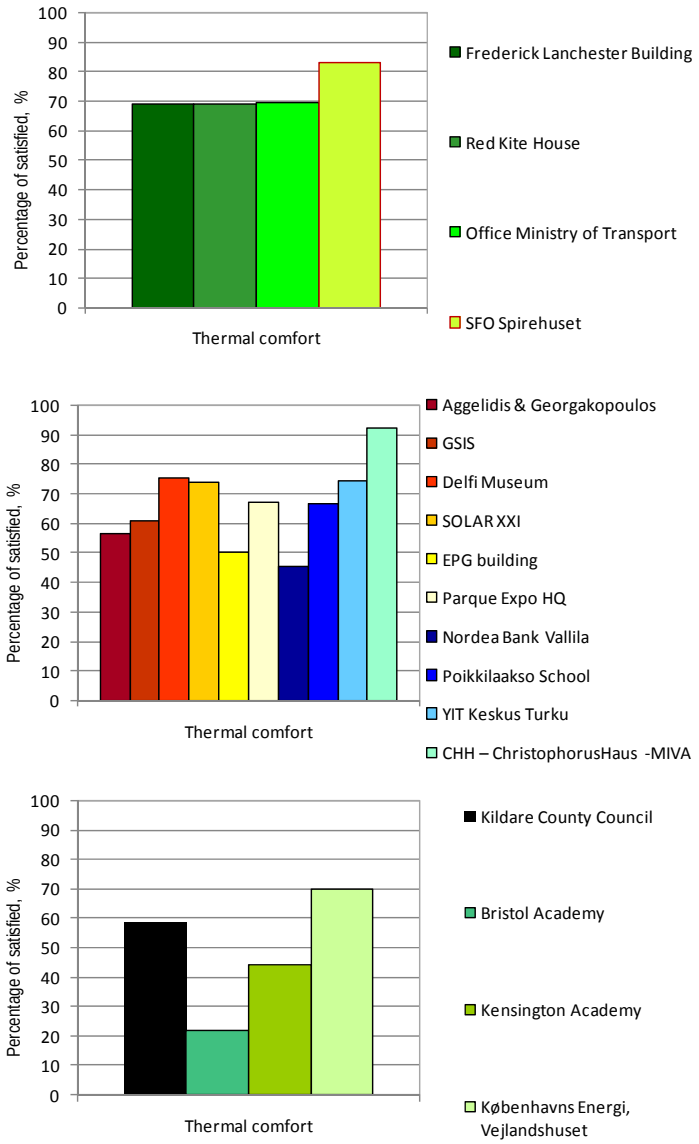


Figure 4-6. Perception of thermal comfort. Results divided into groups: 1- in naturally ventilated buildings. 2- in mechanically ventilated buildings. 3- hybrid ventilated buildings.

4.4 AIR MOVEMENT AND DRAUGHT

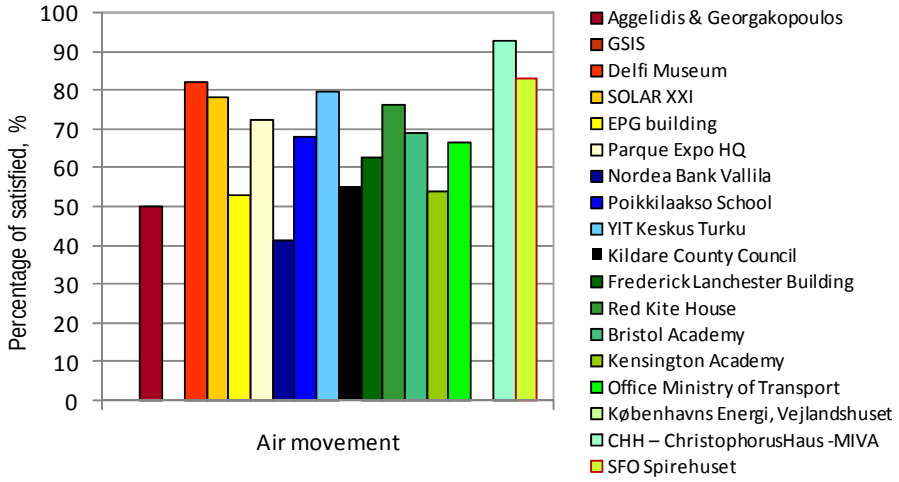


Figure 4-7. Perception of air movement and draught.

It is apparent that there is generally low satisfaction rate between the occupants when movement and draught is evaluated (Figure 4-7). This denotes rather low satisfaction rate, without any preference to one or another ventilation principle between users.

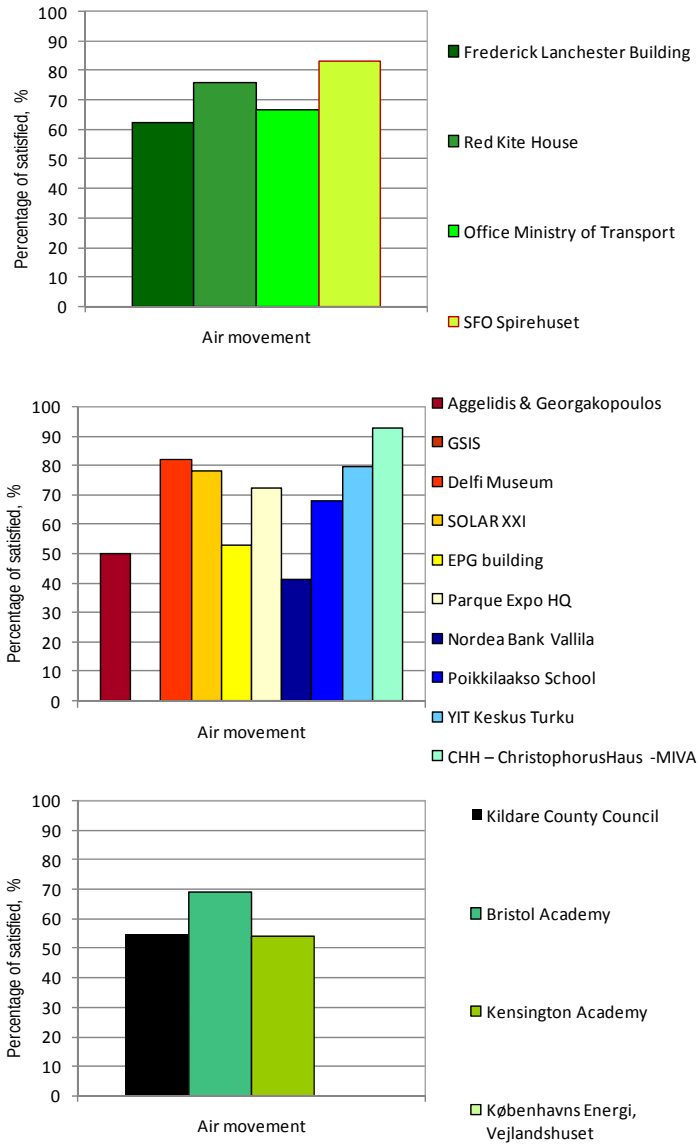


Figure 4-8. Perception of air movement and draught. Results divided into groups: 1- in naturally ventilated buildings. 2- in mechanically ventilated buildings. 3- hybrid ventilated buildings.

4.5 NOISE

A source of acoustical discomfort in the buildings, besides activities in the building can be in mechanically ventilated buildings from the ventilation system, ducts and inlets. In naturally ventilated buildings the noise can come from the outdoors through the ventilation openings to outdoors.

Number of buildings have got a low score when their acoustical comfort is evaluated (Figure 4-9). This is because most of them are the open space offices or highly occupied buildings, resulting in increased noise level in the occupied areas.

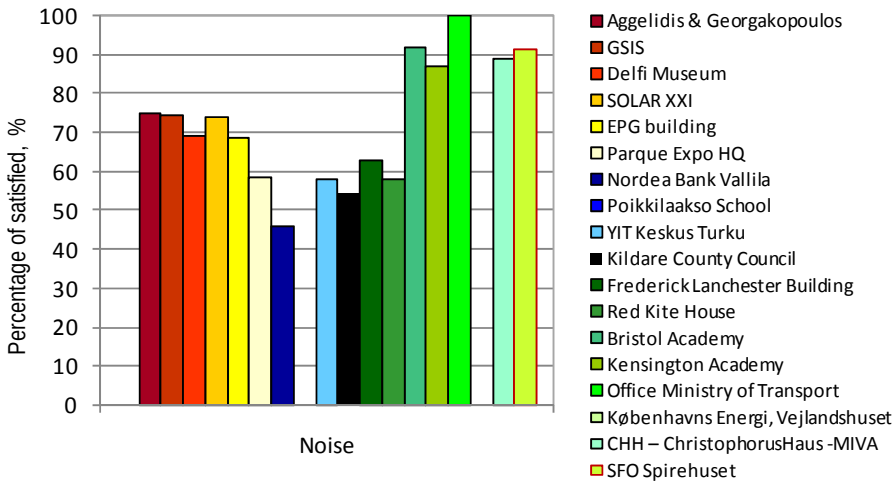


Figure 4-9. Perception of acoustic comfort.

4.6 NATURAL LIGHT AND ARTIFICIAL LIGHT

Questions about natural light were included into the questionnaire, as it is considered to be a significant comfort criterion. The users were asked about their opinion in general, without seasonal distinguishing between the light conditions in summer and winter.

In the Figure 4-10 it is seen that for the majority of buildings, users are well satisfied with the light conditions. For all buildings, except for Kensington Academy, the level of satisfaction is above 70%.

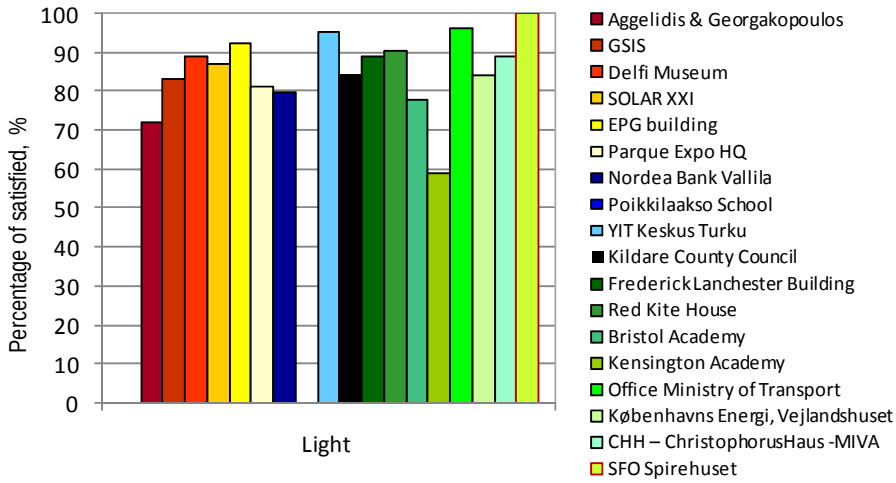


Figure 4-10. Perception of natural and artificial light.

4.7 CONTROL POSSIBILITIES

Questions with regard to control possibilities of room temperature and ventilation were asked only in 11 out of 18 buildings. It is interesting that most users evaluate their control possibilities as very limited, even in buildings with high level of satisfaction with the indoor air quality a comfort (Figure 4-11,Figure 4-12). When the occupants were asked about their need to be able to control comfort conditions in the room, most of users have answered that they need to be able to control conditions in the room.

In addition, users were asked how much do they need to be able to control the room air temperature and ventilation in particular. As a result no preferences were given to control of the room temperature neither to control of ventilation system. Users have evaluated that they need these possibilities and nearly equal level.

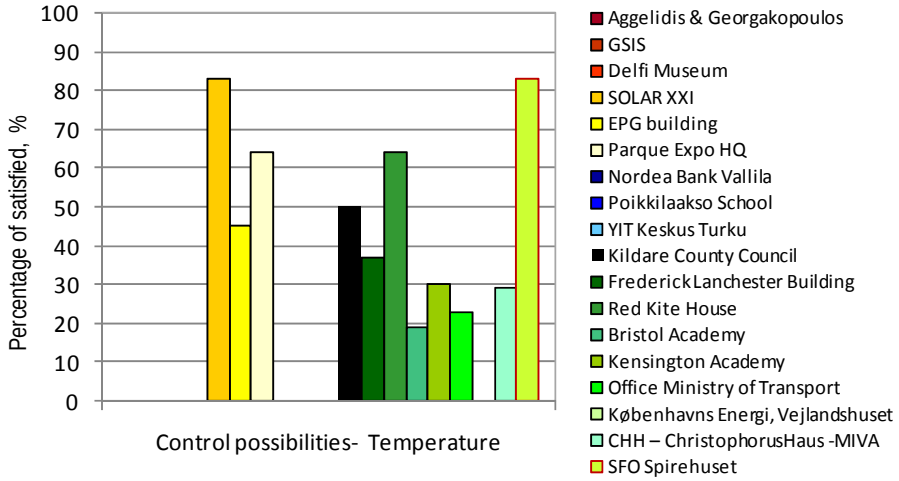


Figure 4-11. Possibility to control room temperature.

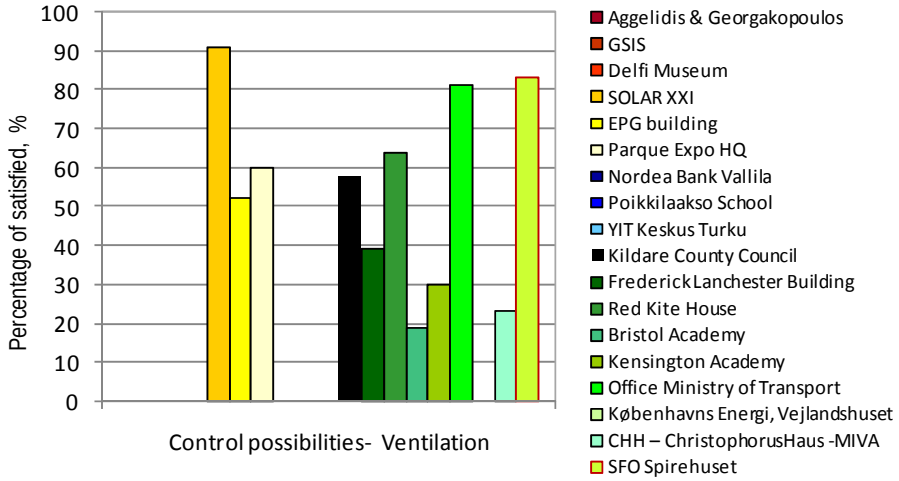


Figure 4-12. Possibility to control ventilation.

Observations, with regard to control possibilities in the buildings, confirm that user wish to be able to control the room temperature and ventilation in the room. Improved control possibilities of ventilation system follow higher satisfaction vote for IAQ. The same tendency is seen when compare possibilities for temperature control and satisfaction votes with thermal comfort.

5. DISSATISFACTION

5.1 GENERAL

Earlier, 18 buildings in the Building AdVent project were investigated with regard to comfort conditions and level of satisfaction with these conditions between the users. It has already been shown that the level of satisfaction with comfort in these buildings is very different. Some buildings were rated as buildings with insufficient comfort conditions, while the others appeared to provide the superior indoor air quality and comfort.

It was aimed to investigate buildings which are located in the different climatic zones with significantly different cooling and heating loads during year. Moreover, the building use varies radically from a small office building to a large headquarter office with numerous occupants, some of the buildings are represented by schools, libraries, research centres, governmental institutions, museums and storage buildings. Finally, heating, ventilation and air conditioning systems in these buildings are significantly different from each other, and as a consequence these buildings represent a wide spectrum of possible reasons for discomfort experienced by the occupants in those buildings. In addition, reasons for discomfort will also depend on building use, occupancy, occupant age and sex, operating strategy in the building, etc.

Despite the dissimilarity in building performances, certain advantages and disadvantages are characteristic for different ventilation principles in terms of comfort and indoor air quality. In this section the results of user satisfaction survey are investigated to distinguish reasons for dissatisfaction between the occupants with indoor air quality and comfort in 18 buildings, characterised by different climatic zones and ventilation principles.

The dissatisfaction results are available only for 15 buildings. All results are combined and illustrated in Figure 5-1. From the figure it is seen that the majority of problems are pointed by the occupants are:

- Stagnant air
- Draught
- Stuffy air
- Too cold, too warm or too varying air temperature
- Noise from the activities in the building

Next, the reasons for discomfort in the buildings named by the occupants must be studied in detail according to ventilation principles in the building and climatic zone it is located in. This is investigated in the following sections.

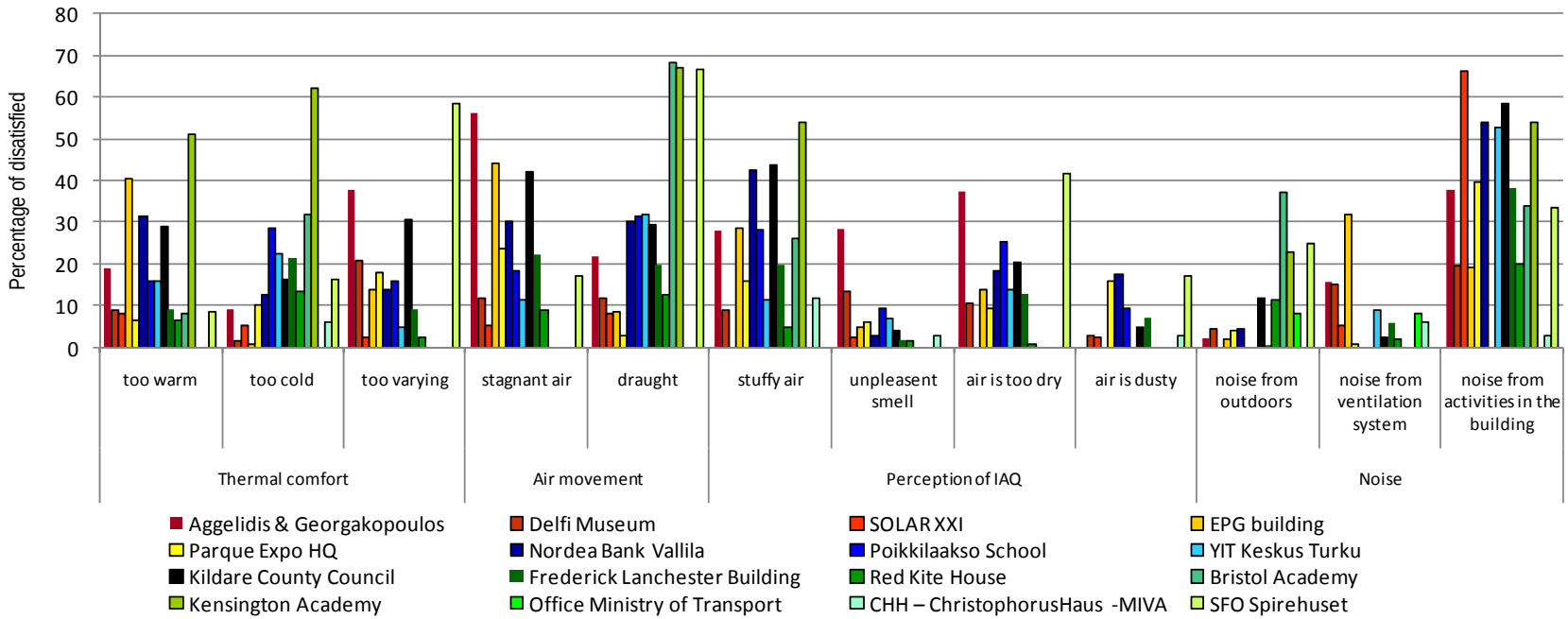


Figure 5-1. Reasons for discomfort experienced by occupants in 18 buildings.

5.2 VENTILATION PRINCIPLE

In this section the response from the occupants and reasons of their dissatisfaction are studied according to the ventilation principle used in the building.

5.2.1 Mechanically ventilated buildings

There are 9 mechanically ventilated buildings with all-inclusive questionnaire survey results available.

In Figure 5-2, it is seen that many different reasons for discomfort are pointed out by the users. These must be evaluated critically, as some users may prefer warmer and the others cooler air temperature, some of them can be very sensitive to smell and the others can be sensitive to noise. This is the reason why nearly each parameter in the figure has been pointed out. However, the questionnaire format was prepared so, that user had to explain about their reasons for dissatisfaction *only* if they were dissatisfied with corresponding comfort parameter.

From Figure 5-2 it is seen that there are many occupants who are dissatisfied with the air movement in the buildings, air quality (stuffy air), air temperature (too warm), air movement and noise from the activities in the building. The noise from the activities in the building has been discussed earlier and user dissatisfaction is explained by the open space offices. Therefore it will not be discussed further.

In the previous paragraph the observation was made according to percentage of dissatisfied as evaluation criteria. Therefore the parameters with the highest vote were pointed out. High voting rate for some particular buildings can be caused by the building use, building operation etc. This however does not apply for all mechanically ventilated buildings. Therefore it is also important to consider the results in Figure 5-2 according to number of buildings where complains were received. For example complain about unpleasant smell and too cold air temperature was received for all 9 buildings considered. There are also complains about too warm and too varying air temperature, air movement, stuffy air and noise from ventilation system was pointed out in 8 out of 9 buildings.

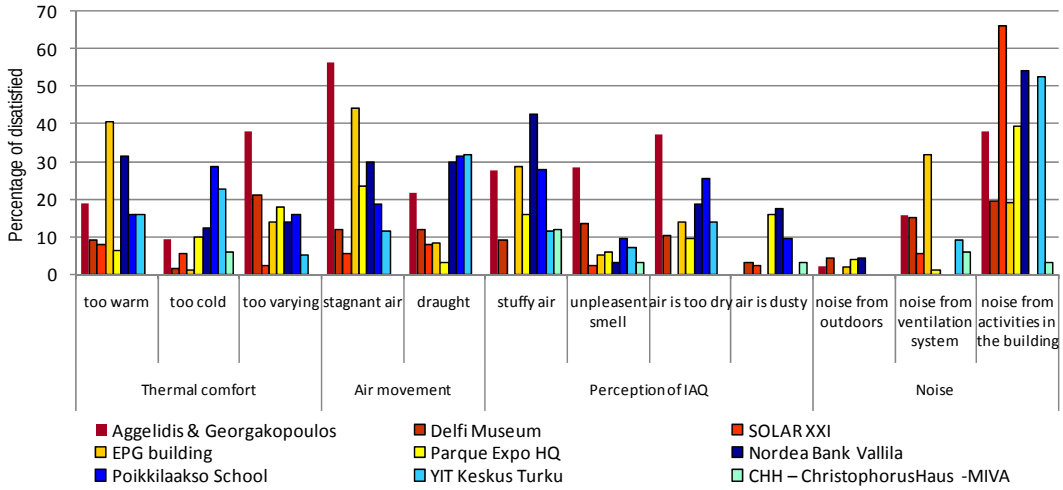


Figure 5-2. Reasons for dissatisfaction with indoor air and comfort in mechanically ventilated buildings.

5.2.2 Naturally ventilated buildings

Similarly to the previous section, Figure 5-3 illustrates reasons for dissatisfaction between the occupants with the comfort conditions and IAQ in naturally ventilated buildings. Unfortunately this information is available only for 4 buildings.

The most significant reasons for dissatisfaction are due to inappropriate air movement in the buildings (the air is either stagnant or it is draughty), too cold/too varying air temperatures and noise from outdoors.

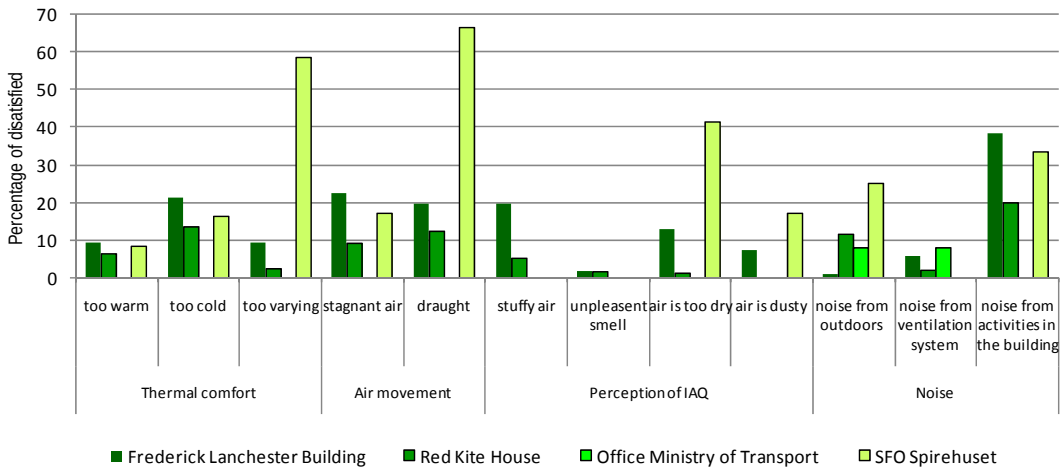


Figure 5-3. Reasons for dissatisfaction with indoor air and comfort in naturally ventilated buildings.

5.2.3 Hybrid ventilated buildings

There are 3 buildings in the project that are hybrid ventilated. These combine positive and negative aspects of naturally and mechanically ventilated buildings.

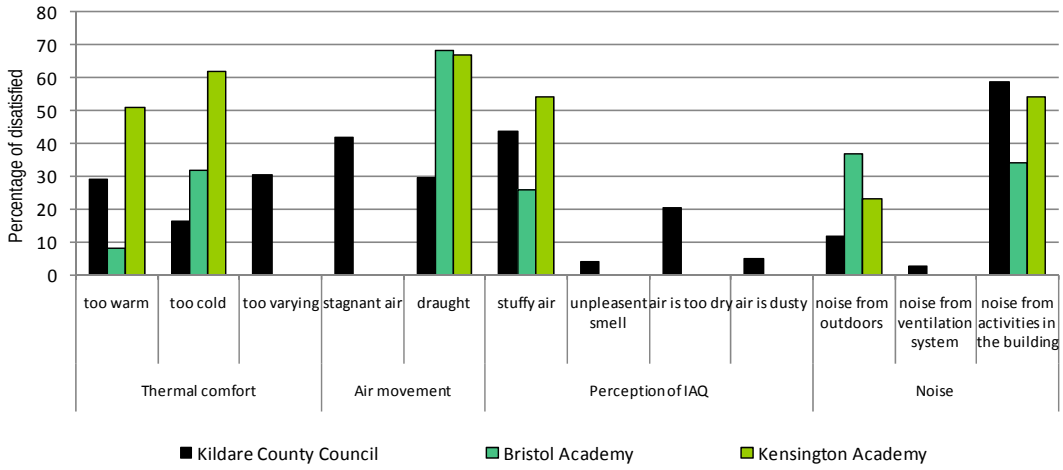


Figure 5-4. Reasons for dissatisfaction with indoor air and comfort in hybrid ventilated buildings.

5.3 CLIMATE

In this section the response from the occupants and reasons for their dissatisfaction are studied according to the climatic conditions.

The data is available only for 5 buildings in hot and 3 buildings in cold climates, while most of information is available for the moderate climates. Consequently, any statements with regard to cold climatic regions are limited, due to the lack of reference data.

5.3.1 Hot climates

From Figure 5-5, it is seen that the main problems are:

- Stagnant air
- Draught
- Unpleasant smell
- Too warm/too varying air temperature
- Noise from activities in the building

Are seen to be present in both buildings

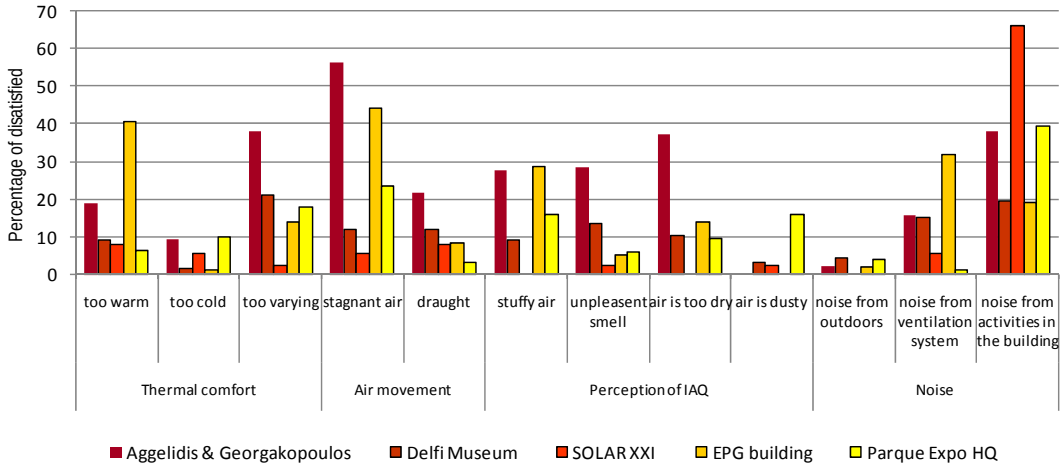


Figure 5-5. Reasons for dissatisfaction with indoor air and comfort in buildings located in hot climate.

5.3.2 Cold climates

In the cold climates, however, most of the parameters have been named by the occupants in all 3 buildings. More case studies are necessary for further representation and synthesis of these results.

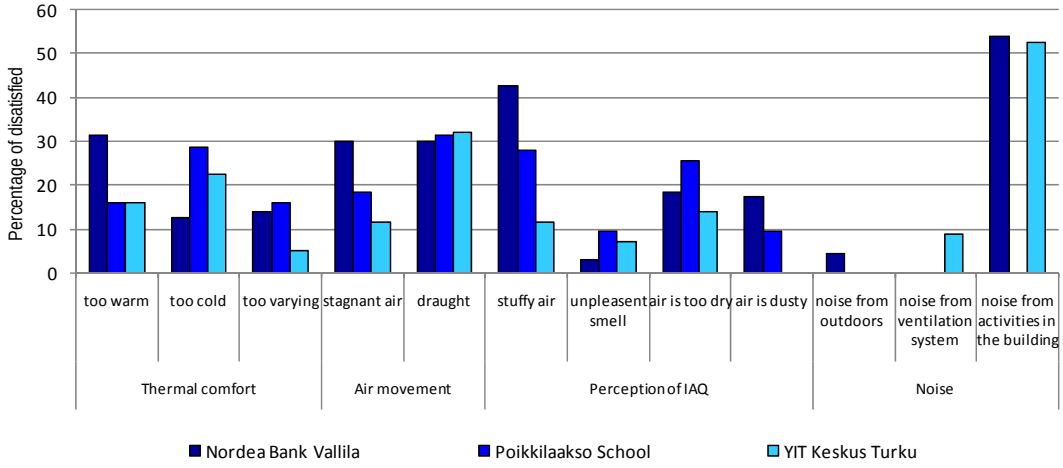


Figure 5-6. Reasons for dissatisfaction with indoor air and comfort in buildings located in cold climate.

5.3.3 Moderate climates

Moderate climate is represented by six buildings with the complete questionnaire survey data. The results are illustrated in the Figure 5-7. The moderate climate is represented by buildings with the wide spread of ventilation strategies and building use. As a consequence many different reasons for dissatisfaction between users can appear. Parameters that were identified by users in most buildings are as following:

- Stuffy air
- Draught
- Too cold/too warm air temperature
- Noise from the activities in the building

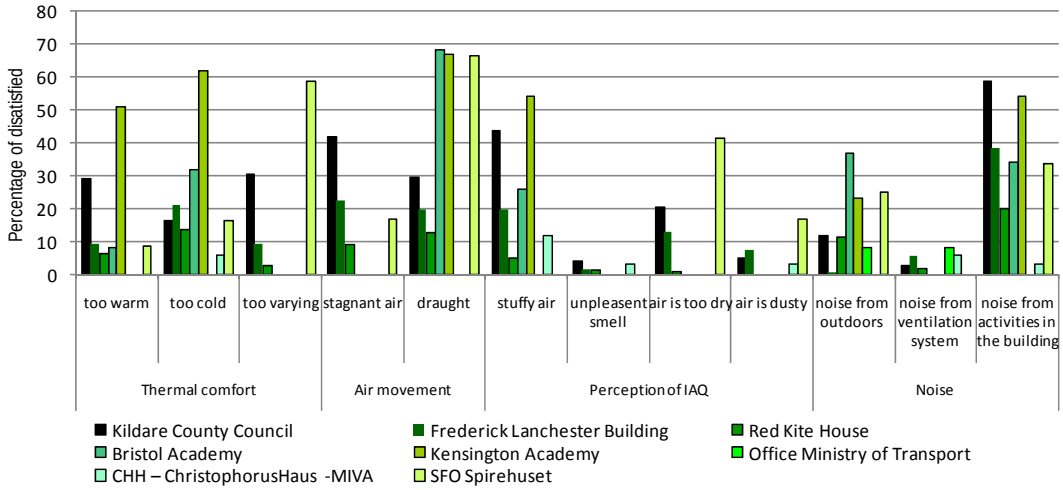


Figure 5-7. Reasons for dissatisfaction with indoor air and comfort in buildings located in moderate climate.

Summary

6. SUMMARY

6.1 OVERALL QUESTIONNAIRE RESULTS

Results from occupant questionnaire surveys in 18 case studies from Building AdVent project are summarized in this report with the focus on user acceptability of ventilation technologies.

In many case studies results from questionnaire survey were obtained within other than Building AdVent projects, leading to some limitations within the data treatment and analysis. The limitations present in this report are described in detail in section 1.4.

Due to the limitations of the data, all results in this report are assessed on a yearly basis, without any consideration of summer/winter seasons.

In general, it is seen that there is no preference between the users with regard to one or another ventilation technology. Users' satisfaction varies from building to building and no clear pattern of user preferences can be observed from the plots of overall results (Figure 3-1, Figure 3-2) or further analysis in chapter 5.

A parametric study is carried out to assess whether the climatic zone the building is located in or the ventilation principle in the building has any effect on user satisfaction with IAQ, thermal comfort, air movement and noise in particular. As a result it was found that:

- The level of satisfaction with the indoor air quality in naturally ventilated buildings is good (above 71% of satisfied). In the mechanically ventilated buildings the satisfaction rate with overall comfort conditions is spread between 38-98%. In hybrid ventilated buildings it is between 60-74%.

- Thermal comfort satisfaction rate appeared to be similar to overall perception of comfort.

- User satisfaction with air movement in the buildings is generally low. This low satisfaction vote is independent of ventilation principle used in the building or climatic zone the building is located in. The satisfaction rate is below 70% for most of the case-studies.

- Noise problems are present in almost all case studies

- For all buildings, except for Kensington Academy the level of satisfaction with the natural and artificial light is above 60%

In the above statements, climatic conditions were not discussed. This is due to the lack of reference data, as for each climatic zone the case studies represent different ventilation principles and building performance, as well as occupant perception changes significantly.

Observations, with regard to control possibilities in the buildings, confirm that user wish to be able to control the room temperature and ventilation in the room. It is interesting that at nearly equal level, users desire to be able to control the room temperature and ventilation.

Furthermore, reasons for dissatisfaction with indoor air quality and comfort in buildings, identified by occupants, are examined with regard to ventilation principle. It is done for a limited number of case studies, as all-inclusive results from questionnaire survey are available for only 15 case studies. However, this amount of data is still not enough for further conclusions and it can only be used to identify general tendencies.

First of all it was argued that it is unreasonable to focus on those parameters which are described by the maximum number of dissatisfied in one or two buildings. The parameters which require most of attention are those, which are identified by occupants in all or almost all buildings with the high percent of dissatisfaction rate. As a result, the main reasons for dissatisfaction between occupants in the mechanically ventilated buildings are:

- Noise from activities in the building (identified in 8 out of 9 buildings)
- Stagnant air (identified in 8 out of 9 buildings)
- Draught and stuffy air (identified in 8 out of 9 buildings)
- Too varying/too high air temperature (identified in 8 out of 9 buildings)
- Unpleasant smell (identified in 9 out of 9 buildings)

Results from naturally ventilated case studies are available only for 4 of them. The occupants in these buildings agree when identifying their reasons for dissatisfaction, which are as following:

- Noise from activities in the building
- Stagnant air /draught
- Too varying/too low air temperature
- Noise from outdoors (identified in 4 out of 4 buildings)

The reasons for dissatisfaction in hybrid ventilated buildings, as appeared, combine those that were already identified for naturally and mechanically ventilated buildings.

Noise from the activities in the building has been pointed out as one of most significant problems in all case studies. In many cases it is explained by the open plan office or highly occupied areas in the buildings.

6.2 QUESTIONNAIRE RESULTS IN THE CONTEXT OF BUILDING OPERATION AND OCCUPANT BEHAVIOUR

In Figure 3-1 it is seen that the level of satisfaction with indoor air quality and comfort between the buildings is significantly different. For many parameters the satisfaction rate is just above 60%.

It theory, buildings which perform well in terms of indoor air quality and comfort should have a satisfaction rate of at least 80%. However, user perception of indoor air quality and comfort is not only physical, but psychological as well: general mood and culture in a company, building architecture, management and policy in a company, etc. has a lot to say about the occupant's perception of comfort.

In D7 report of results of user satisfaction surveys it was already explained that for a number of buildings i.e. Nordea Bank and Københavns Energi, the change in the internal policy and organisational issues in the company were the main reasons for dissatisfaction between the occupants, as monitoring results of indoor air quality and comfort have not revealed any significant problems in building performance.

In many cases, it was discovered that the building operation was not appropriate, as its application was significantly different from the intended application. Therefore the ventilation system designed for the building cannot provide the desired comfort level, leading to increased concentration of carbon dioxide and/or overheating problems. One of the most relevant to this topic issue is overload of certain thermal zones with occupants, while other thermal zones in the building stay empty (i,e. local increase of occupant density was observed in Københavns Energi building and SFO Spirehuset, overall increase of employees documented in Nordea bankbuilding). In the other buildings i.e. Delfi Museum, number of occupants can vary a lot and therefore some situations with lower comfort conditions in the building can appear when the occupant density is higher than expected.

For the renovated buildings (i.e. GSIS building) the satisfaction level with indoor air quality and comfort between the occupants is rather low. This, however, must be seen in the context of occupants' perception to these indoor parameters prior and after the renovation. When this is considered, significant improvement in building performance is evident.

It is also seen that in open space offices, the overall satisfaction with comfort, as well as IAQ and thermal comfort score is very low, especially if manual control possibilities are present. The impact of occupants opening or closing windows or changing the set point for thermostat on individual thermal comfort is the main reason for general dissatisfaction. The impact of other occupants' behaviour on personal comfort should not be underestimated.

In some buildings, incomplete installations for the moment of questionnaire survey (Ministry of Transport), unused installations (i.e. solar shading devices), too low or too high set points for thermostats, no manual control over the thermostats in the room (Frederick Lanchester Building), etc. were found to be very important reasons for comfort perception in the buildings. In general, proper building operation in most of these cases can significantly reduce the number of dissatisfied votes.

For the majority of buildings with the low satisfaction score, the reasons for discomfort between the occupants have been evaluated and explained in D7 report. In most of

cases, monitoring results of building performance are used to confirm or doubt the results of questionnaire survey. The doubts are often found in the above mentioned topics i.e. company polices and management, building application, company culture, etc. Moreover, a low response rate in a number of buildings provides a background for further doubts of the results of these questionnaire surveys. As in case of low response rate, responses are received mainly from dissatisfied occupants. Besides that, any statistical data treatment is insufficient, for buildings with low response rates.

Another issue to raise, is differences in culture, experience and tolerance level between the occupants with regards to IAQ and thermal comfort in different climatic zones, but also in different organisations. For example, occupants in the warmer climates have higher level of tolerance to overheating problems; occupants who have an experience working in a naturally ventilated building are more likely to complain about the thermal comfort if they moved into a mechanically ventilated building and backwards.

In view of all these issues, the questionnaire survey results, supported with the monitoring results of buildings' performance do not necessarily require satisfaction rate of 80%. On the contrary, these results do help to document that the buildings actually work, and, in any rule – there is an exception, caused by human behaviour, human psychology, human culture and earlier experience.

No clear statements were achieved during the investigation of reasons for dissatisfaction with indoor air quality and comfort in buildings according to climatic zone they are located in. Generally speaking, all statements made within this report correspond well with commonly identified advantages/ disadvantages of different ventilation technologies. There is no clear preference is seen between the occupants with regard to ventilation strategy, as well as no general conclusion can be made about preferable ventilation strategy for different climates.

Every building and its occupants are unique and therefore all precautions must be taken to avoid presence of known in advance disadvantages when choose the ventilation principle in the building.

Appendix

Welcome to the BuildingAdvent Occupant Survey

This survey is being conducted to help with future planning and design of offices and workplaces. The information collected will be treated as completely confidential by the survey team. Survey reports will use summaries of information and not reveal the identities of individuals.

Please fill in as many questions as you can. Write any further comments in the spaces provided.

You will be asked a number of questions, some of them ask to provide personal info such as your age and sex, since this is relevant to people needs in buildings.

Thank you for your help.

Queries:
If you have any queries, please contact:
Olena Kalyanova, ok@civil.aau.dk

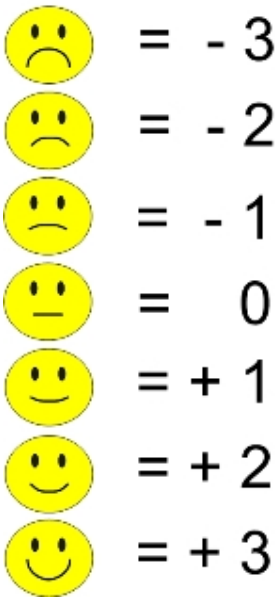
PLEASE PAY ATTENTION!

In this survey you will be asked to evaluate different parameters according to your opinion or level of satisfaction, using a scale from -3 to +3.

In this scale, zero- is always neutral, while the plus and minus grades identify how your opinion differs from neutral, see figure to the right.

Below every scale-question, there will always follow an explanation to the scale.

ALL OF THE QUESTIONS ARE FOCUSED ON THE COMFORT AND INDOOR ENVIRONMENT IN YOUR OFFICE/ROOM.



BACKGROUND INFORMATION

How long time have you been working in your office building, in years?

___

On which floor is your current room located?

(1) ❑ 1st floor

(2) ❑ 2nd floor

(3) ❑ 3rd floor

(4) ❑ 4th floor

Looking at the drawing below, please answer[1]:
In which zone of the building do you normally work?

[1] The drawing and definition of zones is not included into Appendix, as these were different for each building

How long time have you been working in your current room, in years?

___

How many days in a normal working week do you spend in your room?

_

How many hours in a normal working week do you spend in your room?

___

How many hours in a normal working day do you spend at your desk?

__

Is there any window in your room?

(1) ❑ Yes

(2) ❑ No

What is the approximate distance from your workstation to the closest window, in meters?

___

Do you or other colleagues in the room open windows regularly?

(1) ❑ Yes

(2) ❑ No

How many workstations are located in your current room?

__

PERSONAL INFORMATION

What is your age?

___

What is your sex?

(1) ❑ Male

(2) ❑ Female

What is your position in the company?

(1) ❑ Managerial

(3) ❑ Clerical

(4) ❑ Secretarial

(5) ❑ Technical staff

(6) ❑ Other

GENERAL PERCEPTION

How do you generally perceive indoor environment and comfort conditions in your room?

Please give a grade according to level of your satisfaction, from -3 (very unsatisfactory) to +3 (very satisfactory).

	-3	-2	-1	0	+1	+2	+3
during summer?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
during winter?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

INDOOR ENVIRONMENT AND COMFORT IN YOUR ROOM

How would you describe the typical indoor environment and comfort conditions in your room regarding the ROOM TEMPERATURE?

Please give a grade according to level of your satisfaction, from -3 (very unsatisfactory) to +3 (very satisfactory).

	-3	-2	-1	0	+1	+2	+3
during summer?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
during winter?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

What is the cause of your dissatisfaction, in the previous question, regarding the ROOM TEMPERATURE?

... during summer? (2) ❑ Too warm

(3) ❑ Too cold
(4) ❑ Too varying

... during winter?

(2) ❑ Too warm
(3) ❑ Too cold
(4) ❑ Too varying

How would you describe the typical indoor environment and comfort conditions in your room REGARDING AIR MOVEMENT and DRAUGHT?

Please give a grade according to level of your satisfaction, from -3 (very unsatisfactory) to +3 (very satisfactory).

	-3	-2	-1	0	+1	+2	+3
during summer?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
during winter?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

What is the cause of your dissatisfaction, in the previous question, regarding the AIR MOVEMENT and DRAUGHT in the room?

... during summer?

(2) ❑ Stagnant air
(3) ❑ Draught

... during winter?

(2) ❑ Stagnant air
(3) ❑ Draught

How would you describe the typical indoor environment and comfort conditions in your room REGARDING AIR QUALITY?

Please give a grade according to level of your satisfaction, from -3 (very unsatisfactory) to +3 (very satisfactory).

	-3	-2	-1	0	+1	+2	+3
during summer?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
during winter?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

What is the cause of your dissatisfaction, in the previous question, regarding the AIR QUALITY in the room?

... during summer?

(2) ❑ Stuffy air
(3) ❑ Unpleasant smell
(4) ❑ Air is too dry

(5) ❑ Air is dusty

... during winter?

(2) ❑ Stuffy air
(3) ❑ Unpleasant smell
(4) ❑ Air is too dry
(5) ❑ Air is dusty

How would you describe the typical indoor environment and comfort conditions in your room REGARDING NOISE?

Please give a grade according to level of your satisfaction, from -3 (very unsatisfactory) to +3 (very satisfactory).

	-3	-2	-1	0	+1	+2	+3
during summer?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
during winter?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

What is the cause of your dissatisfaction, in the previous question, regarding the NOISE in the room?

... during summer?

(2) ❑ Noise from outdoors (i.e. traffic)
(3) ❑ Noise from ventilation system
(4) ❑ Noise from activities in the building

... during winter?

(2) ❑ Noise from outdoors (i.e. traffic)
(3) ❑ Noise from ventilation system
(4) ❑ Noise from activities in the building

How would you describe the level of LIGHTING in your room?

Please give a grade according to level of your satisfaction, from -3 (very unsatisfactory) to +3 (very satisfactory).

	-3	-2	-1	0	+1	+2	+3
Regarding the natural light?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
Regarding the artificial light?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Can you identify certain situations or specific moments where you are not satisfied with the indoor environment in your room?

(1) ❑ Yes

(2) ❑ No

What are these specific situations where you are not satisfied with the indoor environment in your room?

_____

POSSIBILITY TO INFLUENCE THE INDOOR ENVIRONMENT

To what extent do you personally feel the possibility to ínfluence and adapt conditions in your room?

Please give a grade according to your opinion, scaling between -3 (no possibility to control) and +3 (full personal control).

	-3	-2	-1	0	+1	+2	+3
regarding the room temperature?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
regarding the ventilation?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

If you have the possibility to influence...

Please give an answer, scaling between -3 (very slowly) and +3 (very fast).

	-3	-2	-1	0	+1	+2	+3
... how fast does a change occur to the room TEMPERATURE, if you make a change?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
... how fast does a change occur to VENTILATION, if you make a change?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Do you feel a need to be able to influence...

Please give an answer, scaling between -3 (NO, never) and +3 (YES, very often).

	-3	-2	-1	0	+1	+2	+3
... room air temperature?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑
... ventilation?	(1) ❑	(2) ❑	(3) ❑	(4) ❑	(5) ❑	(6) ❑	(7) ❑

Can you identify certain situations or specific moments where you are not satisfied with the POSSIBILITY TO INFLUENCE the indoor environment in the building?

(1) ❑ Yes

(2) ❑ No

Can you specify the situations or moments where you are not satisfied with the POSSIBILITTY TO INFLUENCE the indoor environment in the building?

	YES	NO
Is your dissatisfaction caused by the automatic control of indoor environment in your room?	(1) ❑	(1) ❑
Is your dissatisfaction caused by the options for personal control?	(1) ❑	(1) ❑

Here you can explain why there are situations when you are not satisfied with the POSSIBILITY TO INFLUENCE the indoor environment in the building.
This question is optional.

_____

_____

INFORMATION AND FOLLOW-UP

Have you and your colleagues received information about how the control system works and what you can do to adjust the indoor environment if you find them unsatisfactory?

(1) ❑ Yes

(2) ❑ No

What is your opinion about the information?

Please give an answer, scaling between -3 (very unsatisfactory) and +3 (very satisfactory).

-3	-2	-1	0	+1	+2	+3
(1) ❑	(7) ❑	(8) ❑	(9) ❑	(10) ❑	(11) ❑	(12) ❑

Have you or your colleagues expressed a wish to have the control of the ventilation system changed?

(1) ❑ Yes

(2) ❑ No

You've answered that you or your colleagues expressed a wish to have the control of ventilation system changed. HAS IT BEEN CHANGED?

(1) ❑ Yes

(2) ❑ No

What is your opinion about the results of changes?

Please give an answer, scaling between -3 (very unsatisfactory) and +3 (very satisfactory).

-3	-2	-1	0	+1	+2	+3
(1) ❑	(7) ❑	(8) ❑	(9) ❑	(10) ❑	(11) ❑	(12) ❑

You have completed the questionnaire.
Thank you for your help!

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