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NatVent™

Overcoming technical barriers to low-energy natural ventilation in office type buildings in moderate and cold climates

EC CONTRACT: JOR3-CT95-0022 (DGXII)

Barriers to Natural Ventilation Design of Office Buildings

National Report: *Norway*

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INTRODUCTION

The objective of the study described in this report is to identify barriers restricting the implementation of natural or simple fan assisted ventilation systems in the design of new office type buildings and in the refurbishment of existing such buildings. The perceived barriers are identified in an in-depth study with structured interviews based on questionnaires among leading designers and decision makers. The interviews have focused on general knowledge, viewpoints, experience and perceived problems with natural ventilation in office type buildings and on the decisions actually taken in specific building projects.

To our knowledge, there are no modern office building in Norway with natural ventilation. Why is this so? It is important to identify the barriers seen by designers and decision makers that restrict the implementation of natural or simple fan assisted ventilation systems.

The identification of perceived barriers to natural ventilation design of office buildings is the first phase (work package) of the ***NatVent*** ™ project being carried out under the JOULE programme. The two other work packages in the ***NatVent*** ™ project are:

- Performance of naturally ventilated buildings.
  The aim is to evaluate the performance of twenty existing buildings designed specifically for natural ventilation.
- 'Smart' technology systems and components.
  The aim is to develop systems, components and solutions to the barriers and shortcomings identified in the first two work packages. This work package includes:
  - Air supply components suitable for high pollution and noise loads
  - Constant (natural) air flow inlets
  - Advanced natural ventilation systems with heat recovery
  - 'Smart' components and 'intelligent' controls for night cooling
  - Integration of 'smart' systems for year-round performance

The ***NatVent*** ™ project is performed by nine organisations in seven central and north European countries. The project is headed by Building Research Establishment, BRE (UK). The other partners are:

Centre Scientifique et Technique de la Construction, CSTC (B)
Danish Building Research Institute, SBI (DK)
TNO Bouw (NL)
AB Jacobsen & Widmark, J&W (S)
Technical University, Delft (NL)
Willan Building Group (UK)
Norwegian Building Research Institute, NBI (N)
Sulzer Infra Laboratory (CH)

This report is an output from the ***NatVent*** ™ project which is part funded by the European Commision DGXII within the JOULE programme 1994-1998 and under contract: JOR3-CT95-0022. The Norwegian work in the project is also part funded by the Norwegian Research Council (NFR)

This report describes the results of the Norwegian interviews. Similar reports giving the results of the interviews in the other countries are also produced.

In addition the main results of the interviews will be published in a common final international report. The final report will summarise the results from the interviews in each country and compare them to identify common problems with the implementation of natural ventilation systems and to gain experience from countries that have solved some of the problems. The final report will also give recommendations on how to overcome the identified barriers.

The ***NatVent***™ project team would like to thank all the interviewees: designers and decision makers for the knowledge and experience they have brought to the project and for the time they have spend.

In addition to the results from the interviews, this report also brings some requirements concerning ventilation in the Norwegian building code and in Norwegian occupational health regulations.

SUMMARY

Objective and method

The objective of the study is to identify barriers restricting the implementation of natural or simple fan assisted ventilation systems in the design of new office type buildings and in the refurbishment of existing such buildings. The perceived barriers are identified in an in-depth study with structured interviews based on questionnaires among leading designers and decision makers. The interviews have focused on general knowledge, viewpoints, experience and perceived problems with natural ventilation in office type buildings and on the decisions actually taken in specific building projects. The interviews were performed among: 5 architects, 3 consultant engineers, 2 contractors, 2 developers, 2 owners and a governmental decision maker.

Ventilation systems in Norway

Natural ventilation is not in use in office buildings in Norway today. As the questionnaires show, no one of the interviewed persons had designed/built or owned a building with natural ventilation. Due to the lack of experience with natural ventilation, all found it difficult to answer many of the questions in the questionnaire.

Almost all office buildings in Norway have ducted air supply/extract to and from the office rooms. Many new office buildings have mechanical cooling, normally with a base cooling in the ventilation system and a supplementary cooling system in the room (cooled ceilings, baffles). 5-10 years ago, new office buildings were designed with an air flow rate 5 $m^3/h\ m^2$ (1,4 l/s m^2, or ca. 14 l/s p) . Nowadays, this has increased to 10-12 $m^3/h\ m^2$, due to new requirements in the Norwegian Building code.

Results from the interviews

The interviews identifies significant lack of knowledge and experience on both special designed and ordinary natural ventilation in office buildings compared to the knowledge and experience on mechanical ventilation. In addition there is a lack of sources to natural ventilation knowledge in standards, guidelines and building studies and a desire for new design tools on natural ventilation including also calculation rules and easy to use, simple and advanced computer programmes.

In the interviewees opinion, mechanical ventilation have several advantages compared to natural ventilation regarding cooling effectiveness, draught minimisation, ability to remove odours and pollutants, ability to prevent ingress of odours and pollutants, insulation against external noise and central controllability, especially if the mechanical ventilation systems are well designed. The interviewees also expect a higher user satisfaction in mechanical ventilated offices.

All interviewees expect both higher installation, higher running and higher maintenance costs for mechanical ventilation in offices than for natural ventilation. Room temperatures in summer are the most important design parameter, but also room temperatures at winter and indoor air quality are often critical design parameters. The architects, consultant engineers and owners have the biggest influence on the design of a building.

On average the interviewees expects a moderate increase or unchanged future use of natural ventilation in office buildings in Norway. In general the architects have the highest expectation of increasing use of natural ventilation.
There is a need for good, standardised and general accepted natural ventilation system solutions and if possible for system solutions including heat recovery. In addition there is a need for new components regarding windows and vents with better air flow and draught performance, better controllability and better design.

General comments from the interviewees
On the whole, the HVAC-engineers among the interview-objects were negative to the concept of natural ventilation, which they considered would give less control over the air flows and the indoor climate. But some of them were interested in guidelines and components for low-cost ventilation concepts, which could be natural ventilation.

The architects were far more positive to natural ventilation, which they thought were environmentally sound, was cheaper and had less maintenance/running problems. Some architects pointed out that natural ventilation would give them more control and design freedom of the volumes of the building.

Some building owners and HVAC-engineers thought the new air volume requirements were too high, giving little flexibility in solving cooling problems. They thought 5-7 $m^3/h\ m^2$ was satisfactory with respect to air quality, and then the cooling could be obtained mechanically. High air volumes (10-12 $m^3/h\ m^2$) could give low temperatures in rooms that are used intermittently (eg. meeting rooms) and also give very dry air during the winter.

Especially some of the owners pointed out that high temperatures by far was the most important indoor climate parameter. They also said that the acceptable room temperature range is becoming ever stricter, mechanical cooling seems to be mandatory in the future.

The HVAC-engineers claimed cooling to be a central problem for natural ventilation. The air flows would be low, and mechanical cooling (cooled ceilings etc.) can not be used, due to condensing problems.

The HVAC-engineers did not see any big point in reducing the pressure drop in mechanical ventilation systems. The pressure drop in the air terminals to the rooms are a big part of the total pressure drop, and to obtain stability in the air flow distribution, they can not be reduced significantly.

METHOD

The perceived barriers to natural ventilation design of office buildings are identified in an in-depth study with structured interviews among leading designers and decision makers: architects, consultant engineers, contractors, developers, owners and the governmental decision maker responsible for regulations and standards.

Interviews with ordinary users of office buildings are not included in this study, because they are not the ones making the decisions in the design phase. The users perception of the indoor climate is part of Work Package 2: 'Performance of naturally ventilated buildings', where physical parameters e.g. ventilation rates, room temperatures and indoor air quality are also measured and compared with the users responses.

The interviews consist of two parts:

General view on natural ventilation in office buildings.

This part focus on general knowledge, viewpoints, experience and perceived problems with natural ventilation systems in office type buildings.

Specific building project.

This part focus on the decisions actually made during the design or refurbishment of an office type building.

Both parts of the interview were in general performed with all interviewees. The only general exception is the interview with the governmental decision maker, where only the general view on natural ventilation in office buildings is relevant.

The interviews were performed among:

5 Architects
3 Consultant engineers
2 Contractors
2 Developers
2 Owners
1 Governmental decision maker (responsible for regulations and standards)

The number of designers and decision makers interviewed are limited due to limited financial resources in the project. The persons interviewed are therefore selected with the intention to also identify the variety in opinions and viewpoints on natural ventilation in office buildings.

The interviews were based on questionnaires. There were two questionnaires to be filled in during an interview. The first questionnaire covers: General view on natural ventilation in office buildings and the second questionnaire covers: Specific building project.

The questionnaires are designed to facilitate the performance of statistics on the viewpoint of the interviewee. The questionnaires are not too tight and there are ample space for additional comments, remarks and viewpoints not included in the questions.

The questionnaires were completed by the interviewee and the interviewer together and the interviewer also if necessary guided the interviewee in understanding the questions. If a question couldn't be answered by the interviewee or is irrelevant to the interviewee it was indicated in the questionnaire.

Questionnaire on general view

The questionnaire concerns general view on natural ventilation in office buildings. The questionnaire are reproduced in annex IV. The questionnaire comprises 14 subjects:

1. Interviewee

Identification of the interviewee

2. Organisation

Description of the organisation: type, disciplines, number of employees and building types.

3. Knowledge

Knowledge on mechanical ventilation, heat recovery, mechanical cooling, ordinary natural ventilation and special design natural ventilation in offices including special ventilation windows, advanced vents, internal ventilation openings, roof openings etc. The questions were answered by indicating the knowledge on a specific 5 point scale ranking from 'None' to 'Thorough'.

4. Experience

Ventilation experience in the organisation focusing on the extension of new and refurbished office buildings designed or owned by the interviewees organisation. Also questions to identify the percentage of buildings with: mechanical ventilation, ordinary natural ventilation and special design natural ventilation in the offices.

5. Project fee

Type of project fee received by architects and consultant engineers for the design of office buildings. Questions were asked to identify the percentage of projects with fee paid as: fixed fee, percentage of construction cost, per hour rate or other type of payment for design.

6. Natural ventilation in cellular offices

7. Mechanical ventilation in cellular offices

8. Natural ventilation in open plan offices

9. Mechanical ventilation in open plan offices

General views on perceived advantages or problems with either natural or mechanical ventilation in cellular and open plan offices. The questions asked under subjects 6, 7, 8 and 9 are identical and only the ventilation system and the office type differs. The questions concern: design, availability of products, performance in practice, controllability and costs and were answered by checking the same 5 points scale as used in subject 3.

10. Your source of natural ventilation knowledge

Possible sources are: standards, guidelines, building studies, experience, own design and other.

11. Expected future use of natural ventilation in office buildings

Expected future use of natural ventilation in office buildings designed or owned by the organisation. The question were answered by checking a specific 5 points scale ranking from 'Decreasing' over 'Unchanged' to 'Increasing'. The interviewees were also asked why they have this expectation.

12. Requirements restricting the use of natural ventilation in offices

Perceived restriction in the use of natural ventilation in offices from requirements in building codes, norms, standards, working condition codes etc. The question were

answered by checking a 5 points scale ranking from 'None' to 'Comprehensive' and by indicating which code, norm or standard that includes the restrictions.

13. Desirable new design tools for natural ventilation

Possible new sources and design tools could be source books, guide lines, examples, simple or advanced computer programmes etc.

14. Desirable new components for natural ventilation

Possible new components could be air inlets, control systems etc.

Questionnaire on specific building project

The questionnaire concerns one specific building project. The questionnaire are reproduced in annex II. The building could be either newly constructed or newly refurbished and could be with either natural or mechanical ventilation. The building were selected by the interviewee to be typical. The questionnaire comprises 5 subjects:

1. Interviewee

Identification of the interviewee

2. Building

Identification of the building and indication of key figures including building name, address, building type, year of construction, year of refurbishment (if any), site (urban, sub-urban, industrial or rural), m^2-floor area, number of storeys, building depth from facade to facade and storey height.

3. The design

Description of the actual design of the ventilation system and the building design parameters with influence on the ventilation demand and the ventilation system design. The design were described by checking a row of boxes for each room type in the building: offices, meeting rooms, canteen, corridors, stairways, entrance hall, atria, lavatories and others. The design specification includes:

Ventilation system:	Mechanical ventilation, mechanical exhaust, natural ventilation, heat recovery, night time ventilation
Mechanical cooling:	In ventilation system, cooled ceilings
External openings:	Ordinary windows, special ventilation windows, ordinary vents, advanced vents, stack ducts, ventilation chimneys, roof openings, ducted air supply
Int. horizontal flow openings:	Doors, ventilation openings, open connection
Int. vertical flow openings:	Ventilation openings, open connection
Solar shading:	Internal, between panes, external, protective glazing
Ceilings:	High ceiling, false ceiling, exposed heavy structure
Floor and walls:	Exposed heavy floor, internal walls, external walls

4. Background for the design

Indication of critical parameters in the ventilation system design and in the relevant parts of the building design. The critical parameters were prioritised for each of the room types on a 5 point specific scale ranking from '1. low' to '5. high'. The critical parameters includes:

Winter conditions:	Room temperatures, indoor air quality, draught
Summer conditions:	Room temperatures, solar loads, internal heat, draught
Controllability:	Individual control
Noise:	Internal noise, external noise
Pollution and odours:	Internal air and external air pollution or odours
Safety:	Fire regulations, security
Costs:	Construction, operating and maintenance costs

5. Biggest influence on chosen design

Indication of biggest influence on the chosen design. The influence could be from: architect, consultant engineer, contractor, owner, developer, investor, user, the actual building site, requirements in codes, norms, standards or from other. The influence were prioritised on the same 5 point specific scale as used in subject 4 above.

RESULTS

The main results of the interviews are described in this chapter.

The interviewee

The five *architects* interviewed represents some of the leading Norwegian architect offices. They have between 4 and 65 employees. They annually design 5-90,000 m^2 floor area in new office buildings and 1-10,000 m^2 in refurbishment of office buildings. All of them design new office buildings, but they also work with other types of buildings e. g. schools, institutions, housing and production buildings. None of them have specialised in natural ventilation.

The three *consultant engineers* interviewed represents three typical HVAC-consultant offices in Norway. They have between 15 and 23 employees. They annually design around 100,000 m^2 floor area in new and refurbished office buildings. All of them also design other types of buildings, plants and constructions.

The two *contractors* interviewed represents typical HVAC-entrepreneurs in Norway. One of them also do HVAC-consulting. One company have 16 employees and constructs annually about 30,000 m^2, the other have 250 employees and constructs around 300,000 m^2.

The two *developers* interviewed represents a large insurance company and a company specialised in building development. The latter have 48 employees and annually design/construct 40,000 m^2.

The two *owners* interviewed represent the governmental building office, who manages all new official offices, and a private, real estate company.

The *governmental decision maker* were from the National Office of Building Technology and Administration. He is responsible for formulating the indoor climate and ventilation requirements in the Norwegian Building Regulations.

General view

Knowledge on ventilation

Figure 1 shows the interviewees perception of own knowledge on the five topics: mechanical ventilation, heat recovery, mechanical cooling, ordinary natural ventilation and special designed natural. A specific 5 point scale ranking from 1: *None* to 5: *Thorough* is used to indicate the level of knowledge.

The interviewee have indicated their level of knowledge on the five topics based on the knowledge necessary to perform their normal task in the design or decision process and relative to their profession. It is therefore not possible to compare the absolute level of knowledge between the professions based on the results. The results can merely be used to compare the relative knowledge on the five subjects group by group.

Nearly all the interviewees have a lower knowledge on natural ventilation compared to their knowledge on mechanical ventilation in offices.

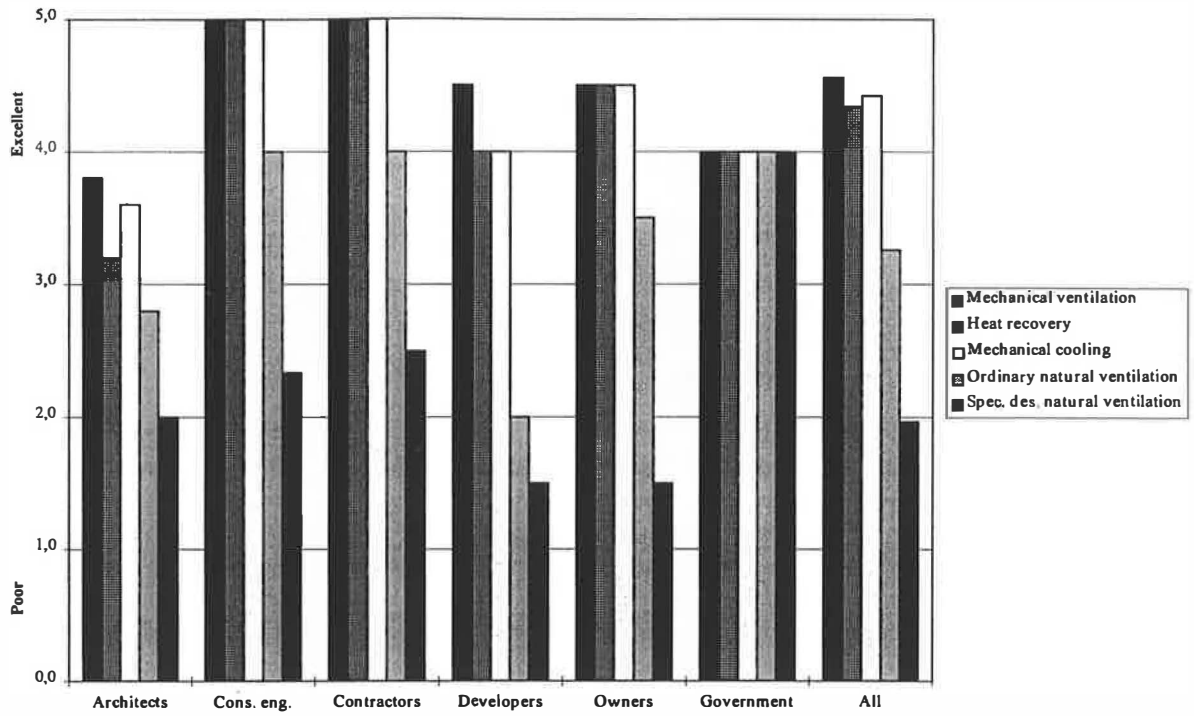

Figure 1. The interviewees perception of own knowledge

Experience

None of the interviewees had any experience in designing office buildings with natural ventilation.

Project fee

The type of fee received by the interviewed architects and consultant engineers for the design of office buildings is shown in Figure 2. The possible fee types are: Fixed fee, percentage of construction costs and per hour rate.

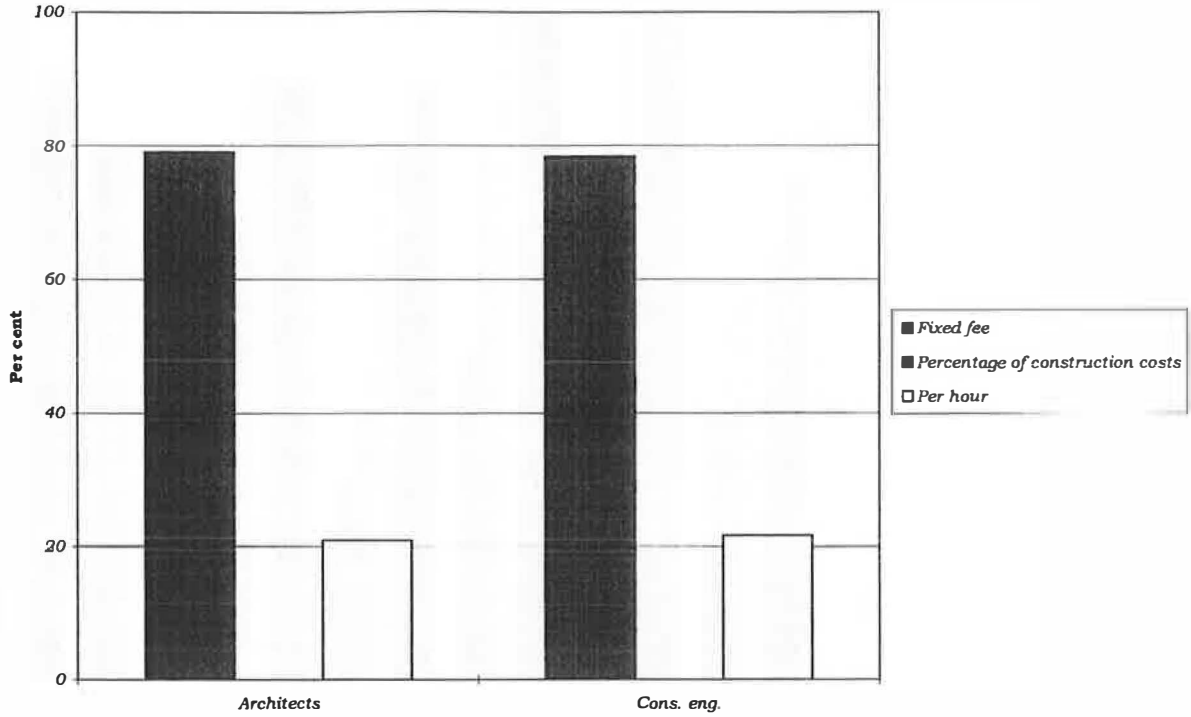

Figure 2. Type of fee received by the interviewed architects and consultant engineers for the design of office buildings.

Design

The interviewees perception of the design of natural and mechanical ventilation in cellular and open plan offices regard ease of design, availability of design guidelines and advises, availability of products, flexibility to building use and user satisfaction are shown in Figure 3. A specific 5 point scale ranking from 1: *Poor* to 5: *Excellent* is used to indicate the interviewees perception of the design.

The answers reflects that there are a lack of guidelines and products concerning natural ventilation. Further the interviewees on average believes that the user satisfaction will be lower in natural ventilated buildings.

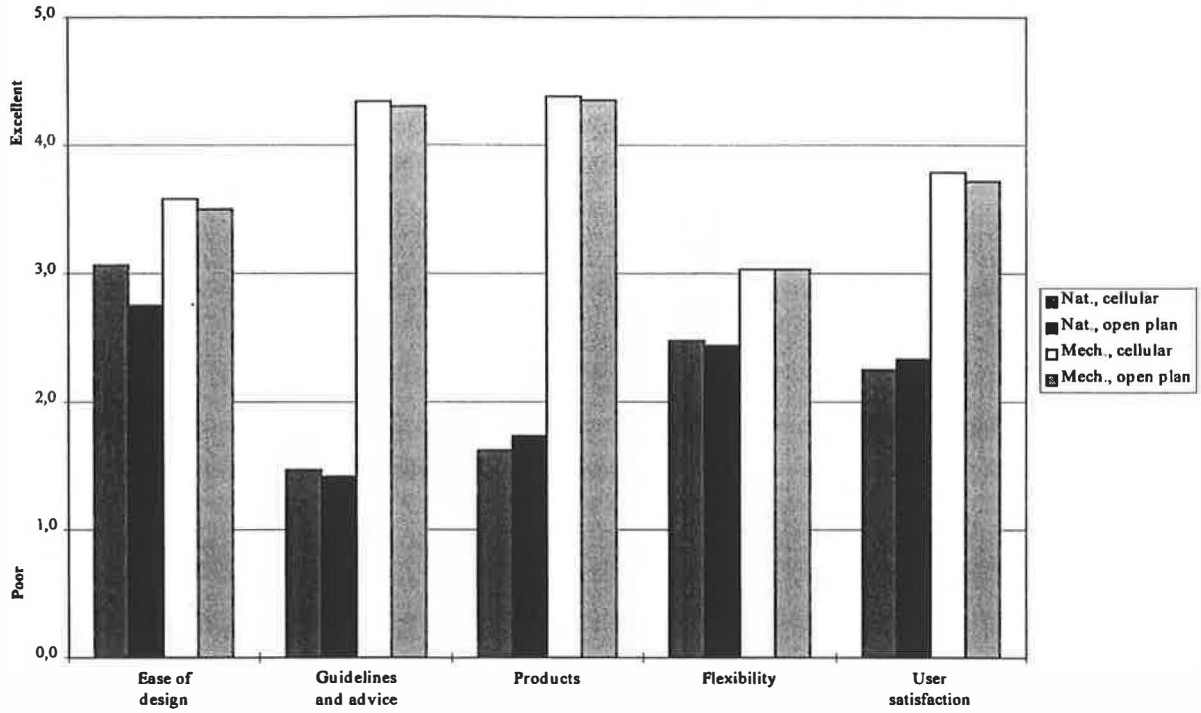

Figure 3. The interviewees perception of natural and mechanical ventilation in cellular and open plan offices.

Performance in practice

The interviewees perception of the performance in practice of natural and mechanical ventilation in cellular and open plan offices regard cooling effectiveness, draught minimisation, ability to remove odours and pollutants, ability to prevent ingress of odours and pollutants, insulation against external noise, generation or transmission of internal noise are shown in Figure 4. A specific 5 point scale ranking from 1: *Poor* to 5: *Excellent* is used to indicate the interviewees perception of the performance in practice.

In general the interviewees expect a better performance in practice of mechanical ventilation systems than of natural ventilation systems regarding all the parameters, except internal noise generation.

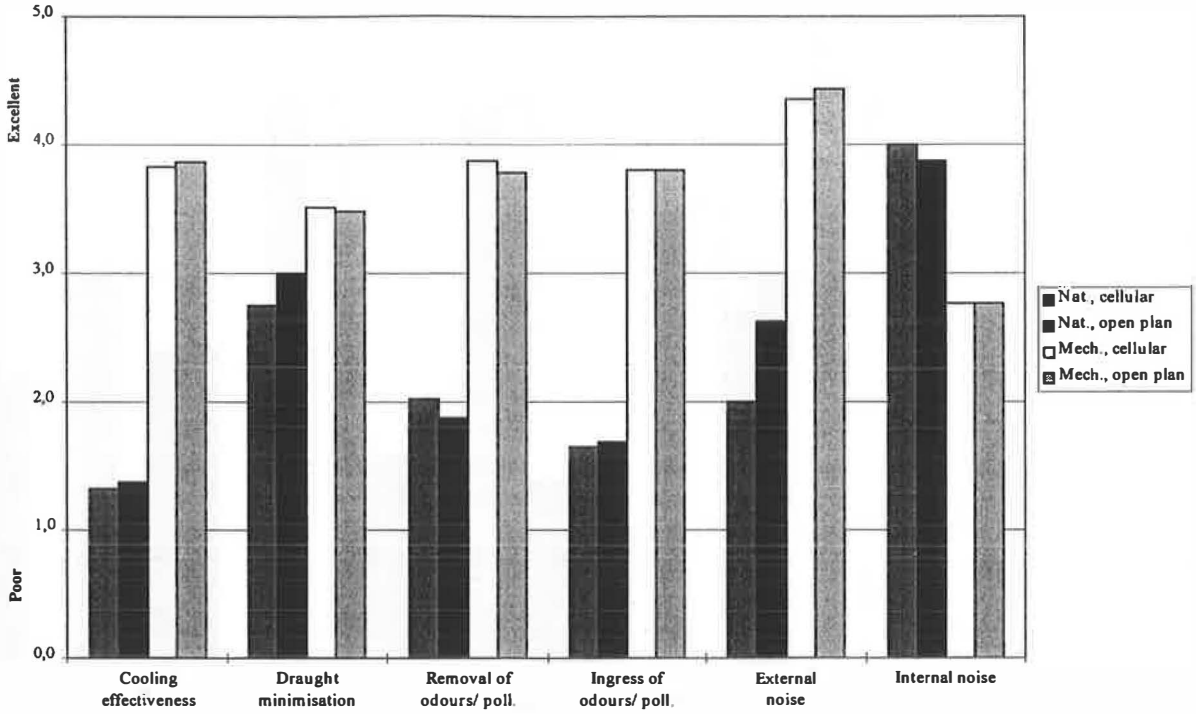

Figure 4. The interviewees perception of the performance in practice of natural and mechanical ventilation in cellular and open plan offices. The scale ranks from 1: Poor to 5: Excellent.

Controllability

The interviewees perception of the controllability of natural and mechanical ventilation in cellular and open plan offices regard central controllability, local controllability (per office) and individual controllability (per person) are shown in Figure 5. A specific 5 point scale ranking from 1: *Poor* to 5: *Excellent* is used to indicate the interviewees perception of the controllability.

In general the interviewees expect a high central controllability of mechanical ventilation systems and a low central controllability of natural ventilation systems, especially in cellular offices.

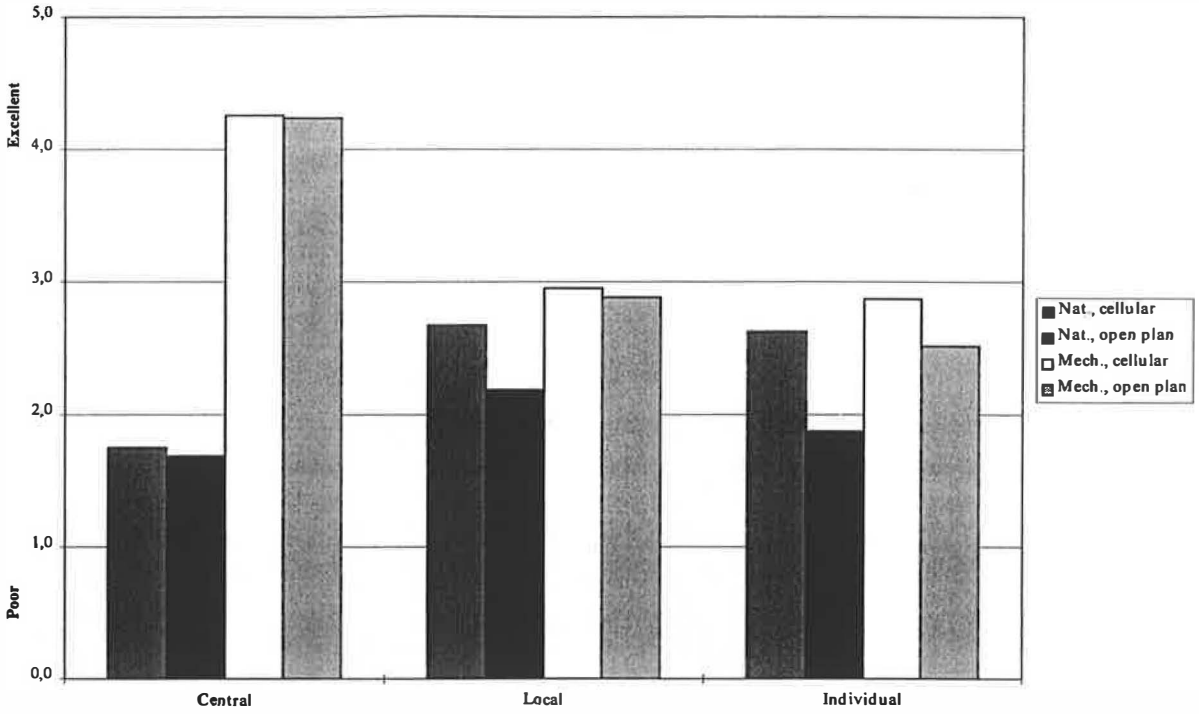

Figure 5. The interviewees perception of the controllability of natural and mechanical ventilation in cellular and open plan offices. The scale ranks from 1: Poor to 5: Excellent.

Costs

The interviewees perception of the costs for natural and mechanical ventilation in cellular and open plan offices regard installation costs, running costs and maintenance costs are shown in Figure 6. A specific 5 point scale ranking from 1: *Inexpensive* to 5: *Expensive* is used to indicate the interviewees perception of the costs.

All interviewees expect both higher installation costs, higher running costs and higher maintenance costs for mechanical ventilation in offices than for natural ventilation in offices.

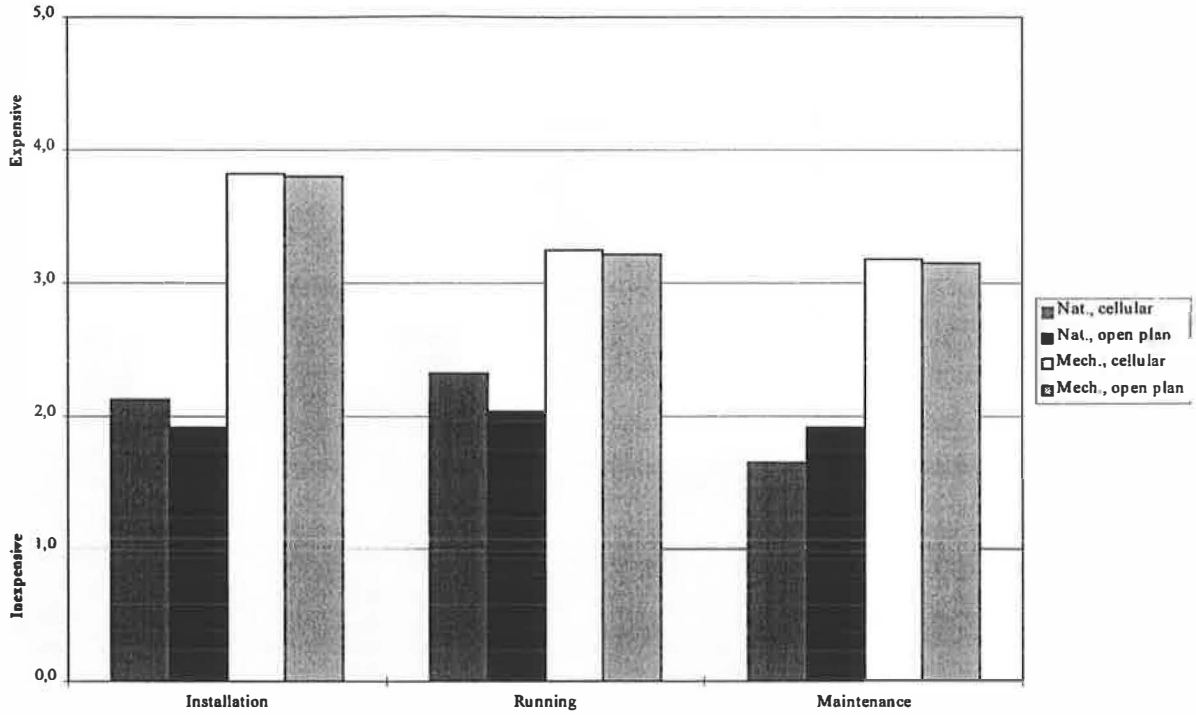

Figure 6. The interviewees perception of the costs for natural and mechanical ventilation in cellular and open plan offices. The scale ranks from 1: Inexpensive to 5: Expensive.

Source to natural ventilation knowledge

The interviewees sources to natural ventilation knowledge are building codes, periodicals/magazines, building studies, experience, own design and general literature.

The general opinion among the interviewees is that there is huge lack of good sources to natural ventilation knowledge.

Expected future use of natural ventilation

The interviewees expectations on the future use of natural ventilation in offices are shown in Figure 7. The expectation is indicated on a specific 5 points scale ranking from 1: *Significant decreasing* over 3: *Unchanged* to 5: *Significant increasing.*

The architects in general have the highest expectations of an increase in the use of natural ventilation in offices. The others (except the governmental representative) assumes no change/a slight increase. The governmental representative sees no future for natural ventilation, mostly because of the required air flows in the building code in Norway.

The HVAC-contractors and -consultants see no change in the current situation, which means that natural ventilation will continue to be non-existent in Norwegian office buildings.

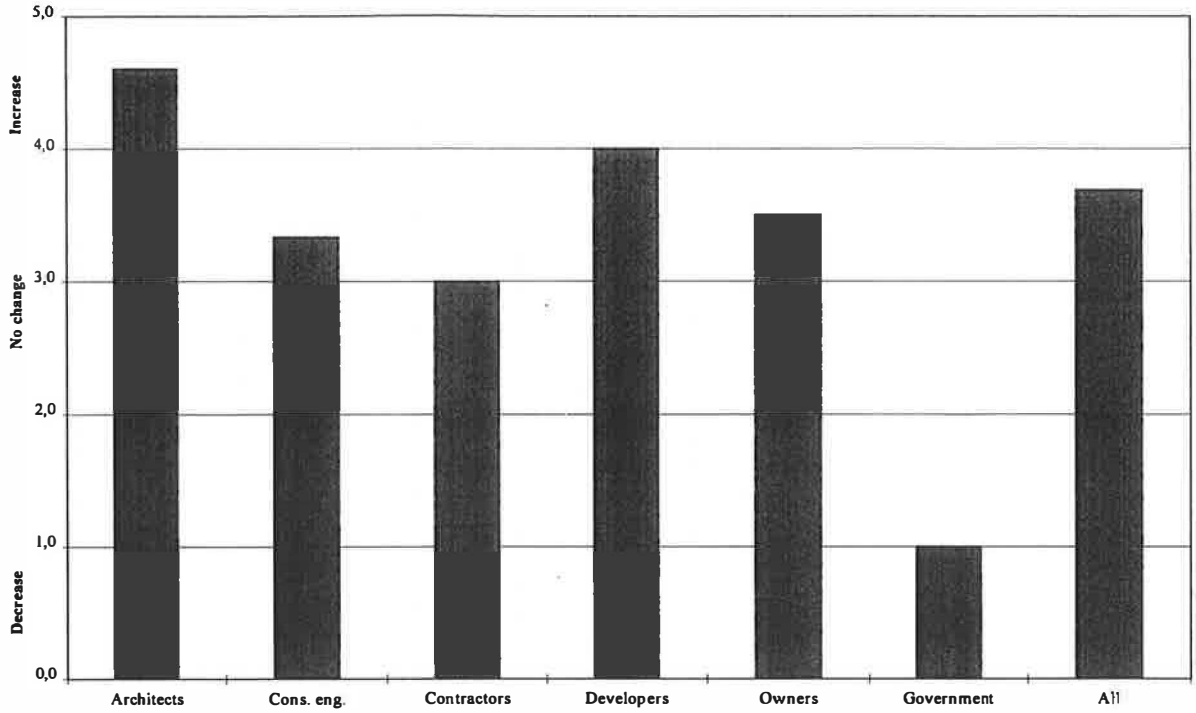

Figure 7. The interviewees expectations on the future use of natural ventilation in offices. The scale used ranks from 1: Significant decreasing over 3: Unchanged to 5: Significant increasing.

Restricting requirements in codes

The interviewees perception of requirements in building regulations, codes, norms and standards restricting the use of natural ventilation in offices are shown in Figure 8. The figure shows that the interviewees regard the restrictions to be substantial. A concentrate of Norwqegain regulations, codes, norms and standards related to natural ventilation or simple fan assisted ventilation systems in offices is given in annex II: 'Requirements in codes related to natural ventilation'.

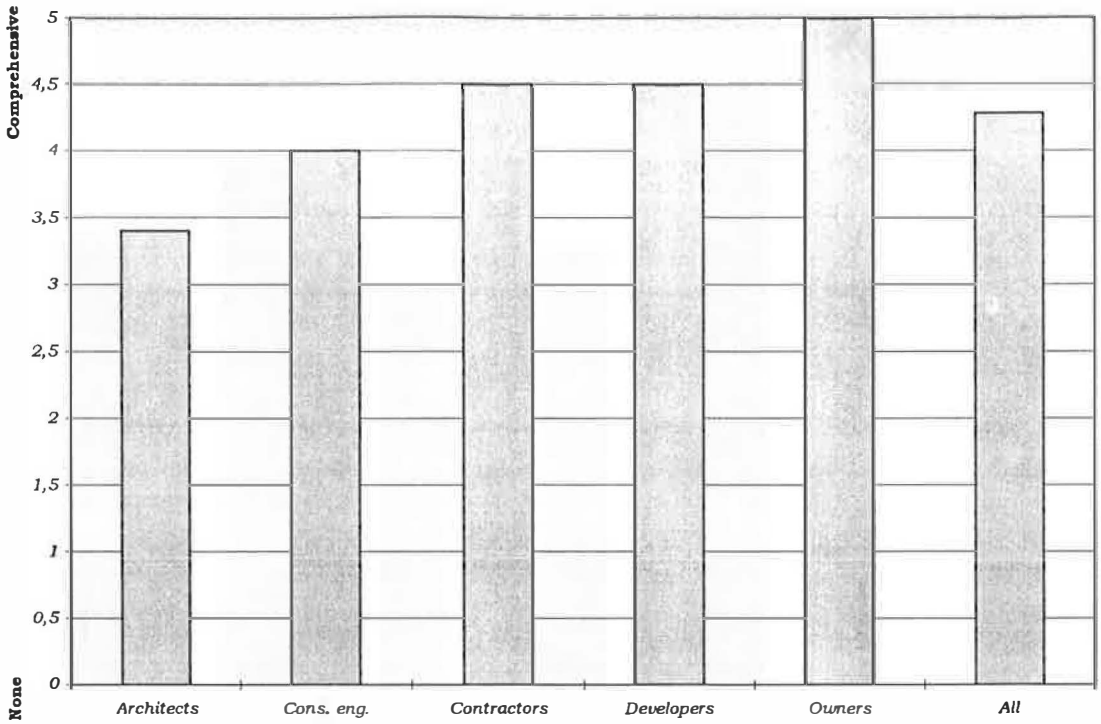

Figure 8 The interviewees perception of requirements in building regulations, codes, norms and standards restricting the use of natural ventilation in offices. The scale ranks from 1: None to 5: Comprehensive.

Desirable new design tools

All the interviewees said that design tools for natural ventilation are desirable. This includes:

- Simple and easy to use guidelines and design rules related to Norwegian climate.
- Standards for calculation of air flows
- Source books with simple description of the principles: basic theory, ventilation requirements, air flow, temperature and draught.
- Good examples of offices buildings with natural ventilation easy to understand for architects.
- Mock-up tests of natural ventilation systems.
- Simple, graphic based computer programmes.

Desirable new components

All the interviewees said that design tools for natural ventilation are desirable. This includes:

- air inlets
- heat recovery units designed for natural ventilation
- air flow control systems

Specific building project

14 the 15 interviewees also filled in the questionnaire on a specific building project. The exception are the governmental decision maker.

The results in the figures in this section of the report are the average of all the buildings included in the interviews.

The buildings

All the buildings are office buildings. Four of the projects are refurbishments of old office buildings, the rest are new office buildings. All the buildings are situated in an urban area. The buildings have from 4 to 8 storeys and a floor area between 4000 and 24,000 m^2. All the buildings are constructed or refurbished recently, between 1990 and 1996.

Design

The design of the buildings are quite similar. All the buildings have mechanical, balanced ventilation, with inlet and extract terminals in each room.
Heat recovery is included in all the buildings except one.
Three out of four have mechanical cooling, as a rule both in the ventilation system and as cooled ceilings.

All except one of the offices have external solar shading.

Most of the offices have false ceiling and only a few have high ceiling or ceiling with a heavy structure exposed by the room air. A few of the offices have exposed heavy floor or exposed heavy internal walls, but most of the offices have an exposed heavy inner leaf of the external wall.

Critical parameters

The interviewees perception of the critical parameters for the design of the ventilation system in the offices is shown in *Figure* 9 . Each interviewee were allowed to point out maximum 5 critical parameters and were asked to prioritise them from 1: *Low* to 5: *High*.

Room temperatures at summer are indicated as a very critical parameter. Room temerpature winter and indoor air quality are also important.

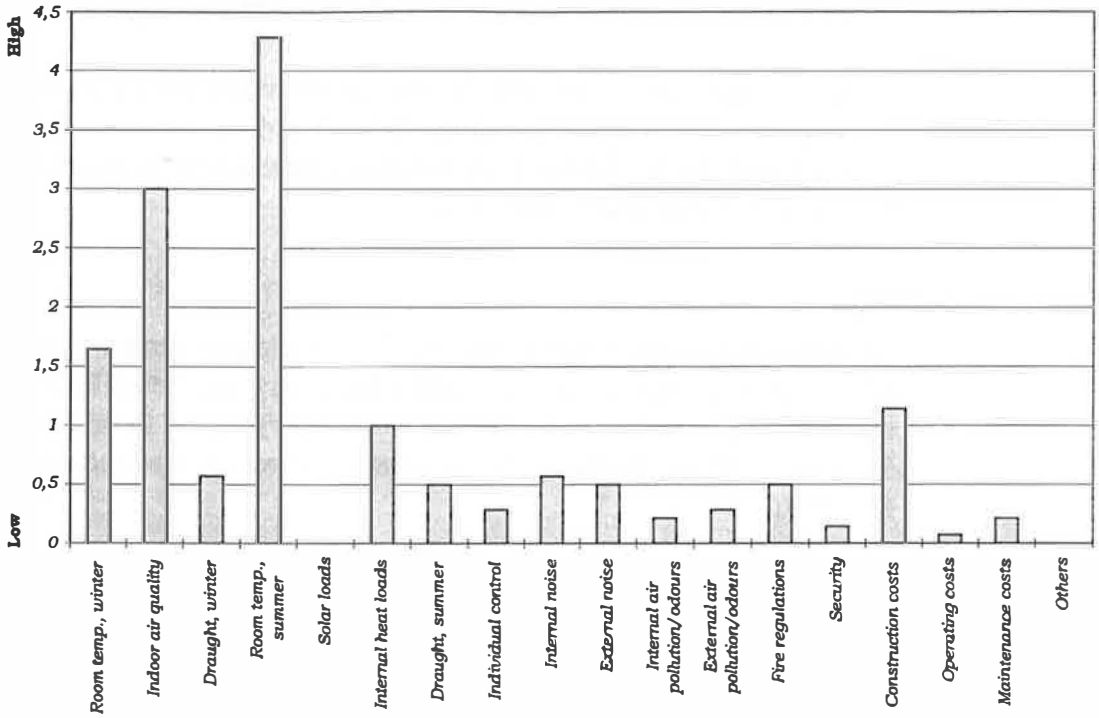

Figure 9. Critical parameters in the design of the buildings.

Influence

The interviewees perception of the persons or conditions having the biggest influence on the chosen design is shown in *Figure* 10. Again each interviewee were allowed to point out a maximum of 5 critical parameters and were ask to prioritise them from 1: *Low* to 5: *High*.

The architects, the consultant engineers and the owners are the ones with high influence on the chosen design.

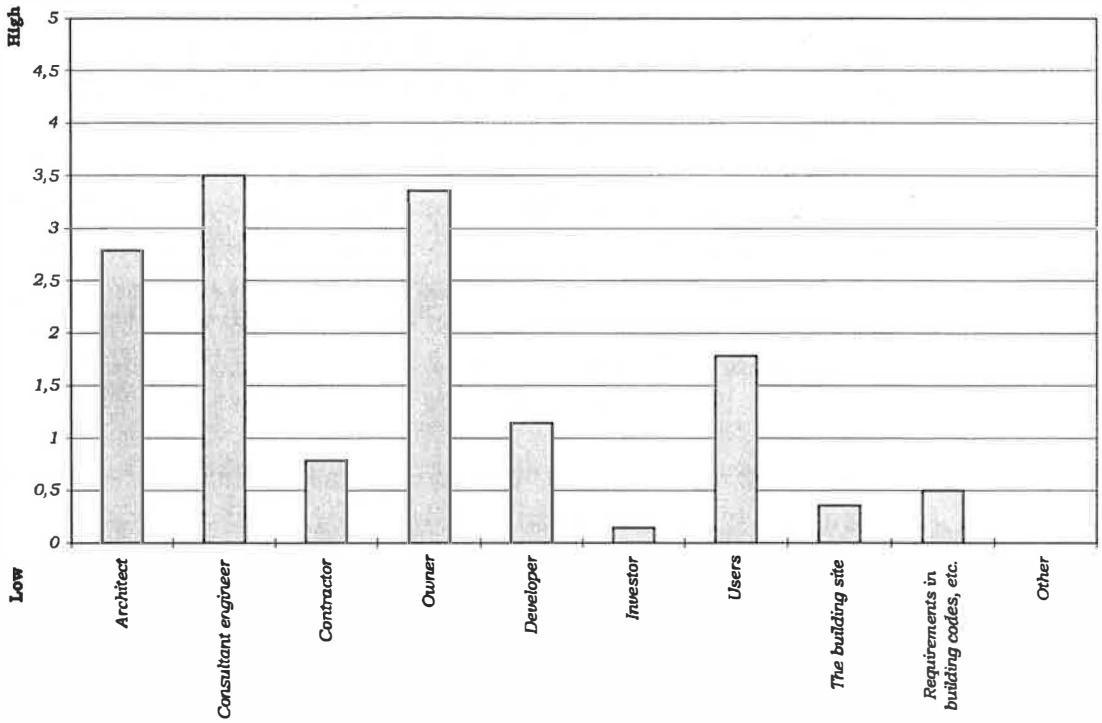

Figure 10. Influence on the design of the buildings.

GENERAL COMMENTS ON OFFICE BUILDING VENTILATION

Natural ventilation is not in use in office buildings in Norway today. As the questionnaires show, no one of the interviewed persons had designed/built or owned a building with natural ventilation. Due to the lack of experience with natural ventilation, all found it difficult to answer many of the questions in the questionnaire.

Almost all office buildings in Norway have ducted air supply/extract to and from the office rooms. Many new office buildings have mechanical cooling, normally with a base cooling in the ventilation system and a supplementary cooling system in the room (cooled ceilings, baffles). 5-10 years ago, new office buildings were designed with an air flow rate 5 $m^3/h\ m^2$ (1.4 $l/s\ m^2$, or ca. 14 l/s p) . Nowadays, this has increased to 10-12 $m^3/h\ m^2$, due to new requirements in the Norwegian Building code.

On the whole, the HVAC-engineers among the interview-objects were negative to the concept of natural ventilation, which they considered would give less control over the air flows and the indoor climate. But some of them were interested in guidelines and components for low-cost ventilation concepts, which could be natural ventilation.

The architects were far more positive to natural ventilation, which they thought were environmentally sound, was cheaper and had less maintenance/running problems. Some architects pointed out that natural ventilation would give them more control and design freedom of the volumes of the building.

Some building owners and HVAC-engineers thought the new air volume requirements were too high, giving little flexibility in solving cooling problems. They thought 5-7 $m^3/h\ m^2$ was satisfactory with respect to air quality, and then the cooling could be obtained mechanically. High air volumes (10-12 $m^3/h\ m^2$) could give low temperatures in rooms that are used intermittently (eg. meeting rooms) and also give very dry air during the winter.

Especially some of the owners pointed out that high temperatures by far was the most important indoor climate parameter. They also said that the acceptable room temperature range is becoming stricter, mechanical cooling seems to be mandatory in the future.

The HVAC-engineers claimed cooling to be a central problem for natural ventilation. The air flows would be low, and mechanical cooling (cooled ceilings etc.) can not be used, due to condensing problems.

The HVAC-engineers commented that good planning was necessary to avoid a "waste" of pressure drops in ventilation ductwork. Apart from that, the engineers did not see any big point in reducing the pressure drop in mechanical ventilation systems. The pressure drops in the air terminals to the rooms are a big part of the total pressure drop, and to obtain stability in the air flow distribution, they can not be reduced significantly.

FORMAL BARRIERS TO NATURAL VENTILATION

Requirements to ventilation systems are formulated both in the Norwegian Building Code and in occupational health regulations.

Building code with guidance

Filtering

Buildings in polluted areas (industry, traffic) must have a ventilation system that makes it possible to clean the air. (§8.32)

Air flows

The amount of necessary fresh air flow to the building shall be determined on the basis of expected pollution in the building. In office buildings this is number of occupants (A) and pollution from materials, interiors, etc. (B).

The necessary air flow into office buildings can be calculated from (§8.32, guidance):

$$q_{tot} = (q_A + q_B) \cdot A_{office}$$

here is:

q_A:	0,47 l/(s·m²)	7 l/s pr. person, with the default 15 m² pr. person
q_B:	1 l/s pr. m²	If the materials used are well known to be low-emitting
	0,7 l/s pr. m²	If the materials in emission tests have proved to be low-emitting
	2 l/s pr. m²	If nothing is known about the materials
A_{office}:		Total floor area of the building

The fresh air brought into the building shall balance the extract air. The extract air flow shall at least be (according to the guidance to the code §8.34):

- 15 l/s pr. shower
- 10 l/s pr. wc
- 8,5 l/s pr. m² elevator shaft
- 0,35 pr. m² total area in basement

The air flow under operation shall be possible to measure in an easy way (code §9.32).

Fire and smoke control

According to the code and its guidance, smoke control in the buildings can be achieved with either passive measures (eg. sectioning), active measures (smoke ventilation) or a combination of these. Very often, mechanical ventilation is used for smoke control. However, in principle there are no formal barriers to the use of natural ventilation in office buildings, provided necessary use of fire insulation, dampers etc. A satisfactory smoke control must be found for each project.

Thermal comfort

The guidance to the code recommends the following indoor air temperatures (§8.36):

winter	21-22
summer	23-24
min. winter	20
maks. summer	26

Higher temperatures than 26 should be accepted in warm summer periods with outdoor air temperature over what is passed 50 hours in a reference year.

Occupational health regulations

A guidance to the law of occupational health deals with climate and air quality on the workplace. (Best. nr. 444, Arbeidstilsynet).

The guidance requires air flows quite similar to the air flows in the guidance to the building code. If nothing is known about the building materials used, the q_B is increased to 2,8 l/s pr. m².

The guidance requires filtering, with filter class EU7/F85. The guidance requires further that rooms with permanent workplaces must have draught-free air inlets. As a rule, this requires balanced, mechanical ventilation, according to this guidance.
The thermal comfort requirements is quite similar to the guidance to the building code.

CONCLUSIONS

The interviews identifies significant lack of knowledge and experience on both special designed and ordinary natural ventilation in office buildings compared to the knowledge and experience on mechanical ventilation. In addition there is a lack of sources to natural ventilation knowledge in standards, guidelines and building studies and a desire for new design tools on natural ventilation including also calculation rules and easy to use, simple and advanced computer programmes.

There is a need for good, standardised and general accepted natural ventilation system solutions and if possible for system solutions including heat recovery. In addition there is a need for new components regarding windows and vents with better air flow and draught performance, better controllability and better design.

In the interviewees opinion, mechanical ventilation have several advantages compared to natural ventilation regarding cooling effectiveness, draught minimisation, ability to remove odours and pollutants, ability to prevent ingress of odours and pollutants, insulation against external noise and central controllability, especially if the mechanical ventilation systems are well designed. The interviewees also expect a higher user satisfaction in mechanical ventilated offices.

All interviewees expect both higher installation, higher running and higher maintenance costs for mechanical ventilation in offices than for natural ventilation.

Room temperatures in summer are the most important design parameter, but also room temperatures at winter and indoor air quality are often critical design parameters. The architects, consultant engineers and owners have the biggest influence on the design of a building.

On average the interviewees expects a moderate increase or unchanged future use of natural ventilation in office buildings in Norway. In general the architects have the highest expectation of increasing use of natural ventilation. The main reasons for expecting increasing use of natural ventilation are saving of resources and lower costs, Some architects pointed out that natural ventilation would give them more control and design freedom of the volumes of the building.

The main reasons for expecting decreasing use of natural ventilation are less control over indoor air temperatures and indoor air quality. Cooling is problematic in naturally ventilated buildings. Mechanical cooling is usual in modern Norwegian buildings, reflecting the narrower acceptable temperature comfort range.

The building code in Norway requires quite high air flows in office buildings, especially if nothing is known about the emissions from the building materials. According to the code, the air flows in natural ventilation systems must be documented.