



# Energy-efficient ventilation for hospitals



# Energy-efficient ventilation for hospitals and cleanroom environments in the industrial sector

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## Preface

“E2B2 – Research and innovation for energy-efficient building and housing” is a programme where academia and industry collaborate to develop new knowledge, technology, products and services.

In Sweden, the built environment accounts for about 35 percent of energy usage, and it is a societal challenge to achieve real energy efficiency so we can achieve our national climate and environmental goals. In E2B2, we contribute to greater energy efficiency in the construction and use of buildings in a number of ways. We ensure long-term competence management in the form of knowledgeable people. We build new knowledge in the form of innovative research projects. We develop technology, products and services, and demonstrate that they work in reality.

Through the programme, over 200 construction contractors, real estate companies, material suppliers, installation suppliers, energy companies, engineering consultants, architects and more collaborate with academia, institutes and other experts. Together, we create benefit from the knowledge that develops through the programme.

*Energy-efficient ventilation for hospitals* is one of the many projects conducted in the programme with the help of state aid from the Swedish Energy Agency. It was led by Lund University and conducted in partnership with Avidicare AB.

Purification of the air in operating rooms plays an important role in preventing disease transmission. However, the ventilation is extremely energy-intensive since the air turnover rate is usually 20–40 higher than in standard rooms. This E2B2 project examined a new type of ventilation developed to maintain air cleanliness with 30 percent less energy consumption. The project was conducted using field measurements, laboratory studies and other means.

Stockholm, 17 March 2017

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This report presents the results and conclusions of the project. Publication does not mean that E2B2 has formed an opinion on the content.



## Summary

Ventilation in rooms with high hygiene requirements is extremely energy-intensive since the air turnover rate usually is 20-40 times higher than residential ventilation, for example. This type of facility exists at many hospitals and industries working with electronics, food and pharmaceuticals. This project conducted an experimental evaluation of a new type of cleanroom ventilation based on temperature-controlled airflows, referred to as TAF technology. TAF has higher ventilation efficiency and lower energy consumption than traditional laminar airflow, LAF.

Measurements were performed at different locations during 45 surgical operations in operating rooms at Helsingborg Hospital. Three types of ventilation were compared – TAF, LAF and mixed ventilation, TMA (i.e. turbulent mixed airflow). Air cleanliness was measured at three critical points in the room: at the surgical wound, at the instrument table and outside the sterile zone. Other factors, such as safety, noise and draught, were also evaluated. We also developed a weighted index of energy and air cleanliness, namely  $I_{\text{HygieneEfficiency}}$ . The index is the product of the energy consumption and the number of airborne bacteria – i.e. the lower the better.

The study showed that the TAF technology meets the limit values for ultra-clean surgery in all locations in the room. The reported impact on staff work environment from draught and noise levels was also significantly lower for TAF compared to LAF as a result of the reduced air speeds and the positioning of the fans. The estimated  $I_{\text{HygieneEfficiency}}$  was  $26 \pm 4$ ,  $33 \pm 5$  and  $18 \pm 10$ , for LAF, TMA and TAF, respectively.

The different ventilation systems have different ventilation efficiency at different locations in the room due to differences in the air flow directions. Comparison of experimental data with computer simulations is needed to better understand this and to be able to utilise the ventilation optimally.

*Keywords: Ventilation, cleanroom, airborne particles, energy efficiency, contamination control, disease transmission, temperature controlled airflow*



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# 1 Background

Ventilation and heating at hospitals and in many industrial sectors are crucial for keeping the air clean and thereby limiting disease transmission, reducing staff exposure to contaminants, and protecting production processes. Such types of environments use extremely energy-intensive ventilation since the air turnover rate in a room is usually 20–40 times higher than in typical homes, for example.

This study focuses on one of the environments where clean air is most critical – operating rooms at hospitals. In addition to personal suffering, the transmission of infectious disease during operations amounts to SEK billions in Sweden alone (National Board of Health and Welfare, 2006). An ageing population and an increasing proportion of antibiotic-resistant bacteria are causing the problem to grow. Many hospitals in Sweden currently have plans to renovate or build new operating rooms (examples include Helsingborg Hospital and New Karolinska Solna). It is therefore critical to have good knowledge of how these facilities should be designed in order to reduce disease transmission. Experience can be widely applied in other areas where clean air is a requirement. The energy consumption of these premises contributes significantly to the operating cost and plays a role in the choice of ventilation type.

## 1.1 Project's objectives

This project explores and further develops ventilation with TAF (temperature controlled airflow) technology for cleanroom environments. The technology provides high energy efficiency for ventilation of ultra-clean environments (see below).

The aim of the project is to 1) examine possibilities for further energy reduction of TAF technology by, for example, linking ventilation velocity to air quality and 2) scientifically test TAF technology's ability to transport away contaminated air in a hospital compared to turbulent mixed airflow ventilation (TMA) and laminar airflow ceiling (LAF or UDF).

Specific objectives are:

- Scientific publication comparing TAF technology with conventional ventilation. This is important for both clients (e.g. Helsingborg Hospital) and manufacturers (in this study, Avidicare AB).
- Creation of underlying data to make TAF technology even more energy efficient. This type of ventilation normally runs around the clock, which is a major waste of energy.
- Finding simple air quality indicators that in the future can be linked to ventilation control.





- Reducing operating and energy costs for hospitals and industry through improved ventilation.

### 1.2 High air cleanliness in the healthcare sector

It is well accepted that postoperative infections occur when bacteria reach the surgical wound while the surgical procedure is in progress (Lidwell et al. 1983; Whyte et al. 1982). Such bacteria can reach the tissue through direct or indirect contact or via the air (and, in principle, via any vector as well). Bacteria are spread to the air continuously from people in the room or from adjacent rooms when doors are opened (Andersson et al. 1984; Erichsen Andersson 2013; Ritter et al. 1975). As a result, they travel via air current and are deposited in the surgical wound or some surface (e.g. instrument) that comes into contact with the wound and then give rise to infection (Edmiston et al. 2005; Friberg et al. 1999; Lidwell et al. 1983).

The air is thus one of the most common, and probably the fastest, transmission pathway for many infectious agents. At the same time, it is the transmission pathway that can be largely limited through technical methods and knowledge. Ventilation is a critical factor in removing infectious agents and contaminants from the rooms. For this reason, hospitals (and the industrial sector) use high airflows with power fans that consume large amounts of energy for both heating and circulation.

### 1.3 Methods for creating ultra-clean air

Effective air purification is based on a combination of airflow rate, flow direction and temperature balance. To transport away bacteria in the air, many operating rooms have an advanced laminar airflow ceiling (LAF or UDF (unidirectional airflow)) above the operative zone (see Figure 1 below). Several recent studies have shown that these expensive ventilation ceilings do not significantly reduce – or may even increase – the risk of infection (Breier et al. 2011; Diab-Elschahawi et al. 2011; Gastmeier et al. 2012; Hooper et al. 2011; Iudicello and Fadda 2013; Miner et al. 2007). The ventilation used is extremely energy-intensive, but at the same time has an effect that is unclear and weakly supported by scientific studies.

There is thus a great need for research to clarify which way is most effective when it comes to reducing airborne infection, particularly in surgical environments. Fortunately, opportunities for introducing new knowledge in the field are good thanks to recent development within measurement technology and data models for flow calculations.

This project compares three types of ventilation: 1) turbulent mixed airflow ventilation (TMA), 2) LAF ceilings, and 3) TAF (temperature controlled airflow), which is a newly-developed and more energy-efficient ventilation method that has produced very low levels of bacteria according to the company's own measurements (Figure 1).

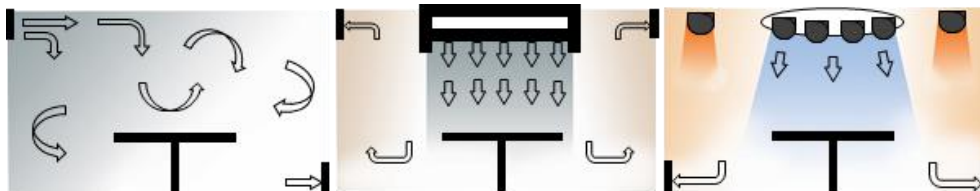
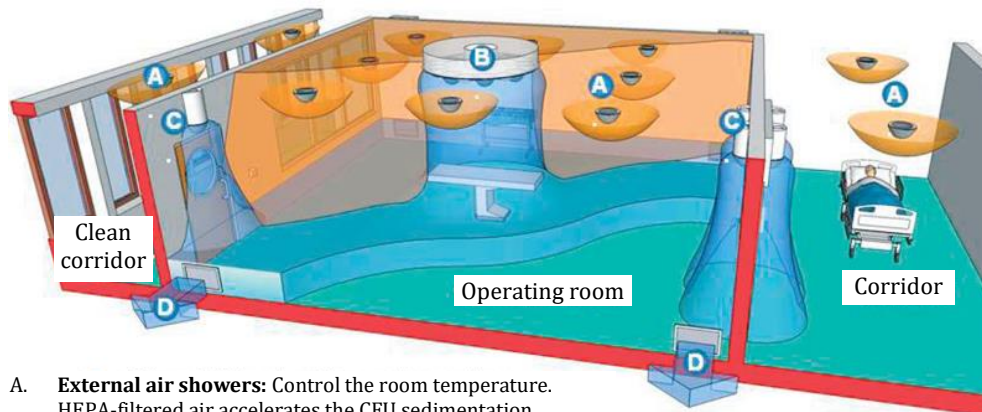


Figure 1. Left: Turbulent mixed airflow. Centre: LAF ceiling Right: TAF.

#### 1.4 Energy consumption in cleanroom environments

The ventilation in environments that require high air cleanliness is extremely energy-intensive. High air cleanliness is necessary in, inter alia, hospitals, food product companies, the electronics industry and pharmaceutical manufacturing. For example, the ventilation in an operating room with high cleanliness requirements consumes 25,000 to 35,000 kWh/year (i.e. more than the total energy consumption of an average Swedish single-family home). A normal-sized hospital generally has 20–40 such rooms along with adjoining spaces that also require high cleanliness. There is therefore great potential for energy savings here.

#### 1.5 Energy-effective technology for ultra-clean ventilation: TAF



- A. **External air showers:** Control the room temperature. HEPA-filtered air accelerates the CFU sedimentation.
- B. **Opragon:** Cooled HEPA-filtered air provides an ultra-clean operative zone.
- C. **Air curtains:** Cooled HEPA-filtered air reduces entry of particles.
- D. **Exit air:** All exit air is evacuated symmetrically at floor level.

Figure 2. TAF technology for operating rooms.

The principle behind TAF technology (temperature controlled airflow) in an operating room is depicted in Figure 1 on the right and in Figure 2 above. With TAF technology, slightly cooled air – thanks to its higher density – falls to the floor at a speed dictated by the temperature difference between the added air and the ambient air level with the operating table. This technology enables very stable and accurate control of the fall speed past the patient and the sterile-dressed staff. The technology also makes it possible to maintain a balance between a speed high



enough to break the body convection of staff and patient, while at the same time avoiding unnecessary turbulence and draughts.

Instead of introducing a new LAF ceiling that takes up even more space and uses even higher airflow than previous versions of LAF ceilings, the method focuses on ventilation efficiency. Instead of using a HEPA filter as both a filter and air distributor, the TAF technology developed by Avidicare separates these functions. The filter is positioned adjacent to the operating room, while inside the operating room there are only air distributors (air showers), which work at an extremely high level of efficiency.

While traditional LAF ceilings require high air speeds to counteract the convection currents from staff, operating lights, etc., TAF breaks the convection currents in a more effective and energy-efficient way. TAF consumes 30% less energy than conventional operating room ventilation with the same air cleanliness level. TAF is economically profitable for hospitals since the higher investment cost is offset by a lower operating cost (through lower energy consumption).

TAF has been verified and approved according to the German standard DIN1946-4, which applies to operating room ventilation, as well as the Swedish standard SIS-TS39:2015. The TAF system developed by Avidicare focuses on the hospital market, but similar systems are also being developed for other types of premises that require a high level of air cleanliness, such as the electronics industry, food product companies and pharmaceutical manufacturing.



## 2 Method and project plan

### 2.1 Project team

The main partners in the project are Lund University, Helsingborg Hospital, and the company Avidicare. The project is led from Lund University's Department of Ergonomics and Aerosol Technology (EAT). EAT has decades of experience with cleanroom technology. Avidicare has developed TAF technology for hospitals.

The project gathered experts in the key areas required to achieve its objectives: ventilation development (Peter Ekolind and colleagues at Avidicare), air quality measurement (Jakob Löndahl, PhD, Faculty of Engineering at Lund University), hygiene in healthcare (Ann Tammelin, MD), cleanroom and hygiene technology (Prof. Matts Ramstorp), surgery and operating room design (Per-Anders Larsson, MD, Head of Research at Helsingborg Hospital).

### 2.2 Project organisation

The experimental part of the project consisted of 1) hospital field measurements and 2) controlled tests in an operating room laboratory. The field measurements, which were the main focus of the project, were performed at the Department of Surgery at Helsingborg Hospital (Skåne University Hospital). The hospital has operating rooms that are essentially identical in all respects except for choice of ventilation type. The two conventional ventilation methods (LAF ceiling and mixed ventilation) are already installed. TAF ventilation was installed in one of the operating rooms at the start of the project.

Avidicare built an artificial operating room at Medicon Village in Lund to mimic an operating room (70 m<sup>2</sup> with great flexibility in design). This was used for method development.

#### 2.2.1 Time frames for implementation of project milestones

Installation of TAF in operating room (completed Dec. 2014); equipment testing and pilot measurements (Sept. 2014–Jan. 2015); measurement campaign during surgery (Jan. 2015–Dec. 2015, supplementation Jan.–March 2016); analysis of data and preliminary report (April 2015–ongoing); compilation of research manuscript (began April 2015, doctoral student employed Sept. 2015 currently working on completion of manuscript); further development of TAF based on measurement results (April 2015). The field measurements took longer than planned due to scheduling at Helsingborg Hospital.

#### 2.2.2 Study design for field measurements

Three types of ventilation were investigated: LAF ceiling, turbulent mixed airflow ventilation (TMA) and TAF. Prior to the study, a functional check in accordance with SIS 39/2012 was performed to verify airflows, filter density, pressure and





purification time. In each operating room, measurements were performed during 15 orthopaedic operations with a knife time of at least 45 minutes. The same types of surgery (and at the same quantity) were measured in each operating room to obtain a valid comparison. The staff were dressed according to standard practice during the surgery. Deviations were recorded. Measurements were only performed during the day by a single individual with long experience of sterile work who was specially trained for this purpose. Measuring instruments were checked and data regularly archived by LTH staff. Annual ventilation inspection of operating rooms according to protocols was performed by Regionservice, which is the internal service provider of Region Skåne.

**Supplementary measurements:** From January to March 2016, necessary supplementary measurements were performed, all of which had a knife time over 45 minutes and no significant deviations among staff. Measurements were also performed to investigate the difference between sterile and non-sterile zones for LAF ceilings since the instrument table was not always located in the sterile zone.

### 2.2.3 Measurement method

Several different parameters were measured to check air cleanliness and ventilation during the operations:

- Active sampling of the number of colony-forming units per cubic metre of air (CFU/m<sup>3</sup>) at the wound, the instrument table and peripherally in the room.
- Passive sampling of colony-forming units at the instrument table.
- Real-time measurement of “viable” bacteria and particles.
- Particle concentration (quantity/cm<sup>3</sup>)
- Carbon dioxide level (at instrument table and peripherally)
- Temperature
- Humidity
- Differential pressure compared to surrounding space
- Noise

Bacterial content was measured at the wound by collecting gelatine filters which were then transferred to agar (Sartorius, MD8 Air Sampler). At the instrument table and peripherally in the room, bacteria was collected directly on agar with rotating slit samplers (Klotz, FH6). During sampling, 1,000 L of air were collected in 10 minutes. 15–30 air samples were collected during each operation for bacteria analysis. The agar plates were analysed at the Medical Microbiology unit following the hospital's standard routines.

A completely new method for analysing bacteria at the instrument table was also created, namely “instrument agar”. To mimic the instrument table geometry, agar



with a similar structure was made. The structure affects airflow and thereby the accumulation site of bacteria.

At the end of the measurement campaign, some bacteria measurements were performed using new fluorescence technology (BioTrak, TSI/Brookhaven). The method analyses bacteria and particles in real time with a 1-minute time resolution, thus providing quick feedback between the activity and air cleanliness.

Particle concentration and average particle size below 0.5  $\mu\text{m}$  diameter were measured with a time resolution of about 30 s using a NanoTracer (Phillips). Temperature, humidity and carbon dioxide levels were logged at 20 s intervals with two Rotronic CL11. Pressure in the operating room relative to the transport corridor was detected at 5 s intervals to capture the effects of door openings (Kimo MP 200 P). Noise was measured both during surgery and in the empty operating room, both to register activity and for information on noise from a working environment standpoint (sound meter, Swema SL 322).

#### 2.2.4 Working environment examination

It is well known that ventilation in ultra-clean environments affects the working environment of the staff. High airflows result in draughts and noise, and thereby muscle tension and difficulties concentrating. In a surgical environment, problems with pain – particularly neck pain – are common due to high vertical airflows, not least from LAF ceilings. For this reason, the staff were asked to complete a survey on their perceived working environment after completion of surgery. The number of respondents was 25 for TMA, 28 for LAF and 29 for TAF. A total of 130 people work in the department, of which more than half work full-time. The survey is attached in Appendix 1.

#### 2.2.5 Energy calculation

The energy consumption of the three ventilation systems was estimated using a model developed by WSP (Report [in Swedish]: LCC analysis OP room ventilation Opragon 8 compared to different ventilation systems by Erwin Spjiker). The incoming amount of outdoor air (18°C) in all operating rooms was 560 L/s (2,000  $\text{m}^3/\text{h}$ ). The remaining air volume was recirculated, and the energy required for heating and cooling was calculated based on this. LAF and TAF require a temperature difference between the incoming air (cooler) and the ambient room air (warmer), which increases energy consumption.

There is no measure of air cleanliness in relation to energy consumption. We therefore developed a proposal for an energy-cleanliness index,  $I_{\text{HygieneEfficiency}}$ , which is a weighted measure of air cleanliness level in relation to energy consumption. Such a measure would make it easier to compare cleanroom ventilation from an energy perspective. The hygiene efficiency index, ( $I_{\text{HygieneEfficiency}}$ ), is based on the average number of CFUs ( $\text{CFU}_{\text{average}}$ ) (in the entire





room) during an operation and energy consumption per hour of operation (E) in kWh/h:

$$I_{Hygiene\ Efficiency} = CFU_{average} * E$$

The index thus increases with both increased number of CFUs and increased energy consumption, resulting in the most beneficial ventilation system having the lowest value.



## 3 Results and discussion

### 3.1 General conclusions

Both LAF and TAF maintain a level close to or below 5 CFU/m<sup>3</sup> at the wound and the instrument table. LAF has the lowest values at the wound and the instrument table when this is located in a sterile zone (which is not always the case), but higher peripherally in the room. TAF produces low values in the entire room.

Turbulent mixed airflow (TMA) ventilation is inferior when it comes to keeping the entire surgical zone clean due to differences in both design and airflows. LAF and TAF both produce significantly cleaner air.

LAF uses airflow that is twice as high as TAF and six times higher than TMA ventilation, which means higher energy consumption and more draughts and noise.

### 3.2 Air cleanliness

From our results, we see a clear difference in air cleanliness in the different operating rooms. The bar graph below (Figure 3) shows that CFU values are lowest in the sterile zone in LAF (wound and staff behind it) and that TAF has slightly higher values in the sterile zone, but lower outside of it in the room. Turbulent mixed airflow (TMA) ventilation has the highest values in all locations in the operating room and is over the recommended value of 10 CFU/m<sup>3</sup> set for surgery with normal workwear.

The standard deviations are relatively large. The CFU values varied greatly from operation to operation, and despite careful documenting of events and air quality, few indicators could be linked to increased contamination of the air.

Since two different instruments were used to measure the CFU values (filters and rotating slit samplers), background measurements were performed to evaluate whether they produced the same results for equivalent measurements. The use of two methods was unavoidable since only filters worked close to the wound. Slit samplers were found to yield values nearly twice as high. Normalisation of data to that of the filter method (which is standard at wounds) was therefore required.

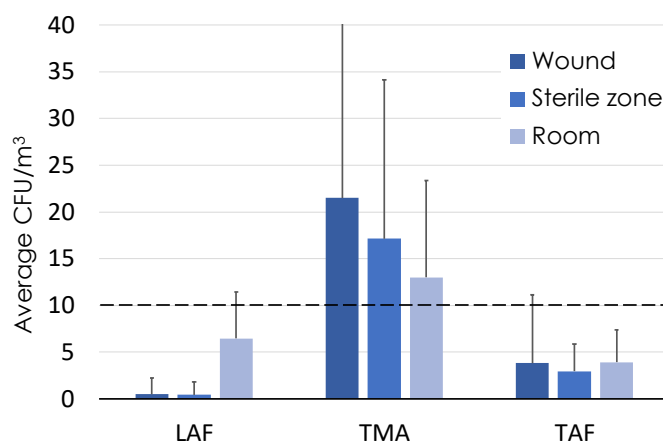


Figure 3: The CFU values for the three ventilation systems measured at three locations in the operating rooms (preliminary data). Limit value for clean surgery marked at 10 CFU/m<sup>3</sup>.

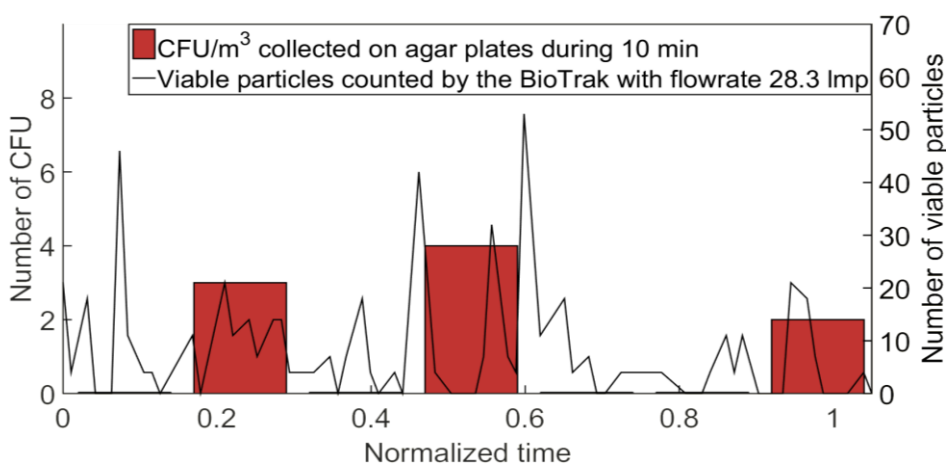


Figure 4: Comparison of two methods for measuring the number of viable particles during surgery

In order to get an idea of the ratio between the number of viable and potentially infectious bacteria in the air and the number of CFUs (not all viable bacteria can grow on agar plates), measurements were performed with a particle counter that uses fluorescence spectrometry. See Figure 4. Fluorescence makes it possible to optically determine whether a particle is viable or not with the help of the high autofluorescence of living organisms. The fluorescence spectrometer was run in parallel with rotating slit samplers which measured CFU values for 10 minutes (see the bars in Figure 4). The results show that the number of viable particles in the air is significantly higher (right Y axis) than the number of CFUs (left Y axis). A current topic of discussion in the cleanroom industry is which is more relevant – CFUs or viable particles via fluorescence.



### 3.3 Instrument agar

A growing amount of attention has been given to the fall of airborne bacteria on the sterile instruments in recent years. In a project from Germany, surgical instruments were allowed to remain laid out under authentic surgical procedures and were then rinsed in a sterile solution. The solution was filtered and the number of bacteria that ended up on the sterile instruments was cultured. A troubling amount of bacteria was shown to fasten on the instruments during surgery. The method of examining sterile instruments in this manner is lengthy and has many potential sources of error.

To investigate whether this way of examining the cleanliness level of surgical instruments could be simplified, Avidicare developed a three-dimensional agar structure that mimics surgical instruments and can be incubated immediately after exposure. After this, the number of CFUs are counted (Figure 5). The aim was to see whether this was possible under clinical conditions, and measurements were performed during about 30 operations. The method worked well and may see spread in the future for the control of air cleanliness. What limit values can be accepted in the future remains to be seen. The results have not yet been fully analysed.



Figure 5. Left: Agar plate in the shape of an instrument table. Right: Growth of bacteria colonies.



### 3.4 Working environment

The differences in perceived working environment were great between the three operating rooms with different ventilation systems (Figure 6).

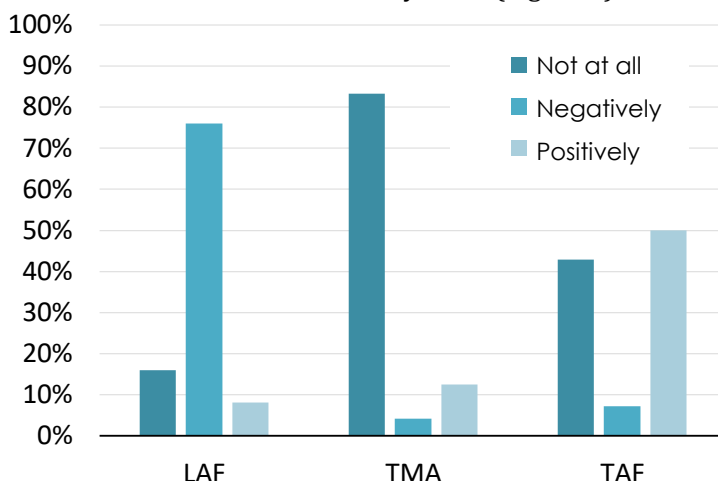


Figure 6. Response to the question "How do you feel the ventilation affects you?"

The working environment of the operating room is important. A high level of performance and concentration is expected from the surgeon, the rest of the surgical team, and the anaesthesia staff during their work with the patient. Known environmental factors in the operating room that negatively impact the staff's ability to concentrate are lighting (not analysed here), noise level and draughts. Rooms with LAF have high airflows that create noise and draughts that negatively impact the staff's ability to concentrate. In the operating room with LAF, 75% of the staff reported disturbing noise or draughts from the ventilation, while less than 10% experienced this for the TAF room. About 50% of the staff in the TAF room had a positive perception of the ventilation with regard to noise and draughts.

### 3.5 Energy efficiency

The table below provides a comparison of the energy consumption of the different ventilation systems. LAF and TAF both have high energy consumption, mainly due to their high airflows. Turbulent mixed airflow (TMA) has both lower airflow and lower energy consumption, but has a high index value due to its high CFU values. Even though energy consumption per m<sup>3</sup> air is lower in LAF than in TAF, the high airflow in LAF gives it a higher index value than TAF.

Table 1: Table of the energy efficiency of the ventilation systems.

	LAF	TMA	TAF
Airflow (m <sup>3</sup> /h)	11,950	3,200	6,300
Energy consumption (kWh/year)	36,202	14,432	25,943
HygieneEfficiency (CFU* Energy)	26 ± 4	33 ± 5	18 ± 10





### 3.6 Conclusion

The main objective of this project was to investigate whether TAF could deliver maintained air cleanliness with 30% lower energy consumption. We have shown that TAF produced bacteria levels significantly below the limit value for ultra-clean surgery at all three areas of the operating room – near the wound, at the instrument table, and peripherally. LAF also delivered bacteria levels below the limit value at the wound and instrument table, while air from turbulent mixed airflow ventilation (TMA) was over the limit value. According to our calculations, the TAF system in this study had 28% lower energy consumption than the LAF ventilation investigated.

While the differences in cleanliness and energy consumption are partly attributable to differences in airflow, ventilation efficiency is also a factor. For example, the TAF system's flow was only twice that of TMA, while producing air that was ten times cleaner at the wound, eight times cleaner at the instrument table, and three times cleaner peripherally (based on the median values of bacterial content). LAF also had relatively high ventilation efficiency in the sterile zone, but was poorer peripherally. The study was thus able to confirm that TAF can produce air cleanliness below the limit value for ultra-clean surgery, but with reduced energy consumption. We also identified methods to further improve energy efficiency and intend to move forward with this in future projects.





## 4 Communication of the project

The project has already been largely published according to the previously written communication plan (Appendix 2). The main reporting that remains is publication of the scientific manuscript, which generally takes 6–12 months due to the time-consuming review process.

### 4.1 Reporting drawing particular attention

**Sveriges Television, SVT:** A report on our research on airborne disease transmission was broadcast by the Swedish public service television company on 30 December 2015; see <http://www.svt.se/nyheter/lokalt/skane/vinterkraksjukan-skapar-stora-problem>. They asked us to do a follow-up report on the ventilation project once our measurements in the operating rooms are complete.

**Award for best poster:** Malin Alsved, a doctoral student working in the project, received a SEK 5,000 award for “Best Poster” when she presented the results at the NDPIA (National Doctoral Programme in Infection and Antibiotics).

### 4.2 Conferences for industry organisations and interest groups

Tema Renrum [Theme Cleanroom]. Industry meeting for cleanrooms (industry and healthcare, approx. 200 participants). Lecture: “Högrena operationsrum, Hur rent och till vilket pris?” [Ultra-clean operating rooms. How clean and at what price?], Jakob Löndahl, November 2015, Stockholm

Framtidens Operationsavdelning [Surgical Department of the Future]. Conference on surgical departments (approx. 200 participants), Lecture: “Erfarenheter från en aktuell forskningsstudie: Så skapas högren luft och god arbetsmiljö i operationssalen” [Experiences from a current research study: How to create ultra-clean air and a good working environment in the operating room], Jakob Löndahl, April 2016, Stockholm

Framtidens Operationsavdelning [Surgical Department of the Future], Lecture: “Framtidens operationsavdelning – rent som industriella renrum, eller?” [Surgical department of the future – clean like industrial cleanrooms, or?], Matts Ramstorp, May 2015, Stockholm

Fortbildning för operationspersonal [Continued Education of Surgical Staff]. Lecture: “Ventilation och Hygien på op-sal” [Ventilation and hygiene in the operating room], Jakob Löndahl, September 2014, Helsingborg

### 4.3 Scientific publications in reviewed journals

Alsved, Civilis, Ekolind, Tammelin, Erichsen Andersson, Jakobsson, Svensson, Ramstorp, Larsson, Bohgard, Löndahl, “Operating room ventilation by temperature



controlled airflow (TAF) in comparison with laminar airflow and turbulent mixed airflow”, *To be submitted to American Journal of Infection Control*

#### 4.4 Scientific conferences

Alsved, M., Civilis, A., Ekolind, P., Tammelin, A., Erichsen Andersson, A., Jakobsson, J., Svensson, T., Ramstorp, M., Santl Temkiv, t., Larsson, P.A., Bohgard, M., Löndahl, J. “Uptake of Semi-volatile Organic Compounds onto Ammonium Sulfate Particles”, Conference Proceedings European Aerosol Conference, EAC, September 2016, Tours, France

Alsved, M., Civilis, A., Ekolind, P., Tammelin, A., Erichsen Andersson, A., Jakobsson, J., Svensson, T., Ramstorp, M., Šantl-Temkiv, T., Larsson, P.A., Bohgard, M., Löndahl, J., “Airborne bacteria during surgery in hospital operating rooms with different ventilation systems”, Conference Proceedings Nordic Aerosol Conference, NOSA, 4-6 April 2016, Aarhus, Denmark

#### 4.5 Popular science publication

Scheduled participation in the magazine Uppdukat at Helsingborg Hospital in August 2016.

#### 4.6 Other activities

Seminar/staff training: Participation in Helsingborg's surgical nurse study days with seminar and discussion on air cleanliness, plus demonstration of fluorescence instruments that can detect visible particles in the air. 22 and 29 January 2016.

Seminar: Presentation of the study's results at Helsingborg Hospital's Department of Surgery, 7 June 2016.



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## Appendix 1, Working environment survey

Ventilation system in operating rooms 11, 15, 16

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Date: \_\_\_\_\_ OP room 11  OP room 15

OP room 16

Male  Female

Initials: \_\_\_\_\_

Age            20-30     31-40     41-50     51-60     61+

Occupation:    Surgical nurse

                    Anaesthesia nurse  Anaesthetist

                    Nursing assistant  Surgeon / orthopaedist

                    Other: \_\_\_\_\_

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**1. Do you perceive a cold draught from the ventilation in the room?**

1                    2                    3                    4                    5                    6                    7

Not at all

Very much

**If you experience it as a problem, in what way does it affect you?**

**(More than one alternative can be selected)**



Freeze/draught on shoulders/neck

Pain in neck/shoulders

Cold hands

Headaches

Other: \_\_\_\_\_  
\_\_\_\_\_

**2. How do you perceive the control of air temperature?**

1	2	3	4	5	6	7
Very poor				Very good		

**3. How do you perceive the sound from the ventilation?**

1	2	3	4	5	6	7
Very quiet					Very loud	

**4. How do you perceive the ventilation as a whole in the operating room?**

1	2	3	4	5	6	7
Very poor				Very good		

**5. How do you feel the ventilation affects you? (E.g. do you feel more awake and alert or do you think it makes you feel tired and unfocused)**

Positively   
Negatively   
Not at all

**If you feel an impact, how large do you estimate it to be?**





1 2 3 4 5 6 7  
Very small Very large

**6. How do you perceive the overall comfort level of the working environment in the room?**

1 2 3 4 5 6 7  
Very poor Very good

**Other viewpoints:** \_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_



## 6 Appendix 2, Communication plan

Abridged version.

### 1. Target groups, objectives and strategy

#### 1.1.1 Target groups and channels

Important target groups we want to reach are people who work specifically with healthcare hygiene, as well as different types of users and suppliers in industrial cleanliness technology: architects, property developers, contractors, installers, property managers, property owners (e.g. Locum – “values for healthcare”), users of operating rooms and industrial cleanrooms, other researchers in the field of air cleanliness.

The individuals interested in cleanliness technology are gathered in different organisations and are effectively reached by participating in their conferences and other events. Important groups in hospital cleanliness are Svensk Förening för Vårdhygien [Swedish Society for Healthcare Hygiene] and SEORNA [Swedish operating room nurses association]). Broader groups in industrial cleanliness are reached via:

- Tema Renrum [Theme Cleanroom]: The Nordic region's leading training days in cleanroom technology. The project leader (Löndahl) gave a speech in 2012 and was invited to talk about the project again once the results are ready.
- Nordic Hygien Expo: The Nordic region's largest expo in cleanliness and hygiene. Organised by Rentforum (whose MD Matts Ramstorp is a participant in this project).
- RenaRum: The Nordic region's leading industry journal in cleanliness technology (publisher Matts Ramstorp).

As a vendor of ventilation for clean environments, Avidicare also works actively to disseminate information and create contacts with a large number of hospitals at both the national and the global level.



### 1.1.2 Objectives of the communication

- *Knowledge objectives:* Call attention to energy consumption and potential for improvements. Explain TAF technology and its potential advantages.
- *Attitude objectives:* External variables (cleanliness, energy efficiency, etc.) should be of benefit for TAF in several situations. During the project, we also discovered that hospital staff perceive other benefits – less noise, no troublesome draughts.
- *Motivation objectives:* Users (staff in clean environments) shall request TAF instead of the current outdated technology. Clients should be able to see the advantages through an analysis.
- *Behaviour objectives.* Test out and continue.

### 1.1.3 Strategy for achieving the objectives

Responsible for the project's communication: Avidicare as supplier, BioTekPro as trainer in cleanroom technology, Department of Ergonomics and Aerosol Technology (LU) or dissemination of research results.

Ongoing dialogue with different target groups that has been open for decades.

Communication occurs:

- At project start-up for the staff of Helsingborg Hospital.
- When there are results to present to users, customers and researchers.

The project involves several professional communication officers who work with this full time (BioTekPro, Avidicare and public relations staff at LU). Naturally, how much the results are disseminated depends on the outcome of the research.

## 2. Message

With unique TAF technology (temperature controlled airflow), we combine safe functionality with a comfortable working environment. Instead of introducing a new LAF ceiling that takes up even more space and uses even higher airflow than previous versions of LAF ceilings, we focus on ventilation efficiency.

Instead of using a HEPA filter as both a filter and air distributor, we separate these functions. When TAF is installed, the filter is positioned adjacent to the operating room, while inside the operating room there are only air distributors (air showers) which are suited to the purpose and work at an extremely high level of efficiency.



While traditional LAF ceilings require high air speeds to counteract the convection currents from staff, operating lights etc., we introduce a system, which adheres to the fundamental laws of nature, and which breaks the convection currents in an effective and energy efficient way.



» *About 35 percent of all energy in Sweden is used in the built environment. In the E2B2 research programme, researchers and societal actors work together to develop knowledge and methods to streamline energy use and develop the construction and use of buildings in society. In this report, you can read about one of the projects that make up the programme.*

*E2B2 is being conducted in partnership between IQ Samhällsbyggnad and the Swedish Energy Agency 2013–2017. Read more at [www.E2B2.se](http://www.E2B2.se).*

