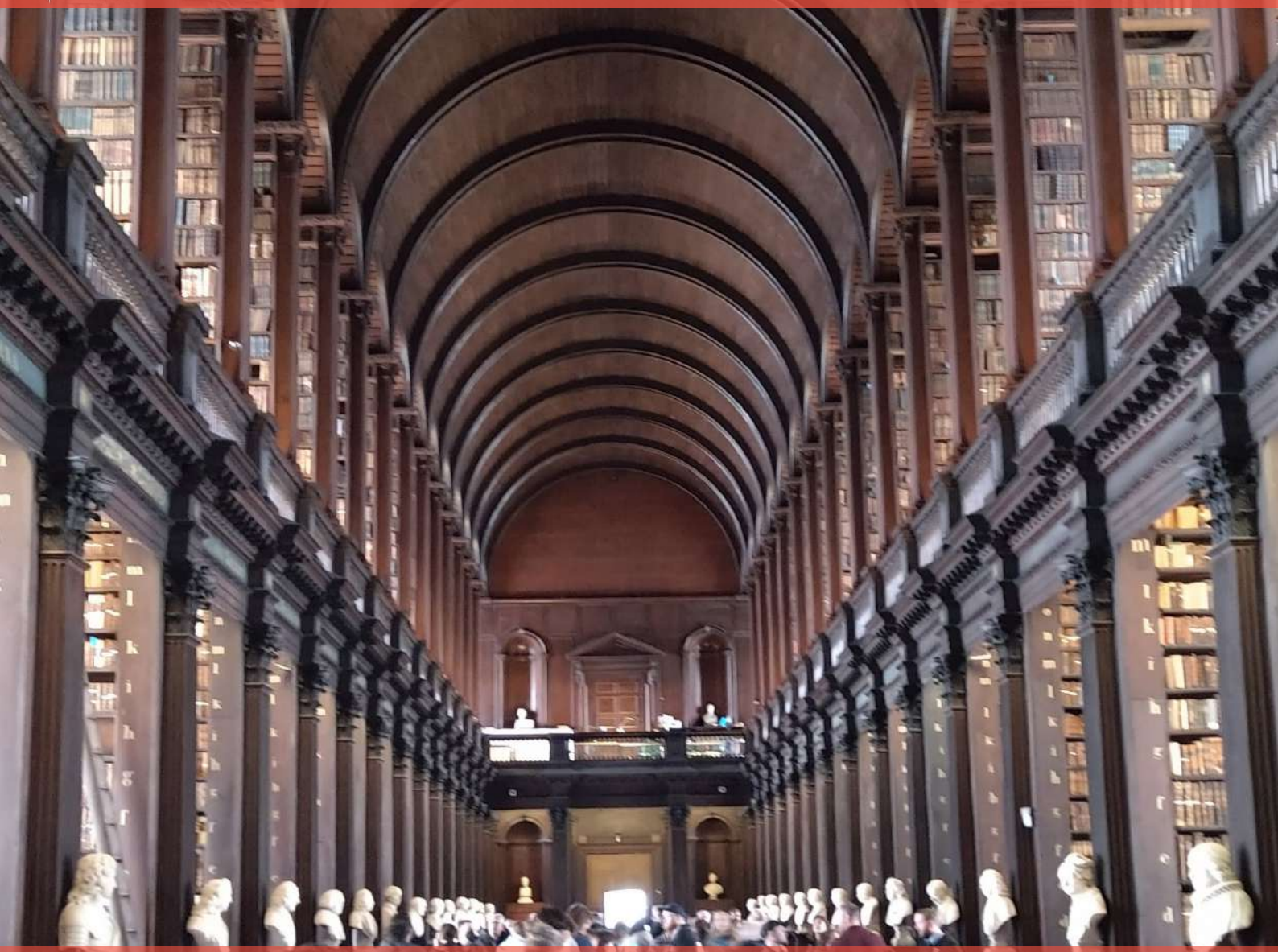
Calendar year 2022

MOLLIER

Study Association
Building Physics and Services

INSIDE INFORMATION

MOLLIER | UNIT BPS | STUDENTS | ACTIVITIES | MEMBERS



Energy-economic Evaluation of a NZEB Tiny House Design

ir. F.M. (Floortje) Arnts

Study trip 2022, Dublin

VOC Emissions from (Biobased) Building Materials

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FINDING THE RIGHT PH FOR ARTIFICIAL CONCRETE REEFS...

Foreword

Nora Kuiper

Dearest reader,

It is my pleasure to present to you the 2022-edition of INSide Information, giving you all a good read during the Christmas break. Likely as our readers after a December filled with treats, it is our fattest edition yet. ;) I'm proud of the product that Menno, Laurens and I have again put together and we hope that you'll enjoy this magazine as much as we do.

First off, a new academic year also means that we have a new Mollier board, and I'm very positive that they'll make this year into a great success. Get to know them in the Meet the board column! We'll look back at the activities that have been organized in the past year and we'll give you the opportunity to meet not just one, but two of our new students in the IceBreaker columns. What our students are up to during their studies, can be found in the articles written about their projects and the experience of studying abroad. What life has to offer after the completion of Building Physics and Services, is illustrated with the Alumni at work column, and in multiple articles written by former BPS students that now have a job at our company partners.

Besides it being our fattest edition yet, it is also the greenest. We have decided to go into business with a new publisher, namely Opmeer Drukkerij. Opmeer Drukkerij focuses on a sustainable publishing process, completely CO_2 neutral and in the process also supports multiple charity organizations.

As for now, I would like to thank my fellow committee members Menno and Laurens for their hard work and keeping up with me as the editor in chief for this edition. On behalf of the committee, I would like to wish all of you happy reading!

Yours sincerely,

Nora Kuiper
Editor in chief

INSide Committee
Left: Menno Peijnenborgh, Laurens Castenmiller, Nora Kuiper

COLOPHON

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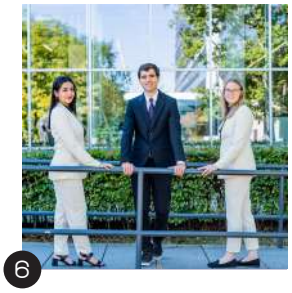
This INSide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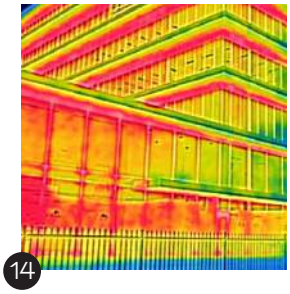
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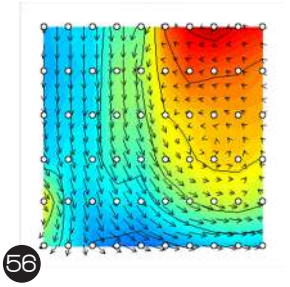
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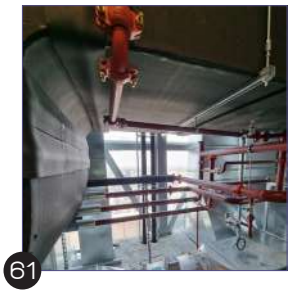
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Introduction to the 27th Board of Mollier

FARIMA VOSOUGHI, CHAIRWOMAN

Hello everybody, my name is Farima (with soft English R), and I am the chairwoman and commissioner of external relations in this academic year. I studied Architecture for my bachelor, however currently I am studying Building Physics & services and working on my graduation project.

Mollier was my lifesaver on the first year of my studies. At first it started with attending to educational activities so I could improve my skills and knowledge about BPS program. However, later on, by attending to fun activities I realized studying abroad is so much fun. That is how I decided to be part of Mollier so I can make a safe, friendly and educational environment for future students like me. Moreover, I have always looked for a proper and active way to learn Dutch and I thought joining an association and being in touch with more Dutch people might help, which so far it did.

At first, I was interested in being commission of external relations. As an international student I have been always wondering about the BPS work environment, engineers and indeed their relations with academic world. Therefore, I was really enthusiastic about communicating more with workplaces. Then I thought now that I communicate beyond university, why not starting within university, with other students and teachers to be more familiar with the academic atmosphere. That is how I became charwoman

Hopefully by the end of this year, I'll be able to socialize more within school, practice more official attitude, meet the goals of Mollier, en Ik ga beter Nederlands spreken!

JUDITH DE WILDE, TREASURER AND COMMISSIONER OF EDUCATION

Hi everyone! My name is Judith de Wilde and I am 26 years old. I am currently living in Eindhoven, but I grew up in De Meern, a few kilometers from Utrecht. Previous year I was part of the 26th board, and this year I'll be still one of the board members of the 27th board of Mollier!

Before my board year I mostly was present during the pizza lectures due to COVID-19, however last year I organized the lunch for the lunch lectures, and this year I hope to organize the lunch again.

In my spare time I enjoy spending time with my friends, cooking and reading. I am looking forward to a great year and meeting everyone.

Last year I did finish my Bachelor End Project and started my Master's. I am very glad that I joined the Mollier and BPS community, and will fulfill my role as treasurer also coming year.

I want to take this opportunity to thank my fellow board members and I'm looking forward to the upcoming year with Martin and Farima.

MARTIN DANIEL MARINO, SECRETARY

Hello world! I am Martin, and I come from the far land of football, "mate" and meat: Argentina. I am 28 years old, and I will be the secretary of Mollier this year. In my spare time, I like taking long bike rides across the forests and canals of Tilburg, and when my studies allow it, travel to nearby cities to discover new places. I also love sharing barbecues with friends and having a chat over some beers at SkyBar or Hubble after those long hours of study.

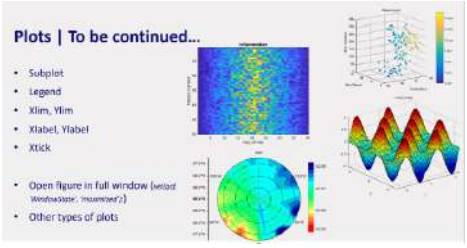
Back in Buenos Aires, my home city, I studied civil engineering for quite a few years. My first international study experience was as an exchange student in Prague, where I spent one of the most memorable semesters of my life. It was then that I decided to expand my horizons and go for a full master study abroad. After graduating, I came to the Netherlands looking to further develop my knowledge in sustainable and energy-efficient buildings, and it was then when I found the Building Physics and Services master at TU/e.

Coming to a new country without knowing anybody posed not only a challenge for me but also an opportunity for meeting new and 'gezellige' people. I started joining the activities that Mollier organized from the beginning of my studies, and by getting to know this nice community is that I got the courage to become a more active member, and even be on the board. That is how I ended up becoming the new secretary of the 27th board of Mollier. I hope to see you around! Salud!

Mollier Activity Calendar

MATLAB WORKSHOP

As is often communicated by students, courses involving Matlab are difficult to follow due to a lack of knowledge on the software and courses often only discuss the basics very briefly. Therefore, Mollier organized a Matlab workshop on February 14th hosted by Juliëtte van Duijnhoven. With this refresher/introduction we hope to have made the upcoming courses easier to follow for our members.



GMM #2

With the lead of Pam as our chairman the second GMM on February 21st was very streamlined and quick, we even skipped the coffee break! During the GMM we got a lot of feedback from our members concerning master projects and planning. In addition, the decision was made to refrain from singing the Mollier Anthem at the start and end of every GMM.

BBD EVENT CAREER TOUR

Additionally to the Meet & Greet, the BBD career market (9th of march) offers students a chance to get a look at what companies have to offer after completing the masters. Mollier hosted a tour for all BPS students so we could all visit the BPS companies together and learn from each others questions. Additionally, Mollier also had their own stand on the market to attract new members and even some company visits.

GALA

Due to Covid-19 the Gala was moved to the 19th of march 2022 and was held in Het Ketelhuis. People from all associations and alumni were invited to celebrate Molliers 5th Lustrum with us. Many people took the opportunity to have their photos taken at the entrance by a professional photographer. Both current members and alumni did a lot of catching up together, as well as getting to know each other better as this also was a chance to meet +1's. We had amazing fun all night with a lot of snacks, drinks and dancing to the live band!

Thank you to the Lustrum committee for their effort in organizing the event!

FSE EXPERT CLASS + DRINK

The fire safety chair invited Mollier on March 25th to their expert class which creates a connection between scientific research, fire prevention and fire suppression. This was done through professional speakers and multiple master project presentations of students. The highlight of the expert class were the nominations of the VVBA IFV thesis award for most innovative , high-profile and relevant bachelor thesis, each nominee also presented a short pitch. The winner of the award will be anounced at the Fire Safety & Science Congress. To conclude the event a small drink was hosted in De Zwarte Doos where the presentations were shortly discussed in a more informal setting

COMFORT LUNCH

One of the most successful activities this year was the comfort lunch organized in Hubble on 14 April. Mollier arranged a nice lunch with good sandwiches and orange juice after one of the most difficult exams of the year, HAM/CFD. Here we got to meet a lot of new people as everyone following the course was invited, leading to more new/active members. Besides connecting with fellow students it offered a good opportunity to blow of some steam and refuel for the acoustics exam.

LUNCH LECTURES #1, #2, #3 AND #4

This year Mollier organized four lunch lectures from Nelissen, Unica, ZRI and VOORT. The first lecture from Nelissen discussed the design challenges of developing a project close to a harbor. The HavenErvaringCentrum (HEC) is completely energy neutral with the help of solar and wind energy. Wind is in abundance at the harbor, so visitors can decide whether they want to accept the challenge and enter the outside stairs and roof terrace. Unica and ZRI mainly discussed what working with them would entail and their work ethic. Lastly, in the lunch lecture of VOORT an ex-built environment student talked about his transition from the master's to the work environment and provided tips on how to make this transition as smooth as possible.

BOARD INTEREST DRINK

In order to find new board members Mollier hosted a board interest drink on April 26th where Mollier gave a short introductionof what a board role at Mollier does entail to interested members who could also ask questions. Fun fact, most people coming to the interest drink were convinced at the comfort lunch.

BEER TASTING

Of course we organized the yearly opportunity for our members and alumni to connect with each other while tasting fine beers. Even though the event had to be postponed to April 29th due to heavy weather conditions in Eindhoven the Beer Tasting was still the most visited activity besides the CoBo. In Belgisch Biercafe everyone got to enjoy 6 specialty beers and fried snacks while catching up with each other and competing in a friendly quiz to win even more specialty beer.

STUDY TRIP DUBLIN

This year Mollier organized a study trip to Dublin where we had a densely packed program from 12 - 16 May. The first full day started off with a 3 hour city tour by the local tour guide Ian, who also convinced us to join the pub crawl that he would be hosting later that evening. After during free time most students decided to visit the lighthouse in Howth and enjoy the beautifull landscape with a hike. We also got introduced to the national sport hurling in Croke Park Stadium, which is a combination of soccer, american footbal, basketball and hockey, after which we also went to a hurling match. On our last full day we visited the Book of Kells and went to a whiskey tasting. The trip was concluded with a workshop on sustainability by the Rediscovery Centre. As you can see the program contained all sorts of activities ranging from a city tour to a pub crawl to visiting the Book of Kells to walking on the roof of Croke Park Stadium. Most importantly, the program contained a lot of fun and everyone had an amazing time!

SEXY SECTION PARTY

All sections of the Built Environment came together to throw one of the biggest parties the department has seen, on June 7th. With the amazing space theme a lot of different costumes were present and seen in Stratum. The first two barrels of beer were on the cost of the sections, meaning there was a lot of free fun, which of course continued afterwards. It was overall a good experience to organize it together with the other sections.

COCKTAIL PARTY

After hosting a beer tasting Mollier of course also had to organize a cocktail party, held on June 10th . One of our members was nice enough to invite us to hold the party in their communal garden providing enough space. We all got to try mixing our own cocktails with a neon theme, so all the bright and colorful drinks were clearly visible after sundown, making them both entertaining and tasty!

COMPANY DINNER

Another new initiative this year was hosting a company diner in Giornale on June 14th. This dinner was the perfect opportunity for (almost) graduating master students to expand their network by joining 5 companies for a 3-course dinner. Students and companies got to know each other in a more informal setting allowing for more in-depth conversation or casual business talk. According to both student and company feedback this event was a great success and should definately be organised again!

ACTIVE MEMBER BBQ

In order to thank our active members this year an active member barbeque was hosted in the garden of another member of ours. In addition to the barbeque the active members also got a Mollier yoghurt cup with a separate compartment for additions and utensils. Everyone had a great fun time catching up and talking about holiday plans and was happy to catch a break after all the studying. Thank you to our board and active members for organizing all these fun and educational activities!

GMM #3/1 - CONSTITUTION

On Thursday, the 15th of September, we organized the last GMM of the 26th board, and the first GMM of the 27th board. The constitution of the 27th board took place, with the members of the 27th board voted in unanimously.

On Friday the 16th of September, the constitution drink of the board members of the 27th board was held where we fed the new board with as many Jägermeister shots as possible. Everybody had a great time an most people also joined us to continue celebrating at the constitution dinner which was held at the Effenaar. To conclude the amazing evening the after party went on in Stratum.

PEUTZ

On the 18th of October we went to Mook to visit peutz and get ideas what they are doing. When we arrived in Mook some nice sandwiches and coffee was made to start the excursion in a good way. We went to the climate rooms and wind tunnel to get an idea what kind of work is done at peutz. Also we saw the acoustic rooms where product are tested to see if they meet the requirements. We were allowed to go into the wind tunnel and made the image next to this article, and got to see some future scale models of cities that needs to be tested. It was not allowed to make pictures of those models, since those ideas are not released to the public yet. Finally we went to visit the fire safety lab and got a talk provided by Ruud van Herpen before we went back home. It was nice to see the different laboratories to get an idea that not everything can be calculated on paper, but also some practical experiments needs to be done.

START ACTIVITY

At the start of the academic year new student subscribed to become a member for free and make use of the many benefits Mollier offers! To get to know the new members the new board organized an intro activity and new, but also current members, could subscribe to take part into this activity. After the lectures we meet at the fifth floor to create groups of new and current members to play a quiz of common and less common knowledge and each team could gain points. After the quiz a treasure hunt was performed in Vertigo, where the groups should find clues where to go to, and to find parts of the secret word. The new board did organize this really good, and the team of the previous chairman did get some minus points because he did run away with the clue so other team's couldn't get this clue. After this nice treasure hunt everyone was hungry, which was solved by ordering pizza's! A few pizza's were left over before the choice of another game or a drink in hubble was made. Another game was executed called the sustainability game where the teams needs to cover a raw egg on a sustainable way to prevent it from breaking when dropped from 1.5 meter. Some eggs were well sealed while some eggs were splashed when hitting the ground. For all the games the points were added and the team of Nora, ... And... Did win the event and got some nice prices! This activity was a nice way to get to know the new members, and also after this event the majority if people went to bubble to enjoy the start of the weekend with one, two, three of more beers!

GLOW WALK & TALK

It's again the time of the year for a cozy walk around different types of lights and for glühwein of course. This can only mean that Mollier will organize a glow tour in cooperation with KOers. Before the walk started, interesting talks about various project across the route were held. Team Ignite presented two of their projects. The idea behind, and the construction of a massive light buld are explained. Also the story behind the idea of the paper trails were explained. The paper trails represent little folded plains made out of acrylic glass. after the interesting stories we walked with the whole group across the route to see the nice exhibitions across the route!

Upcoming Activities!

ICE SKATING
21 December

WINE TASTING
13 January

COMFORT DRINK
27 January

MULTI DAY EXCURSIOIN
16 - 18 February

LUNCH LECTURE LBP
7 March

COCKTAIL PARTY WORKSHOP
31 March

LUNCH LECTURE ZRI + ARCADIS
11/12 May

STUDY TRIP
18 May

Ice Breaker Maud van den Boomen

Hello everyone, my name is Maud van den Boomen. I am 22 years old and I live in Sint-Oedenrode. I am Dutch, but I didn't live my entire life in the Netherlands; I also lived in Belgium for ten years. I did my primary school in Belgium as well as part of my high school. The last three years of high school I did in the Netherlands after which I got my Gymnasium diploma.

I started this academic year with the master track Building Physics and Services (BPS) of the master Architecture, Building and Planning (ABP). I also did my bachelor Architecture, Urbanism and Building Sciences (AUBS) here. It is actually quite funny how I came up with studying BPS. In high school, I always wanted to become a doctor, so I really wanted to study medicine. However, I always wasn't that enthusiastic when I came home from an open day. Once, I decided to join a friend of mine to visit the experience day of AUBS just for fun. When I came home after that day, I was so impressed about this study and I really liked it. It came down to me choosing to study AUBS and my friend choosing another study.

Like almost all beginning AUBS students, I was really interested in becoming an architect. However, after doing some architecture courses, I felt that this wasn't going to be my passion, because I hated having to draw straight lines by hand. I became really enthusiastic after having the course 'introduction to BPS'. After this course, I knew for sure that I was going to do a master's in BPS after I finished my bachelor and so I did. Right now, I am really interested in creating healthy and comfortable buildings (Figure 1 Improving daylighting conditions of a post-war dwelling for my Bachelor End Project). So apparently, medicine was still not completely out of my head, because I still want to improve the health of people; not by prescribing medicine, but by improving buildings. I also want to do this in the future I think.

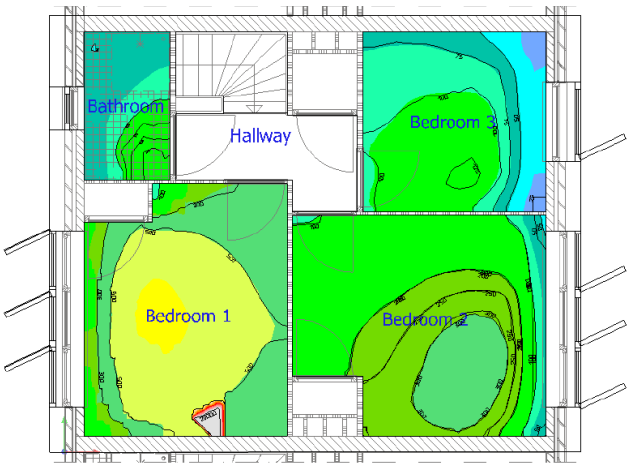


Figure 1. Improving daylighting conditions of a post-war dwelling for my Bachelor End Project.

Figure 2. Indoor sports climbing.

Besides my study, I am also busy with a lot of other stuff. I work at Handel Bouw Advies B.V. (HBA) which is a company that does calculations for the requirements of buildings (like Bouwbesluit, BENG, MPG, etc.). In my spare time, I like to do indoor sports climbing (Figure 2). I am a member of ESAC (Eindhovense Studenten Alpen Club). I also really like to hike in the mountains during summer. The mountains and the jangling of the bells of the cows just give me a fantastic feeling. Besides that, I always realize then how small we actually are as a human (Figure 3). Besides being a member of ESAC, I am also a member of Panache; the badminton association. I am not that experienced in badminton, since I only started this academic year to try something new. I actually really like it. I also really like to be creative during my spare time. I like to make scrapbooks which are books composed out of all kinds of paper materials. I make recipe books and photo albums in this way for example.

This was a small introduction about myself. I am very glad that I am able to introduce myself in this magazine. I hope to meet you all! ■

Figure 3. Mountains in Stubaital in Austria.

unica

samen maken we de toekomst

Wij bieden je geen stage of een baan maar een carrière!

Wil jij samen met ons het verschil gaan maken in de toekomst? Wij zijn in ons vakgebied uniek van soort, daar wij met onze specialisme een totaal oplossing kunnen bieden aan onze klanten. Van projecten in data centers tot renovaties in de zorg en van onderhoud tot gebouwbeveiliging, van specialist in brandbeveiliging tot partner in ICT solutions; kortom een netwerk van bedrijven! Wist jij trouwens dat het nieuwe hoofdgebouw door Unica is ontworpen en gerealiseerd?

Binnen Unica is er genoeg ruimte voor persoonlijke ontwikkeling, waarbij het belangrijk is dat je kunt groeien. Als jij groeit, dan groeien wij met je mee! Wij willen je ook geen baan aanbieden maar een carrière. Er zijn inmiddels al heel wat TU/e voorgangers zoals Marc Scholman, Gert Jan Braun en Ricardo Poortvliet die een uitdaging hebben gevonden bij ons; wellicht kunnen zij jou wegwijs maken?

Wil je bij ons stage lopen, afstuderen of werken. Neem dan gerust contact op met onze recruiter via **info@werkenbijunica.nl**, één van de andere ex TU/ers of kijk op onze websites voor meer informatie; **unica.nl** en **werkenbijunica.nl.**

Quantifying Sustainability in Vanderlande Building 60

Author
ir. E.P.M. (Erik) Bouwens
Nelissen Ingenieursbureau

The building industry attempts to meet the latest government developments concerning CO_2- or NO_x-emission reduction, and sustainability in general. Therefore, several methods are available to assess the sustainability of a building. BREEAM (Building Research Establishment's Environmental Assessment Method) is an international certification method to quantify the level of integral sustainability of a building. It includes for example energy performance and health improvements, but also reducing water usage and pollution. Public transport is encouraged and even ecological aspects are regarded. The highest achievable level is Outstanding. Less than a hundred newly built office buildings in the entire country of The Netherlands can claim the official BREEAM Outstanding certificate. One of these buildings is Vanderlande Building 60 in Veghel. This office building also contains a restaurant, several conference rooms, and a sporting area.

NELISSEN INGENIEURSBUREAU

Nelissen Ingenieursbureau was engaged in the design process of Building 60, fulfilling the role of integrated consultant concerning Building Physics & Services and BREEAM. Nelissen works according to a multidisciplinary approach among the departments of building services, electrical engineering and building physics. Furthermore, Nelissen has the expertise of coordinating a BREEAM trajectory. The work approach allows effective communication, knowledge transfer and design coordination between disciplines, which is essential to attain a BREEAM certificate.
From the very first sketch designs, until the post-construction investigations, Nelissen was involved in the building process. Building services and architectural facilities were designed in order to meet the legal requirements of the building code, as well as requirements from the client and the BREEAM requirements; also referred to as BREEAM credits.

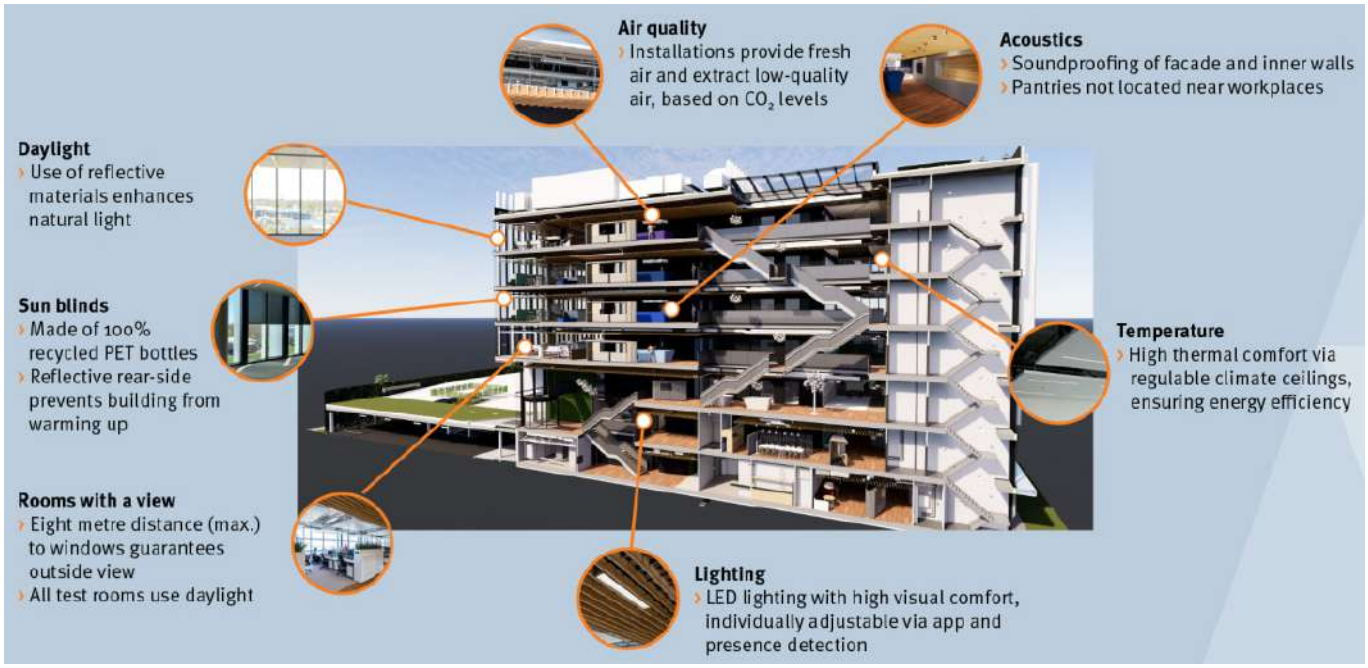
ENERGY EFFICIENCY

Nelissen always aims at sustainable, healthy buildings and advices the design team to achieve this. This resulted in the design of a compact building with vertically and horizontally extended elements as permanent solar blinds to reduce the energy consumption. To meet the demands of the BREEAM credits however, the building services had to be optimized as well. For instance, BREEAM demanded that the full amount of energy used for the building services was generated on-site (ENE 1) by renewable energy sources (ENE 5). In order to attain this requirement, the heating and cooling installation had to be as energy efficient as possible. Therefore, an ATES system in combination with a heat pump was installed. In this system, the heat is distributed through the building at a low temperature of 45°C and is released through the floor (in the restaurant) and through climate ceilings (in offices). To reduce the cooling demand in the summer, the southeast and southwest façade are provided with vertical and horizontal panels to reduce solar gains. In addition, air tightness was considered during construction of all elements to reduce heat loss by infiltration. This resulted into an extremely air tight building façade of $q_{v;10} = 0{,}06\ dm^3/s{\cdot}m^2$.
Despite of all the measures to reduce the heating and cooling energy, still 1.850 solar panels were needed to generate the energy for the building services. This turned out to be a challenge, considering that the roof only provided room for 360 solar panels. The solution was to use neighbour buildings for extra solar panels. The roofs of Building 10 and the parking garage now contribute to the full usage of renewable energy for the building services of Building 60.

HEALTHY ENVIRONMENT

Building services are a tool to create a comfortable and healthy indoor climate. Next to that, (legal) requirements of building physics such as daylight and acoustics also contribute to a healthy environment. Health is an important category of BREEAM. The requirements for these credits had a huge influence on the design of Vanderlande Building 60.
Besides several parts of the ground floor and second floor, the total façade is transparent in order to meet the daylight entrance credit in the offices (HEA 1). The large window surface was also necessary to facilitate the offices with a sufficient view (HEA 2). Internal blinds with

Client: Vanderlande Industries B.V.
Projectmanager: Acuro B.V.
Architect: LA Architecten Ingenieurs
Structural engineer: Verhoeven en Leenders
Contractor: Bouwbedrijf Van de Ven
Building Services: Hoppenbrouwers Techniek BV



Aspects that contribute to a healthy environment

"AFTER SIGNIFICANT HOURS OF ANALYSIS AND CALCULATIONS BASED ON DRAWINGS, IT IS EXCITING TO PERFORM MEASUREMENTS IN THE ACTUAL BUILDING." ~ ERIK BOUWENS, BUILDING PHYSICS CONSULTANT

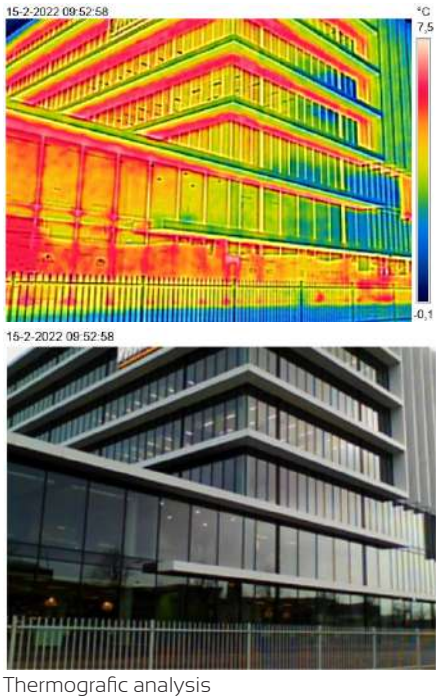
sufficient prevention of solar gains were prescribed in order to prevent both glare (HEA 3) and high local temperatures.
The entire building is provided with a smart monitoring system. Solar blinds are automatically controlled by the amount of sunshine, and a daylight system reduces the power of electric lightning when daylight illuminance is sufficient (HEA 4 and HEA 5). All offices have a minimum ventilation flow rate of 35 m^3/h per person and meeting rooms have a minimum flow rate of 45 m^3/h per person (HEA 8). Additionally, the smart system continuously measures the CO_2-concentration in meeting rooms. In case it exceeds 800 PPM, the flow rate is temporarily increased. In this way, energy consumption for ventilation is limited, while the meetings rooms keep a healthy indoor environment when necessary. This system also monitors and controls the temperature in order to maintain thermal comfort (HEA 10).
Every person experiences comfort differently. Therefore, temperature, ventilation, solar blinds and electric lightning can also be controlled manually. A specific application on a smart phone can be used in order to overrule the smart building system. Due to all these technical solutions, credit points for the BREEAM certification were collected.

VERIFICATION

During the design process, Nelissen Ingenieursbureau has continuously advised the client, the architect and the contractors in order to meet all the requirements. Advices were based on calculations or general experience, and were discussed with the architect and the client. This led to an interactive process. Verification measurements had to be performed after the completion of the building as part of the assignment for the BREEAM certification. After significant hours of analysis and calculations based on drawings, it is exciting to perform measurements in the actual building. To achieve the BREEAM credits, first the building acoustics were considered. Sound insulation of the internal and external constructions, as well as reverberation time in several rooms were measured.


Sound measurements

All the measured constructions met the design requirements of the client and of BREEAM (HEA 13).
Also, devices with temperature sensors were placed in normative areas. These devices measured the indoor air temperature for more than a week. The outdoor temperature was measured as well. In this way, the performance of the smart system regarding thermal comfort was determined, and it was concluded that it worked properly (HEA 10).
Finally, thermographic measurements were conducted on the façade. These measurements required specific weather conditions, such as a minimum temperature difference between inside and outside of 10°C and a cloudy day without rain. High outside surface temperatures would indicate potential thermal bridges, as heat from the inside transfers through the construction. However, no thermal bridges were found (ENE 26). Vanderlande Building 60 can rightfully be stated as an Outstanding sustainable building.



Thermografic analysis

Vanderlande Building 60 is an example of one of the hundreds of various projects Nelissen Ingenieursbureau participates in in a year. Do you want to know more about Nelissen Ingenieursbureau or the project of Vanderlande? Don't hesitate to contact us via nelissen@nelissenbv.nl. ■

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Energy-economic Evaluation of a NZEB Tiny House Design

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Supervisor
dr.ir. L.C. (Lisanne) Havinga

INTRODUCTION

The building sector accounts for 40% of the energy consumption, 35% of the CO_2-emissions and 50% of raw material use in the Netherlands [1]. At the same time, an increasing number of Dutch people experience difficulties in acquiring housing due to the housing shortage and the consequential increase in housing prices in the Netherlands [2]. Traditional housing therefore needs to be replaced by innovative and affordable housing alternatives [3]. The tiny house has gained more popularity in the Netherlands over the past years, as earlier studies have claimed that tiny houses can address the considerations regarding sustainability and the current changes in the housing market [4].

This study investigates and evaluates the impact of design decisions on the energy-economic performance of a tiny house. It entails the development of a design process in which the impact of certain design decisions on a predefined set of key performance indicators (KPIs) is considered. This gives potential tiny house occupiers or builders the ability to evaluate the impact of their design decisions on several KPIs, allowing for an easier decision-making process.

METHODOLOGY

The method entails a process in which five consecutive steps are iterated for each modification of the tiny house, starting with the formulation of a base case. The steps taken in the iterative process are 'research', 'define', 'design', 'test' and 'visualize'. In the first iteration, the base case is defined and modeled on a defined set of KPIs. All other iterations concern modifications of selected design parameters to develop subsequent models that have possibly improved in terms of the KPIs. The product of all design choices resulted in a total of 1,296 model iterations that are evaluated in terms of the KPIs. Three different methods were used to evaluate the tiny house designs on the energy-economic performance.

Figure 1. Exterior impression of the base case design.

First, the results of all design modifications were visualized in a parallel coordinates plot. The parallel coordinates plot is interactive and therefore allows one to select a certain range on multiple specific KPIs. The design decisions that correspond to this selection remain, to be able to select a certain design based on preferences with regard to the KPIs.

Secondly, scatter plots were used to visualize trade-offs between two performance indicators. Pareto fronts were added to the scatter plots to select the design modifications with the best optimization in terms of both performance indicators. The design optimizations on the Pareto front were then grouped into clusters to make a distinction based on the importance of one performance indicator.

Lastly, the data was restricted to select the designs that perform better than 50% of the range of all performance indicators. The remaining options were then evaluated similarly to the second method.

CONCLUSIONS

The results of the three methods of decision-making have shown that the decision-making in the construction of a tiny house is highly dependent on the preferences that are set. Moreover, it appeared that the method of evaluation also has a big influence on the potential design decisions that are made. The study has shown that the building geometry and the DHW system are the design parameters that had the biggest impact on the energy-economic performance of a tiny house. The window to wall ratio, the window orientation, the HVAC system and the solar systems had the second biggest impact.

The tool allows potential tiny house occupants to base their design-decisions on their preferences regarding several performance indicators. However, further research is required to expand in terms of the KPIs, the design parameters and design variants to broaden the range of possibilities and selection criteria in the design of a tiny house. ■

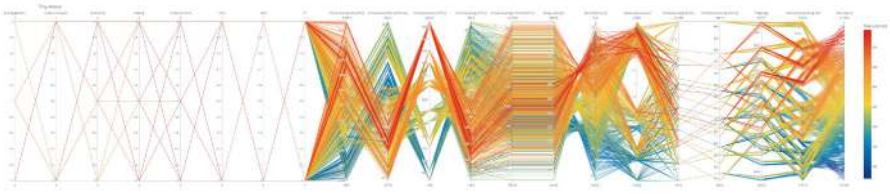


Figure 2. Parallel coordinates plot with all design modifications on all KPIs, color coding based on total costs.

[1] "Circulaire Bouweconomie: Transitie Agenda," 2018.

[2] C. de Groot and N. Vrieselaar, "Housing shortage continues to drive up house prices," Nov. 2019. Accessed: Apr. 25, 2022.

[3] K. Dol and H. Boumeester, "Home ownership under changing labour and housing market conditions: tenure preferences and outcomes among freelancers and flex workers".

[4] K. van de Valk, "Housing Shortage and Tiny Living: Evaluating Tiny Houses as a sustainable answer to relieve the housing crisis in the Netherlands," 2020.

Building Physics in Practice: Integration in the Working Field

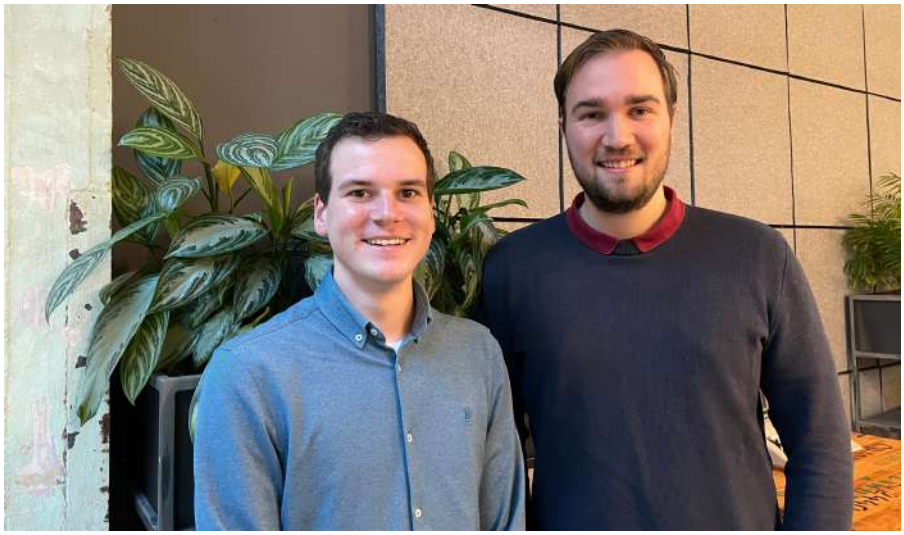
Author
Ir. J.J. Botterweg – Junior advisor building physics at K+ Adviesgroep
Ir. J.H. Hoevers – Junior advisor building physics at K+ Adviesgroep

INTRODUCTION

The transition from studying to working life can be quite a substantial step for everyone. Acquiring a lot of theoretical knowledge which is applied in case studies helps tremendously in bridging this gap somewhat, however the first weeks/months at your first job can be quite challenging. As a building physics advisor your theoretical knowledge at first glance does not seem to connect with the actual practical implementation of the legislation in the specific country. After gaining new knowledge you start to see the overlapping parts between your learned knowledge and the practical side within the legislative side of the building industry.
We both graduated in 2021 and Jan-Joost has been working at this office for over a year. Jeroen joined half a year later. For us, the warm welcome into the company as well as the freedom which was to us from the start, has helped in finding the areas of building physics within practice which suite us best whilst being able to try each of the different facets the building branch has to offer. Building physics, as taught at the TU/e as well as in practice, is subdivided into multiple themes. Working on both small and large projects, we were able to quickly get familiar with each of these facets and bring them into practice.
In this article, we will give a glimpse into the different aspects of building physics within the Dutch legislation and building process. A recent project is used as an example and a selection of topics is highlighted. The project involves is a large plan in which multiple apartment buildings are situated together with large parking garages underneath them, all creating their own difficulties and challenges which have to be tackled with a multidisciplinary team.

DAYLIGHT ENTRANCE

An important factor in the design of buildings is the daylight admittance into the building. It is highly significant for comfort, health and even energy usage within the building. In the Dutch legislation, daylight admittance into the house or apartment is regulated in connection with the health of its inhabitants. Daylight admittance is needed in areas which are used often by its inhabitants such as the living- and bedrooms. Within the legislative text the requirements are defined and linked to the norm from which the equivalent daylight area is to be determined (NEN 2057).



Authors Jeroen Hoevers (left) and Jan-Joost Botterweg (right)

Daylight admittance is a continuous process of tuning the vision of the architect and the requirements as defined in legislation. Architects make the most beautiful designs and often the façade is one of the biggest expressive entities of the building in which windows play a significant role in its appearance. However, the area's which lay behind the façade need to be able to receive sufficient daylight to adhere to the legislation. This process is often one which involves a lot of discussion with the architect to come to an optimal solution in which the architect is satisfied and the calculations we are making show that at least the minimum amount of daylight is achieved and thus makes sure that building satisfies the rules as set in legislation.
This legislation is also prone to changes, with a major revision expected in 2023. For daylight admittance, the equivalent daylight area requirements will be converted in daylight factors requirements. You may have come across these daylight factors in the lighting courses at the TU/e. In practice, this change involves overhauling the complete calculation method. Moreover, these changes in legislation results in new challenges, especially with longer running projects. This is caused by the uncertainty of the actual date the new legislation will be implemented.
Daylight admittance strongly correlates to the size and amount of translucent openings within a building. Therefor it can strongly influence other calculations which are made such as the Energy performance, fire safety (Fire spread) and even the soundproofing which are all bound to legislation.

FIRE SAFETY

Fire safety is an often overlooked but crucial part of building physics and even building design in general. Safety within a building should always have a high priority, fire safety is one of those aspects but connects most if not all of them. Within legislation minimal but strict (especially for housing) requirements are set. When applying for a permit, not

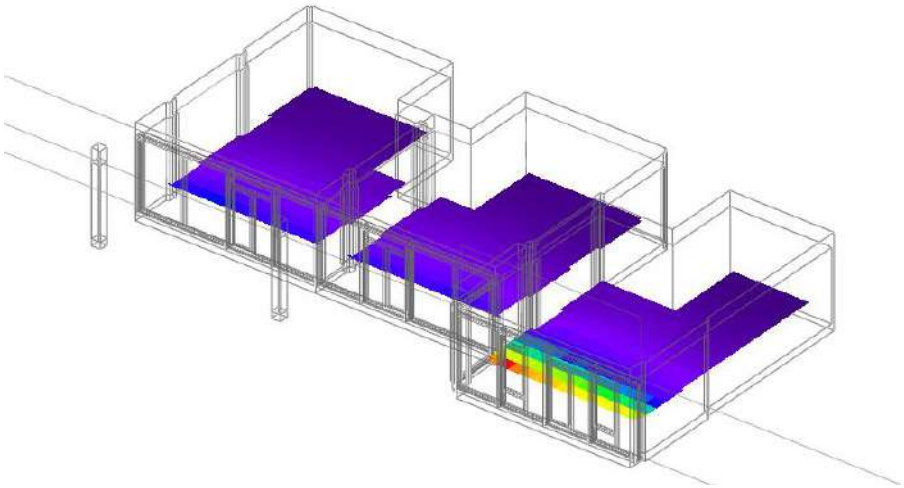


Figure 1. Daylight factor calculation.

only the municipality in which the permit is applied for reviews the documents about fire safety, but also a secondary independent and entity thoroughly inspects the suggested fire safety measures; the fire department. One of the difficulties with the involvement of the fire department is its division in 25 safety regions, which each have their own views and preferences in terms of fire safety and firefighting methods which sometimes deviate somewhat from legislation and rely on equivalencies. During the process from the start of the design until the final definitive design a lot of discussion takes place between the architect, the contractor, the fire safety advisor (us) and often even the fire brigade/Safety Region to discuss the potential solutions to ensure optimal safety within the building. The architect puts their ideas on paper after which we make sure that everything is according to the law and where needed give feedback and solutions to problems that appear within the design. Such feedback can also be relatively small, for example mirroring the doors in the escape routes to ensure they open in the proper direction. Bigger and crucial parts of a building are often discussed with the fire brigade and even equivalencies between suggestions and law are discussed and adjusted within the design with the approval of authorized supervision of the fire brigade.

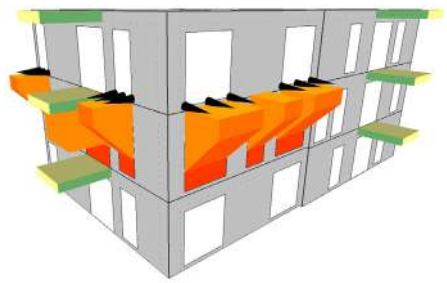


Figure 2. Fire spread calculation.

ENVIRONMENTAL PERFORMANCE

A topic which is getting more and more traction within the building industry is its environmental impact. Large amounts of cement and steel are used which contribute negatively to the environment. In legislation, certain environmental performance indicators are implemented to which residential buildings should adhere to. This gives insight in the environmental impact per square meter of floor area. Each piece of material which is used within the hull of the building is taken into account, from the foundation to the installations and even energy uses is accounted for in the calculation of the Environmental impact factor. The calculation is based on the Life Cycle Assessment (LCA) of all products and materials used. The LCA includes the phases from raw material extraction, manufacturing and processing, transportation, usage, recycling to ultimately the waste disposal. The different design choices and material requirements are adjusted with the architects and contractors to create a building which adheres to the set limits in legislation. Currently, most buildings we work on meet the environmental performance indicators without large adaptions in the design. Figure 3 indicates that over half of the score of the envinronmental performance for this building is generated by the climate- and electrical installations. These installations include the heat pumps, heat recovery ventilation systems and PV-panels. The share in environmental performance for these installations seems relatively high, but it should be noted that the environmental performance is based on the complete LCA of these installations. Moreover, all ducts, pipes and electrical components involved in running such systems, including the base energy use, is taken into account. Towards 2030 the legislation on this topic becomes stricter, which will highlight the role as advisor in the design team in relation to this environmental aspect.

CONCLUSION

Only the tip of the iceberg in terms of the applicability of building physics within the Dutch building sector has been introduced. Its gives a small glimpse into the work that is done on a daily basis as a building physics advisor. It ranges from making calculations in the early stage of the design to performing measurements in the field. The building industry is a very diverse and open sector with tons of different possibilities. Finding an employer who wants to see you grow in the field that you like within building physics, helps with finding what gives you the most satisfaction. With increasingly strict legislation and regulations, we expect that the role of a building physics advisors is becoming increasingly important, making this job even more fun and challenging. ■

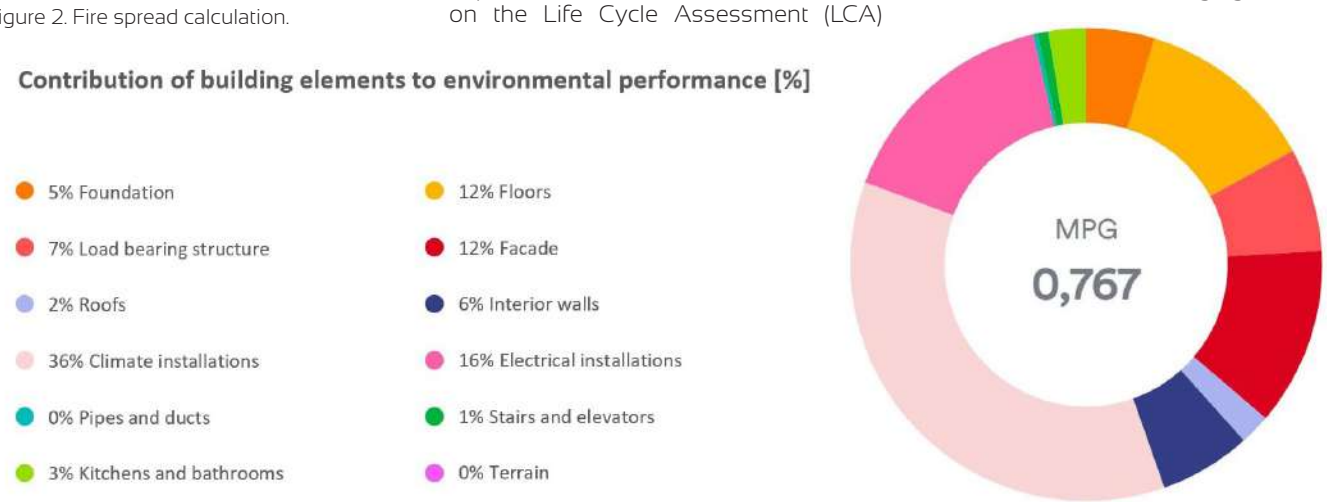


Figure 3. Environemental performance results (MPG).

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Ir. Peter van Mierlo

Als adviseur bij Valstar Simonis ontwerp ik duurzame, gezonde en steeds meer circulaire gebouwen waarin mensen zich prettig en comfortabel voelen. Zo was ik bij de transformatie van het gebouw Atlas op de TU/e campus eindverantwoordelijk voor het ontwerp van alle installaties.

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Studera på Lund University i Sverige

Iris van Dongen

Hello everybody! My name is Iris, and I'm currently a second-year master's student in the building physics and services track of the built environment. Last semester, I went abroad to Sweden to study at Lund University. This has been an amazing experience, which I would like to tell you more about!

First, I would like to give you a bit of background information about me. In 2018-2019, I started with the AUBS bachelor's here at the TU/e. Soon I discovered that I was more interested in the more technical aspect of the built environment. Halfway through my second year, I got more familiar with building physics and services and decided I wanted to learn more about that. Therefore, I decided to proceed with the master of Building Physics and Services when I finished my bachelor's at the end of 2020-2021.

Before I even started studying, I always had the ambition to go abroad when the opportunity presented itself. Everybody who went abroad during their studies told me so many fun stories about it that I needed to experience it myself. So when I heard that there was an opportunity to go abroad during my master, I didn't have to think twice. Besides the fact that I was really looking forward to a semester of exploring a different country and meeting new people, I was also interested in seeing how the education abroad differs from here and what their insights in the building physics and services field were. My choice quickly fell on Lund University since I always wanted to go to Scandinavia someday, and not many other universities provided courses I was interested in.

During my exchange semester, I followed three different courses: ventilation and indoor air quality, daylighting and lighting of buildings, and energy-efficient office building – integrating daylight and ventilation. These courses were part of the master program Energy-efficient and Environmental Building Design. Beforehand, I didn't really have a clear vision on which courses I wanted to follow. I just selected courses that I thought would be interesting, a decision I don't regret afterward. Apart from my main courses, I also followed a Swedish course for beginners, in order to already gain some Swedish language skills. In general, it was quite fun to see how different the master's program in Sweden was structured in comparison to Eindhoven. One big difference, for example, was that Eindhoven has a lot of freedom in choosing courses you like, whereas at Lund University, the program has a fixed structure for everyone. Moreover, due to this fixed program, every course has the same group of people, which kind of creates a class. The energy-efficient and environmental building design program had quite a small group of people (around 30), which also made the connection with the professor more personal.

Besides studying, I also did a lot of sightseeing and fun activities. I visited a lot of cities (small and big), like Malmö, Copenhagen, Lund, Goteborg, Helsingor, Ystad, and Stockholm. Furthermore, I went on hikes to several national parks to see what Sweden's nature had to offer. I also tried several Swedish delicatessens like köttbullar (meatballs), Semlas (sandwich filled with whipped cream and almond paste), kanelbulle (cinnamon bun), and kladdkaka (chocolate cake). It may be funny to mention that almost every Swedish delicacy has its own holiday. At last, I even joined a Swedish football team. This was really a challenge since the main language was Swedish.

Overall, the semester abroad has been a great experience, which not only allowed me to learn a lot in the environmental and energy-efficient building design. I also got to know a lot of different cultures, people, places, and languages (although I may have forgotten most of it). That's why I will tell you the same as people told me over the years:

If you have the opportunity to go abroad during your studies, go! ■

Study Trip 2022 Dublin

Author
Strudy Trip Participants 2022

DAY 1

The day started when we all gathered at the Eindhoven train station. After being there for 10 minutes, 4 individual people had commented on the fact that Jesper was already wearing a green sweater. This was a good start for the 3 hours long queue for the security at Schiphol Airport later in the day. However, we had some nice background music as Anne had the same song (Dua Lipa – Levitating) stuck in her head for the whole three hours. Everyone came up with their own fun games during the waiting time on the airport and in the plane. Luckily the committee prepared some puzzles related to the trip to help us.

We arrived in Dublin to damp and wet weather. After taking the bus to the hostel, the group split up to enjoy Dublin's nightlife. It started off with a drunk local shouting and complementing Ahmed's hair and denim jacket. The first bar had great music, but sadly not enough space for our small group of 6. Following that, we stumbled upon a street that looked lively with music and locals dancing drunkenly. After a few misses with bars closing down, we found a nice place that had live music playing late into the night. Upon sitting down we had to go for our first pint of Guinness.

Figure 1. Due to a misspelling sheep street is now known as ship street

Figure 2. The first beer

Figure 3. Cathedral

DAY 2

The first full day! Breakfast was at a reasonable time (luckily) and provided by Brent and Sietse. The Irish way, of course, so lots of scrambled egg and bacon. Right after breakfast we only had to walk a block to our first activity of the day, a walking tour with the 'gezellige' tour guide Ian from the company Original Dublin, where we had a crash course on Irish history in about 3 hours. To summarise, the Irish had a lot of good ideas but lacked successful execution. Like the millennium clock, asking the Spaniards to help them win against the British, and then eventually inviting the British over to Ireland. The best facts of the day had to be that they accidentally burned down the city while trying to create a battlefield area for the fight against the Vikings and that two-thirds of the Irish population doesn't speak Irish and of course the most important one; that the current political tumult is caused by one guy crawling out of prison through a latrine. The most boring fact according to Ian is that the O'Connell bridge is wider than it is long.

After the wonderful tour, the group split up where Menno, Brent and Kay couldn't get enough of beer, while others needed a nap after yesterday's outings. Of course, Bas and Sietse did some sightseeing where they bonded with some squirrels. Dinner plans were also split up into groups, but luckily in restaurants right across from each other, O'Sheas (also in Eindhoven!) and Gallaghers Boxty House, recommended by Ian.

Our whole day was influenced by Ian. As we write this, we are joining a pub crawl organised by Ian and his friends. Lots of

Figure 4. Listening to Ian's stories

Figure 4. Official study trip group picture

Dutch people, lots of drinks, lots of live music, and lots and lots of fun! Already looking forward to tomorrow morning... For now, we're going to enjoy Piano Man by Shaun, see ya!

DAY 3

On this fine morning, some of us woke up earlier than others. The early birds amongst us planned to go to Howth, a peninsula near Dublin with beautiful cliffs. Others decided to walk around the city centre and a select few decided to explore the botanic gardens. In the city centre, way too much time and money was spent in gift shops. In the botanical gardens, about fifty per cent of the attention was given to the plants and the other fifty per cent of the time was spent following squirrels. At Howth, we had a lovely walk along the cliffs and some extra fresh fish and chips for lunch.

For the afternoon program, everyone gathered at the Croke Park Stadium, which could have taken less time were everyone able to find the entrance. Croke Park Stadium is a stadium for Gaelic sports, such as Gaelic football and hurling. It is the third-largest in Europe. At the stadium, we got a tour on the roof top at a height of 44 meters. Here we had a beautiful view over Dublin. After this, we got a tour inside the stadium and learned about the rules of Gaelic football and hurling. This came in handy since we were going to attend a game of hurling in the evening.

Figure 5. Botanical gardens

Figure 6. Game of hurling

Figure 7. Shirt collection of hurling teams

After a short break in the park with some snack pizza, it was time for the hurling game. We had a great time watching the game (or the players). We ended the night with a really nice dinner with the entire group and some drinks after in one of the many pubs in Dublin.

DAY 4

Today was a day full of cultural and educational activities. We started off with a wonderful breakfast with eggs and bacon. When everybody had their bellies full, we started the short walk toward Trinity college to visit the Book of Kells. The Book of Kells is one of Europe's greatest treasures from the middle ages. The book has been made around 800 AD by monks and is a masterpiece of western calligraphy and decorations that are very rich and colourful.

When we arrived we could immediately go inside, because we were right on time. The first part of the museum was about how the Book of Kells has been made and about the history of the book. The second room was completely dedicated to the Book of Kells itself, as it was dark with the only lighting in the middle of the room focused on the book.

After seeing the Book of Kells we went to the library on the first floor. The library was built between 1712 and 1732 and is one of the most impressive libraries in the world. It's a room of almost 65 meters which contains more than 200,000 books. This is still a working library where students and professors still can borrow and read books for their research.
We spend almost an hour in this room watching and listening to the guard that has been working here for decades and heard the most interesting facts and stories about the library and books, including the future plans for making the library more fire safe.

When we finally came out into the sunshine it was already time for lunch. We went back to the hostel to have some bread with delicious homemade eggsalad.

After everybody was refuelled again it was time to visit Howth by train or bus to have a spectacular walk along the cliffs of Ireland. We started walking at the lighthouse on the other side of Howth and soon saw on google maps there was a hidden beach nearby. Of course, there were a few explorers that climbed down the steep stairs to have a look at the beach. The long climb down was way worth it and it was a spectacular view at the bottom of the cliffs. The beach had its

Figure 8. Library

Figure 9. Book of Kells

Figure 10. Botanical gardens

own tiny waterfall that came down from the cliffs into the sea. When we were done at the beach we had to climb all the way back up, which showed who still had some conditions left after COVID. Even after the hard climb we still decided to walk all the way back to Howth along the cliffs and go back to the city for a quick snack. On our last night in Dublin, we enjoyed a few more Guinness got to see the real Temple Bar with some live music and looked back on a fulfilling last full day in this beautiful city.

DAY 5

On the last day in Dublin, we had an early breakfast and packed all our souvenirs to go on our last visit: the Rediscovery Centre in northern Dublin. The Rediscovery Centre is housed in an old boiler house, where water was heated for the entire neighbourhood. Our tour guide showed us around the site and also onto the roof garden, where they grow vegetables and fruit for their lunchroom. After a quick stop at the compost machine, the facilities officer showed us around the installation room with the water recycling and building management system.

Inside the building, they had different workshops where many products and materials are given a second life: ranging from remixing leftover paint to a bike repair shop or furniture restoration. After this interesting tour, it was lunchtime with some food from the café or from the supermarket across the street.

After our tummies were full, we continued with the sustainability workshop. Starting off with a quiz, everybody was keen to add their opinion to the discussions. The last (and most spectacular) challenge was the egg-drop challenge! We were tasked to make a sustainable construction that should protect the egg from a two-meter fall. Due to the very limited material use, only one group succeeded. One egg shattered completely, which led to a roar of laughter.

After the workshop, it was time to leave and head off to the airport. A quick bite, one last visit to the duty-free shops or the Irish pub, before we got on the plane back home. Back on Dutch soil, we look back at a great week with fun, interesting and educational activities!

Thank you study trip committee for organizing this amazing trip! ■

Figure 11. Mementos from the hike towards the lighthouse

Figure 12. Howth station

Figure 13. Castle

Figure 14. Workshop on sustainability

Figure 15. Roof gardens of Rediscovery Centre

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Towards Determining the Influence of User Behavior on Ocular Light Exposure of Office Workers

Supervisors
dr.ir. M.P.J. Aarts
dr.ir. J. van Duijnhoven
ir. M. Gkaintatzi Masouti

Author
Ir. S.W. (Sietse) de Vries

INTRODUCTION

Ocular light exposure, i.e. light at eye level, is essential for human beings to project images and, by that, perceive their surroundings but it also influences various non-image-forming aspects of human biology and behavior such as alertness and circadian rhythms [1]. These non-image-forming responses are closely related to human performance and well-being, hence the practice of light therapy in medicine [2]. Moreover, circadian misalignment of ocular light exposure can have a negative impact on a person's performance and well-being [3].

Since the development of electric lighting, humans have substantially increased their time spent indoors, resulting in a factor of 100 to 100,000 [4] lower light levels compared to natural lighting. For individuals with an indoor occupation, i.e. an office worker, most daylit hours during a day are spent within a building. The performance and well-being of office workers, influenced by non-image-forming effects of ocular light exposure, are important for the productivity of a company's workforce, opening up investment potential. Thus, adequate stimulation of non-image-forming effects of ocular light exposure in office buildings is essential to contribute to a healthy and productive work environment.

Non-image-forming responses to ocular light exposure are mainly mediated by the intrinsically photosensitive retinal ganglion cells (ipRGCs), with a maximum sensitivity of their photopigment (melanopsin) in the blue part (λ=480 nm) of the visible spectrum [5]. Consequently, photometric quantities are inappropriate to relate ocular light exposure to non-image-forming responses. In 2018, the Commission Internationale de l'Eclairage (CIE) published an SI-compliant standard (CIE S 026/E:2018) that relates photometric quantities (e.g. illuminance) to a corresponding α-opic equivalent daylight quantity (e.g. illuminance, α-opic EDI) of standard daylight for the five known photosensitive cells in the human eye.

Recently, an expert-scientific consensus has published research-based recommendations on daytime, evening, and night-time ocular light exposure for adequate stimulation of non-image-forming effects of lighting [6], based on CIE S 026/E:2018. During the day, they recommend a minimum melanopic ocular EDI (measured vertically at eye level) of 250 lx for workers with a regular day-active schedule in indoor environments, i.e. office workers (referred to as recommendation in the remainder of this article).

In the design phase of an office space, computer simulations are useful to determine if future users' ocular light exposure levels of a certain office building are in line with the recommendation. Current lighting norms for offices primarily focus on visual performance, dictating minimum illuminance levels for (work)planes. As a result, lighting simulations are mainly based on two-dimensional areas of interest. On the other hand, to simulate ocular light exposure of a worker in a specific office building, it is essential to determine the location of their eyes during the day [7]. The location of an office worker's eyes in a building is mainly influenced by their behavior. This research aims to support the design of simulation tools capable of estimating the behavior of future building users, to allow simulation of personal ocular light exposure and prediction of related non-image-forming effects.

The main research question for this research is: "To what extent should user behavior be integrated into a simulation tool investigating non-image-forming effects of lighting for workers in offices?". This question was investigated over three parts. First, the average ocular light exposure levels found in practice were analyzed by conducting a literature review, to compare current conditions to the recommendation. Second, a literature review on the magnitude of various predictors of user behavior influencing ocular light exposure in offices was conducted to determine reasons for inter- and intra-individual differences in ocular light exposure. Third, a semi-controlled laboratory experiment was conducted to determine inter- and intra-individual differences in ocular light exposure due to one of these predictors, gaze behavior. The most important findings for every part are discussed below.

OCULAR LIGHT EXPOSURE OF OFFICE WORKERS IN PRACTICE

Ten field studies were identified that analyzed ocular light exposure in an office (latitudes range: °N 38-56) using wearable light measurement devices. In all offices, a combination of electrical lighting and daylight was present. If it is assumed that all office buildings were in line with the latest European standard (NEN12464-1:2021), an average horizontal illuminance (of electric lighting) on the desk of 500 lx would be present. The light distributions and layout of luminaires typically used for office lighting generally relate the average horizontal desk illuminance and

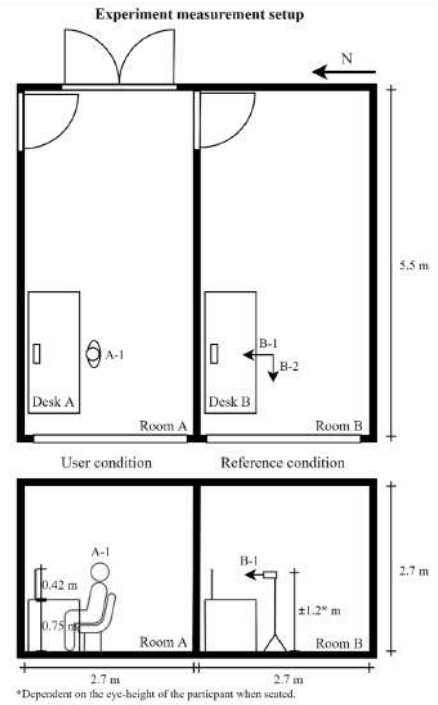

Figure 1a. Schematic representation of the experiment setup.

the vertical illuminance at eye height by approximately 3:1 [8]. Consequently, when only considering electrical lighting and assuming all analyzed offices were designed conform 500 lx average horizontal desk illuminance, approximately 167 lx is present at eye height. The found ocular illuminance levels were considerably higher, which might indicate a substantial contribution of daylight in practice.

Of the studies that allowed extraction of their participants' median ocular light exposure, six out of seven reported a median ocular illuminance between 73 to 668 lx. If the spectral power distributions of common office lighting sources (FL11, LED-B3, or D65) are assumed, most medians are above or in a close range to the recommendation of a minimum 250 lx melanopic EDI during the day. While the found ocular light exposure data did not allow distinguishment for individual participants, the occurrence of considerable inter- and intra-individual differences was determined, indicating low ocular light exposure levels for part of the office workers. This stresses the need to consider ocular light exposure on an individual basis.

PREDICTORS OF USER BEHAVIOR INFLUENCING OCULAR LIGHT EXPOSURE OF OFFICE WORKERS

To determine the ocular light exposure of an office worker in a computer simulation, it is crucial to know the behavior under and interaction with every light source in the work environment. Although behavior is complex, literature allows identification of a set of predictors to relate behavioral aspects of office workers to a range of resulting ocular light exposure levels. Such a predictor describes the behavior under and interaction with a light source of an office worker that influences the personal lighting conditions (i.e. ocular light exposure). For every predictor, e.g. switching on overhead electrical lighting, a range of changes in ocular light exposure levels of office workers is present. Optimally, an office worker's total ocular light exposure is found by combing the ocular light exposure resulting from all predictors.

Six predictors of office workers' behavior influencing ocular light exposure in offices were identified based on thirteen studies. The predictors with the largest influence on daily ocular light exposure are the location and associated general viewing direction of an office worker, and the blinds and electrical lighting setting. For these predictors, simulation strategies are available. Three predictors were identified for office workers seated at a desk, although limited studies were available. The impact of a different distance, while seated, from the visual display unit (VDU) on the daily ocular light exposure is relatively small. Moreover, the influence of a different VDU brightness setting is also deemed small. However, in current simulations of offices, VDUs are often not incorporated. Dynamic gaze behavior, defined by the movement of a person's body, head, and eyes, (relative to a general direction) has, on average, a small influence on daily ocular light exposure. However, inter-individual differences in ocular light exposure due to dynamic gaze behavior are considerable [9][10]. Dynamic gaze behavior is not incorporated into current simulation practices of ocular light exposure in offices [7][11]. Combined, inter-individual differences in user behavior regarding these three predictors may cause considerable differences in ocular light exposure of office workers, opening up areas for further research.

THE INFLUENCE OF DYNAMIC GAZE BEHAVIOR ON OCULAR LIGHT EXPOSURE OF OFFICE WORKERS

In current simulation practice of ocular light exposure of office workers, gaze behavior is often assumed static [7][11]. Past studies [9][10][12] have shown that gaze behavior is dynamic and influenced by a variety of factors, i.e. the task being conducted, lighting conditions in the visual field, and the quality of the view outside.

To determine if such a static assumption in simulations of an office worker's ocular light exposure while seated at a desk is justified, experimental data on the influence of dynamic gaze behavior on ocular light exposure during a workday is required. To generate generalizable data on ocular light exposure, large-scale experiments are necessary since the number of influences on the gaze behavior of an office worker is deemed extensive. However, previous studies [9][10] have shown that in an office, a gaze direction towards the window can cause considerably higher ocular light exposure. Thus, the most significant impact on ocular light exposure levels during a workday of office workers is anticipated to be caused by gazing towards the window. Based on this assumption, it is argued that if predictors of gaze behavior towards the window are identified, estimations on gaze behavior and associated ocular light exposure of office workers may be made.

As a first step, an exploratory laboratory experiment was conducted that aimed to 1) compare ocular light exposure of static and dynamic gaze behavior, and 2) identify predictors of a gaze direction towards the window, using a small participant sample under semi-controlled ambient conditions. Identification of predictors of a prominent gaze direction towards the window allows estimation of ocular light exposure for other environmental conditions, not only the ones present in the experiment. Moreover, if factors influencing gaze behavior are known, assumptions can be made on under which conditions the found experimental data on ocular light exposure of dynamic gaze behavior is valid. Differences in ocular light exposure due to gaze behavior were analyzed by simultaneously measuring ocular light exposure under static and dynamic gaze behavior. To identify predictors of a gaze direction towards the window, activity, alertness, and interview data were gathered.

Two identical mock-up single-person offices were constructed to allow unobtrusive measurements of lighting conditions (figure 1). Both rooms consisted of one desk, two electric

Figure 1b. Pictures of the experiment setup.

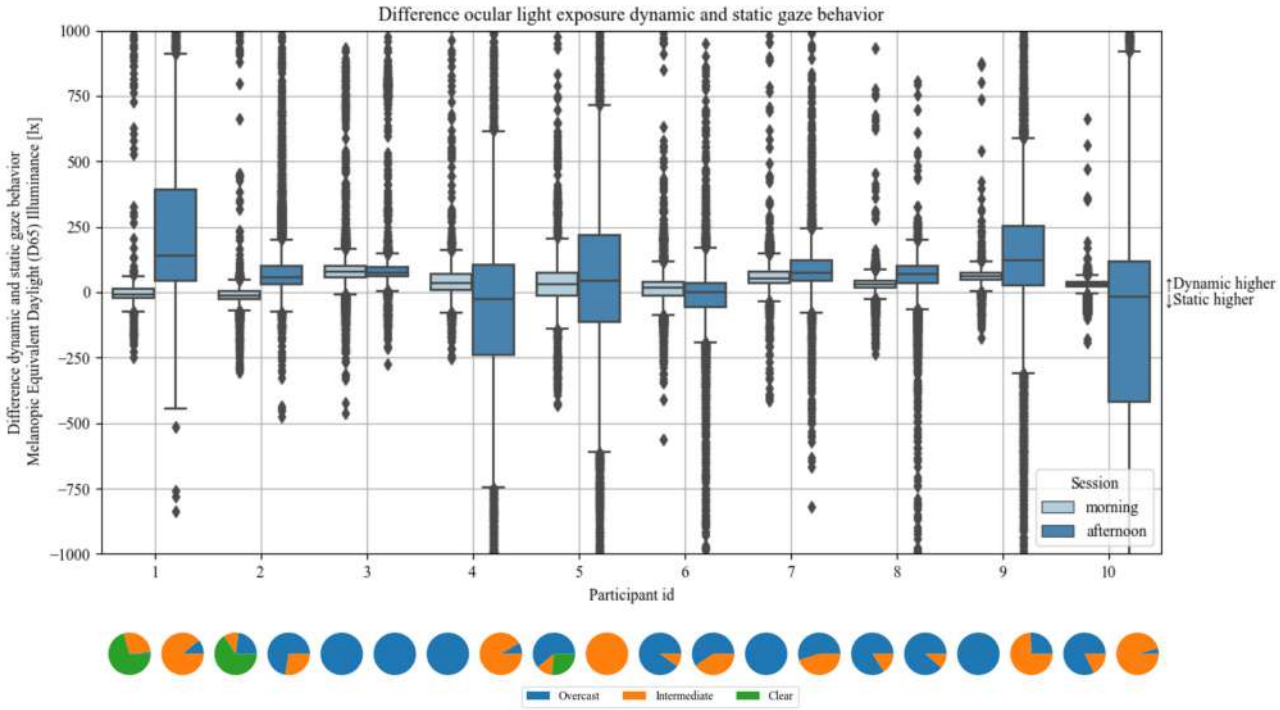

Figure 2. Every participant's differences in ocular light exposure of static and dynamic gaze behavior. Not all outliers are shown. The number of observations for all individual boxplots is approximately 6000. For every participant, sky conditions are shown for both sessions.

lighting fixtures, and a window with manually controlled blinds in the west façade. While in the room, participants wore a set of glasses that measured their head and pupil movement, and (dynamic) ocular light exposure. In the reference room, static ocular light exposure and ambient conditions were measured.

Ten participants took part during two weeks in October 2021. Every day, one participant worked for a day in the mock-up office. During the day, participants conducted their normal work and were asked to keep a logbook of their activities. No information on the goal of the experiment was given to the participants until after the experiment. At the end of the day, a survey and interview were conducted. During the interview, participants were shown field of view recordings of their gazes toward the window and asked to try to indicate the reason for every gaze.

OCULAR LIGHT EXPOSURE OF STATIC AND DYNAMIC GAZE BEHAVIOR

Considerable inter- and intra-individual differences in ocular light exposure, as a result of dynamic gaze behavior, were identified in the participant group (figure 2). Moreover, a statistical analysis (Linear Mixed Model) found for all participants an average statistically significant increase of melanopic EDI of 69.5 lx (morning: 59.6 lx (t-value: -32.190), afternoon: 79.4 lx (t-value: -142.553)), when changing the gaze behavior from static to dynamic. When simulating a static gaze position, the predicted melanopic EDI of dynamic gaze behavior is 11.8% and 9.7% higher for the morning and afternoon, respectively. Due to the orientation of the room, there was a possibility of direct sunlight entering the room in the afternoon. Consequently, under clear and intermediate sky conditions, the range of differences in ocular light exposure due to static and dynamic gaze behavior is more considerable due to areas of (bright) sunlight in the field of view. To identify user behavior profiles to characterize inter-individual differences in ocular light exposure, additional experiments are required.

GAZES TOWARDS THE WINDOW

Considerable inter-individual differences in the percentage of time spent gazing toward the window, during each session, were present (figure 3).

During the experiment, most gazes towards the window per hour occurred when participants were discussing (16.0) or listening (10.4) (figure 4). Both task characterizations were mainly used by participants when they were in an online meeting (86.0% and 72.7% of the time when characterized discussing and listening, respectively). Moreover, for these tasks, the range of gaze durations is small, indicating a (relatively) high number of short gazes towards the window when calling. The longest gazes towards the window (median: 3.0, range: 1.0 to 75.0 seconds) occurred when

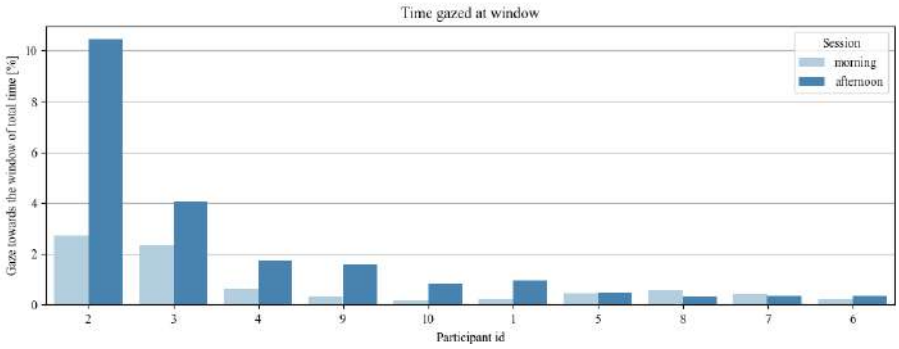

Figure 3. Time gazed towards the window of every participant.

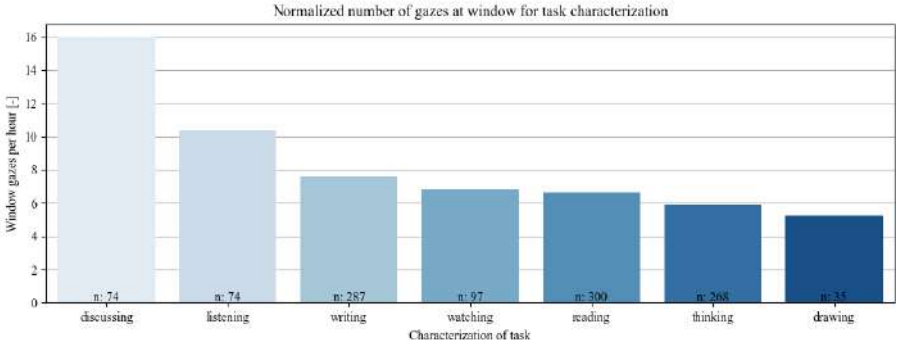

Figure 4. Normalized number of gazes towards the window for every task characterization.

writing, while the shortest duration of gazes was found for discussing (median: 1.5, range: 1.0 to 49.0 seconds). Besides for writing and discussing, all medians were found at 2.0 seconds for the other task characterizations.

Reasons for gazes towards the window given by participants, the duration, and total number of gazes are given in figure 5. The highest numbers of gazes towards the window were attributed to a lack of concentration, a lack of interest in the task, a need for alternation (235), or an interest in the view/surroundings (171). An interest in the view/surroundings can be partly related to a need for alternation [13]. This notion, if supported by additional experimental studies, opens up areas for further research. If the concentration ability and interest for a certain task of a participant is determined, predictions of the number of gazes towards the window might be made.

CONCLUSION

In conclusion, the following recommendations regarding user behavior in a simulation tool of non-image-forming effects of lighting in offices are given:

- To determine the average ocular light exposure of office workers, at least the location and associated general viewing direction, and the electrical lighting and blind switching should be incorporated using profiles or prediction models.
- To determine adequate ocular light exposure for all individual office workers, dynamic gaze behavior should be integrated since the conducted experiment identified considerable inter-individual differences.

In the experiment, on average, ocular light exposure of dynamic (real-life) gaze behavior was 10.8% higher than its static counterpart. However, the found results are case-specific and a group average, thus future work on the identification of predictors regarding dynamic viewing behavior is necessary to predict inter-individual differences. ■

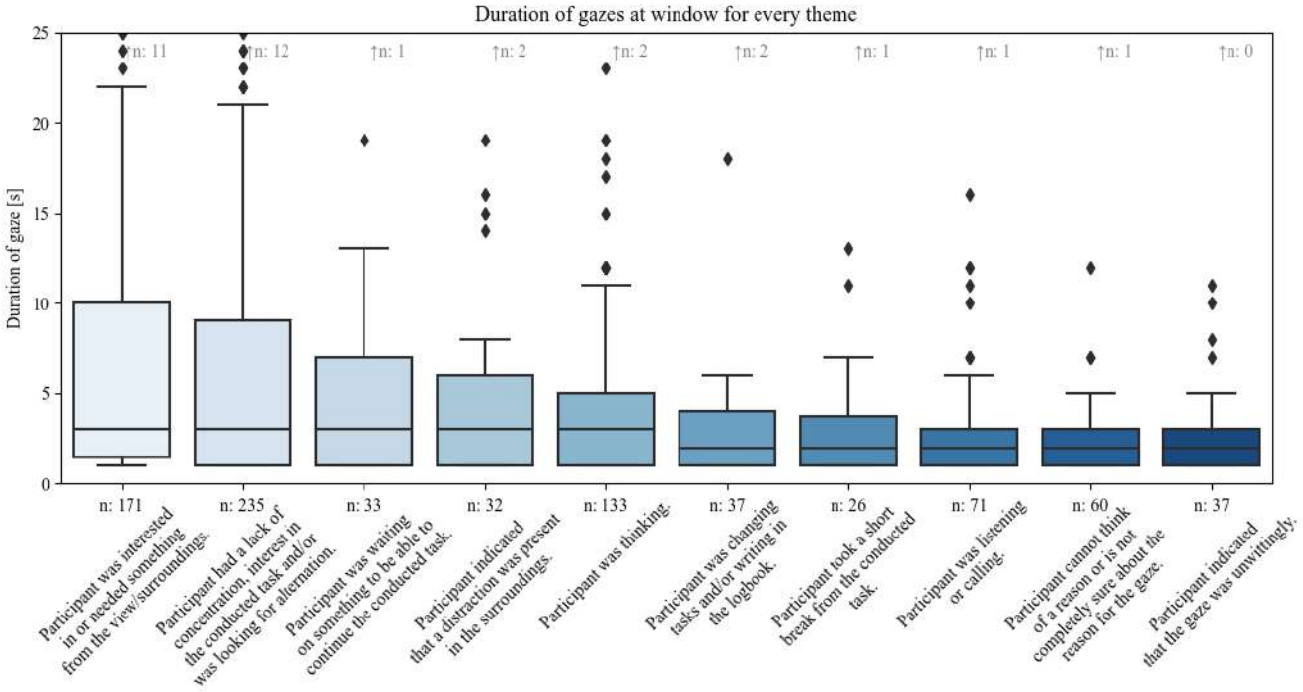

Figure 5. Duration and total number of gazes towards the window for each theme. The number of single outliers is shown in grey.

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Design 'On the Back of an Envelope' vs. Parametric Design

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LBP|SIGHT

Although parametric design isn't a new concept, the topic is more relevant than ever. Like other companies, engineering consultancies in the field of building physics also use the method to combine data into new information in a faster, smarter way. By doing so, they're able to address issues in an integral manner. Does this mean that consultancy in building-physics based solely on knowledge and experience is history? In other words, does parametric design beat consultancy 'on the back of an envelope'? We share our opinion by discussing four statements.

STATEMENT 1: PARAMETRIC DESIGN IS STILL IN ITS INFANCY

It's important to realize that the application of parametric design isn't limited to the construction sector. The method can also be used for designing shoes, electronics, or furniture for example. After all, parametric design is all about combining data or parameters to optimize a design. With that in mind, we can't say that parametric design is still in its infancy.

However, there are still steps to be taken when it comes to building physics and parametric design. Many aspects of building physics that originate from Dutch law and regulations from can't be combined with parametric tools yet. For example, the combination of BENG and daylight requirements for buildings. This is an excellent opportunity for software developers in the field of building physics to fill in this gap in the market, by developing tools specifically for Dutch building regulations in such a way, that they can be controlled parametrically. Until then, engineering consultancies will have to rely on their own programming skills, leaving parametric design for the purpose of building physics still partly in its infancy.

STATEMENT 2: PARAMETRIC DESIGN ISN'T POSSIBLE WITHOUT KNOWLEDGE OF BUILDING PHYSICS

Many building physics consultants are used to 'designing on the back of an envelope. In others words, consults are based on knowledge, experience, and general rule of thumb. The consultant calculates representative and normative situations for each aspect of a design. This works great when directing a design at an early stage when the various back-of-the-envelope conclusions are combined in one design. However, if you want to optimize the design in detail you often depend on parametric analysis. This type of analysis enables you to look for an optimal design based on a set of conditions, by analyzing different variants in a fast and targeted way.

Does this mean that in the future, everyone with the right software and parametric design skills can be a consultant in building physics? Not at all. Especially in parametric design, the

Figure 2. Building physics consultancies need to find the right people and bring them together.

knowledge and experience of building physics consultants are indispensable. Firstly, they need to write the right script and add the right conditions to parametric analysis. Secondly, they need to validate everything that's being calculated.

In addition, a building can never be completely designed based on parameters. First of all, some building aspects – like aesthetics – are hard to put into parameters. And even if it's possible, it will create so much data that software isn't able to analyze such an amount of information. In short, the building physics consultant will always be a key player to combine the outcomes of parametric analyses with aspects that are not in the parametric model.

STATEMENT 3: PARAMETRIC DESIGN ONLY ADDS VALUE TO LARGE PROJECTS

In small projects, a lot of existing knowledge is often already available, coming from comparable projects for example. In these projects, the parametric design doesn't offer added value; consultants are often able to provide consultancy based on existing knowledge and 'conventional' solutions.

Often, the specific, complex, integral – and therefore large – projects do ask for parametric design. Due to their complex nature, existing knowledge or reference material isn't always available in these projects. Or sometimes, a lot of different, unique parameters have to be combined. In these type of projects, parametric design offers the most added value. However, in this case, it also should be noted that parametric design isn't possible without in depth knowledge of building physics. In the end, the goal isn't to calculate a thousand variants of one design. The goal is to find the solution that suits the situation best. Substantive knowledge of building physics is indispensable in this matter.

STATEMENT 4: BUILDING PHYSICS CONSULTANCIES NEED TO INVEST IN PARAMETRIC DESIGNERS

Engineering consultancies that integrate parametric design into their consultancy services, can be of great added value. Fortunately, more and more attention goes to parametric design within construction courses and education. Therefore, there are more parametric specialists. So, does it make sense for consultancies to hire a bunch of parametric specialists at this moment? We don't think so.

Of course, parametric specialists can support building physics consultants in giving integral, optimized advice. On the other hand, we already stated that parametric specialists need consultants for their substantive experience and knowledge. But how do you ensure optimal translation between these two types of specialists? After all, parametric design is a relatively new digital development within the field of building physics. Consultants don't adapt to this at the same pace. On the other hand, parametric designers lack years of experience and knowledge from building physics consultants.

That's why the third type of specialist within consultancies is essential: a building physics consultant with an excessive interest in and affinity with IT. This type of consultant takes care of the connection and communication between different types of specialists, and 'translates' the knowledge, questions, and needs of colleagues. In short, the most important challenge for building physics consultancies at this point is to find the right people and bring them together.

CONCLUSION

Our conclusion? We don't have to choose between designing 'on the back of an envelope' or parametric design. As consultants, it's our main job to ensure that consultancy in building physics stays suitable and meaningful. Use envelopes if necessary and if it offers the results you need. And opt for parametric design if it offers added value, for example in complex projects. ■

Authors: Henk Versteeg (left) and Sierd Tilma (right)

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VOC Emissions from (Biobased) Building Materials

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INTRODUCTION

The construction industry is currently experiencing a transition in the field of circularity and energy conservation, while simultaneously needs and wishes of users in terms of comfort should be maintained. One possible solution to tackle this problem is by using biobased insulation materials with a vapour-open construction.

With a vapour-open structure, no vapour retardant layer is placed between the biobased insulation material and the indoor environment, which means that a direct interaction between the biobased material and the indoor air can take place. This does not only influence the humidity in the indoor environment, but also sets questions in what terms this does influence the indoor air quality. During this research the focus was placed on volatile organic compounds (VOCs) to investigate the impact of these emissions from biobased materials on the indoor air quality in a standardized room.

VOC emissions are gaseous emissions that, among other things, evaporate from the surface of a material into the air. This type of emissions is an understudied class in the field of indoor air quality [1], but it may have the potential to cause (1) irritant effects including perception of unpleasant odours, mucous membrane irritation and exacerbation of asthma; (2) systemic effects such as fatigue and difficulty concentrating; and (3) toxic, chronic effects such as carcinogenicity [2].

In the past, research was already conducted on various wood products, which have shown that untreated wood chips emit higher values of VOC emissions compared to wood panels with added synthetic resins [3]. Furthermore, previous research on biobased materials shows that the total volatile organic compound (TVOC -total sum of VOC emissions between C6 and C16) limits are often not exceeded by current regulations, but that single VOC emissions are of more concern.

This raises the question of what and how much single and TVOC emissions are then emitted by biobased materials that consist largely or entirely of raw plant materials? How does this affect the indoor air quality and how do they compare to synthetic materials we often use these days?

RESEARCH OBJECTIVE

The objective of this study is therefore to qualify and quantify VOC emissions from two 100% biobased expanded cork panels compared to reference materials (particle board, MDF, EPS, PUR board and blonde cork). Expanded cork is made by heating and pressurizing cork particles in an autoclave. During this process a natural glue called suberin is released, which acts as a natural glue. In this way the particles will stick together and form a solid hard board that can be used as an insulation material on walls. Especially the emissions from the suberin and the single cork particles were of main interest in this study, as previous research had already shown that cork has the potential to emit elevated levels of certain single VOC emissions that can be harmful for human health [4], [5]. This was, however, only investigated for blonde cork (cork with a synthetic resin) and not for fully biobased cork.

METHOD

For this research lab studies were conducted combined with a literature review as the main method of research. The literature review investigated key parameters for the method of experiments. After the literature

Figure 1. Test materials.

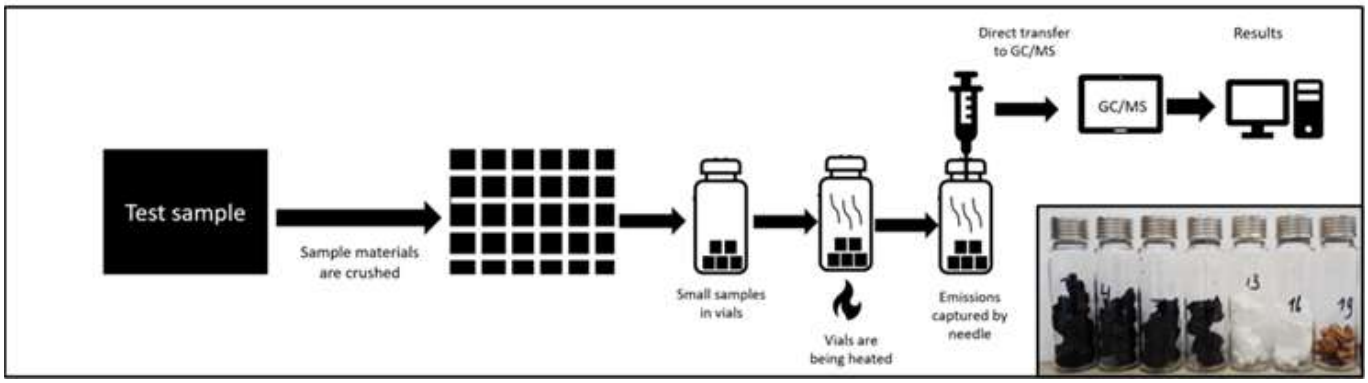

Figure 2. Principle of GC-MS + headspace method.

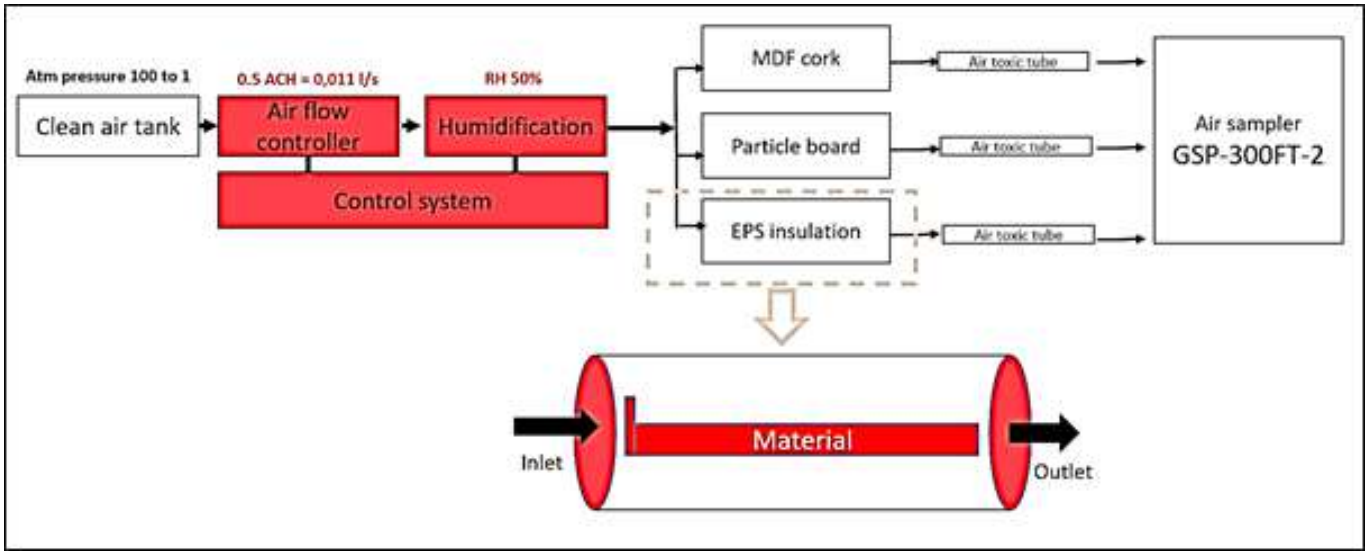

Figure 3. Principle of GC-MS + ATD method (White boxes indicate the qualitative setup, white + red boxes indicate the quantitative setup).

study, two types of experiments were conducted: 1) qualitative experiments to investigate what is emitted by the material and 2) quantitative experiments to investigate how much is emitted by the materials.

QUALITATIVE EXPERIMENTS

For the qualitative experiments a method was developed and validated using two testing methods, namely (1) GC-MS + headspace at 45°C and (2) GC-MS + ATD at 21°C. GC-MS stands for gas chromatography and mass spectroscopy and refers to a device that can detect and quantify VOC emissions from air samples. With this step chemical fingerprints were made of the materials shown in figure 1 to identify the materials chemically. This information is needed as input for the quantification measurements. As can be seen, two temperatures were used for the two methods. With this it was also investigated what the effect of temperature is on the release of VOC emissions.

With method 1 (Fig. 1 - GC-MS + headspace) small samples were taken and placed into small vials. These vials were heated 12 hours at 45°C. With method 2 (Fig. 2 - GC-MS + ATD: white boxes) large test samples were placed in 20-litre test chambers under static circumstances at room temperature (+/- 21°). The test setup is based on ISO 16000 standards and samples were taken by air toxic tubes using active sampling by a hand pump.

QUANTITATIVE EXPERIMENTS

Using the input of the qualification experiments, a method was developed and validated to quantify emissions from three test materials: 1) expanded cork, 2) particle board and 3) EPS insulation. With this it was found how much is emitted per identified VOC-component by the surface of the material. Therefore, the GC-MS + ATD setup was used (figure 3 white & red boxes). The test chambers were ventilated for 28 days with a ventilation rate of 0.5 h-1. The environmental conditions were +/- 21°C and 50% relative humidity. Various samples were taken between day 3 and day 28. Finally, emissions are evaluated by the AgBB scheme [6] to indicate both the performances in terms of TVOC and single VOC emissions.

RESULTS AND DISCUSSION

KEY EXPERIMENTAL PARAMETERS

During the literature study, looking at many reference studies after 1996, it was concluded that limited information can be found on the emittance of VOC emissions from biobased building materials, such as expanded cork. What did become clear was that wood-based materials are still the most investigated materials that are most in line with fully biobased materials. Therefore, key parameters were obtained from these reference materials and are shown in figure 4. By performing measurements on VOC emissions, it is important to include these key parameters into the design of the experiment. To clarify the parameters as detailed as possible allows for an easier comparison between the obtained experimental results and literature, after the experiments have been performed.

QUALITATIVE RESULTS

During the experiments, the effect of temperature was analysed by comparing the outcomes for the two testing methods described. First the reference materials such as particle board and EPS insulation were checked, as these materials are relatively well described in literature. From this analysis, conclusions could be confirmed in terms of the effect of temperature on the emission release as obtained from the methods applied, including: 1) under an elevated temperature, chemical reactions take place and 2) at higher temperatures emissions with a higher boiling point are emitted.

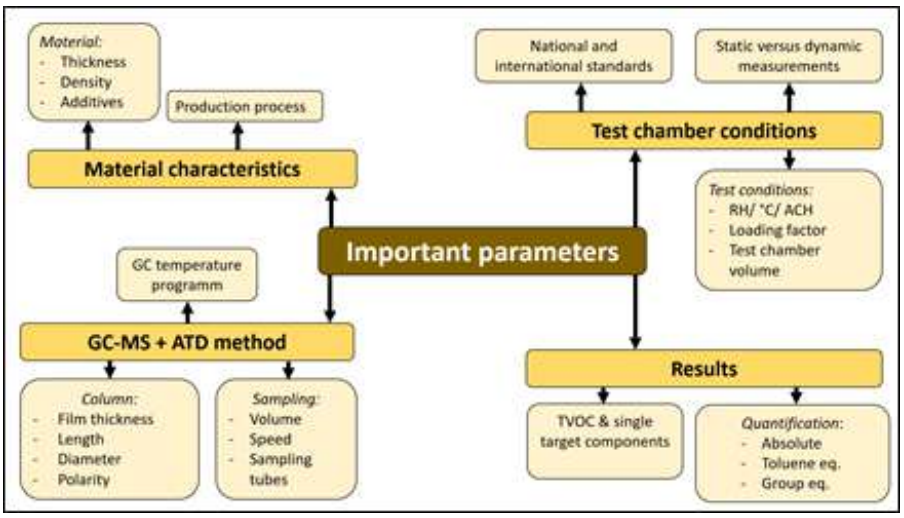

Figure 4. Key parameters experiments of VOC emissions.

Applying this knowledge, the results from the experiments allowed for the evaluation of the emissions from the unknown source, expanded cork, as function of temperature. A so-called chemical fingerprint was made to exam the main differences between 45°C and 21°C samples. In figure 5 an overview is shown of the emissions measured with the headspace method (45°C) and the ATD method (21°). IDF cork is expanded cork with a density of 110 kg/m^3 and MDF cork is expanded cork with a density of 130 kg/m^3.

What can be seen in figure 5 is that the different emissions found can be separated in groups, where especially aliphatic hydrocarbons were found in both materials at room temperature and acids at an elevated temperature. The main concerns for single emissions emitted from the materials included furfural, toluene, acetic acid, phenol, acetone and various terpene emissions. These emissions were found in literature before for blonde cork and are most harmful for the health of humans. At room temperature toluene and acetic acid were found for expanded cork, while at an elevated temperature also phenol was found. This gives the indication that, similar to the results of the reference materials, the temperature has an influence on the type of emission release at different temperatures for expanded cork.

QUANTITATIVE RESULTS - EQUIVALENTS

For quantifying the results, emission peaks found for various emissions should be recalculated using a calibration curve. Most of the time a toluene equivalent is used for this purpose. With this a peak found with GC-MS, for instance the detection of butanol, is recalculated to a toluene equivalent emission rate. This reduces the analysing time of the results. However, this method is not very specific. What it basically does is comparing all emissions as equals, while in practice some groups of emissions have a higher sensitivity to the GC-MS device. As a result, the exact amount of a specific emission can be over- or underestimated.

It can be seen that especially alcohols, ketones and aliphatic hydrocarbons are underestimated by the toluene equivalent, and that terpene emissions are overestimated, meaning that the measured terpene emissions are lower in reality as to what the toluene equivalent outcome would project.

To minimize the differences between the compounds a new method was created, called group equivalents. With this method each emission is quantified based on its own group, instead of recalculating everything back to toluene. With this method the real-time emission rate can be obtained as close as possible. The difference in outcome for both methods is presented for toluene, see table 1.

QUANTITATIVE RESULTS – AMOUNT OF EMISSIONS

Using previous knowledge of the qualitative stage and using group equivalents, the amount of emissions being released from three test materials was evaluated. The results can be seen in table 2. The emissions are shown as area specific emission rates for the total

Table 1. Deviation between toluene and group equivalents used for the calibration curve.

Compound	Deviation between toluene and group eq.
Toluene eq.	0 [%]
Aliphatic hydrocarbon eq.	74 [%]
Alcohol eq.	914 [%]
Terpene eq.	-29 [%]
Ketone eq.	107 [%]
Aldehyde eq.	12 [%]

Table 2. Area specific emission rate of tested materials and reference materials of Maskell et al. [7].

Material	TVOC Area specific emission rate [µg/m²h^{-1}]			
	Day 3	RSD[c]	Day 28	RSD[c]
Expanded cork (group eq. / toluene eq.)[a]	52/50	31%	19/16	40%
EPS insulation (group eq./ toluene eq.)[a]	177/155	22%	38/26	40%
Particle board (group eq./ toluene eq.)[a]	100/70	37%	30/19	40%
Cellulose flakes[b]	11		ND	
Wool[b]	4		ND	
Hemp fibre[b]	33		8	
Wood fibre/ wool[b]	911		160	
Hemp lime mix (330 kg/m^3)[b]	34		ND	
Hemp lime mix (275 kg/m^3)[b]	28		ND	
Rigid wood fibre[b]	14		9	

a) measured TVOC emissions based on C6-15 instead of C6-C16 due to limitations desorption tubes; b) Maskell et al. [7]; C) Estimated RSD based on research of Yrieix et al. [8]

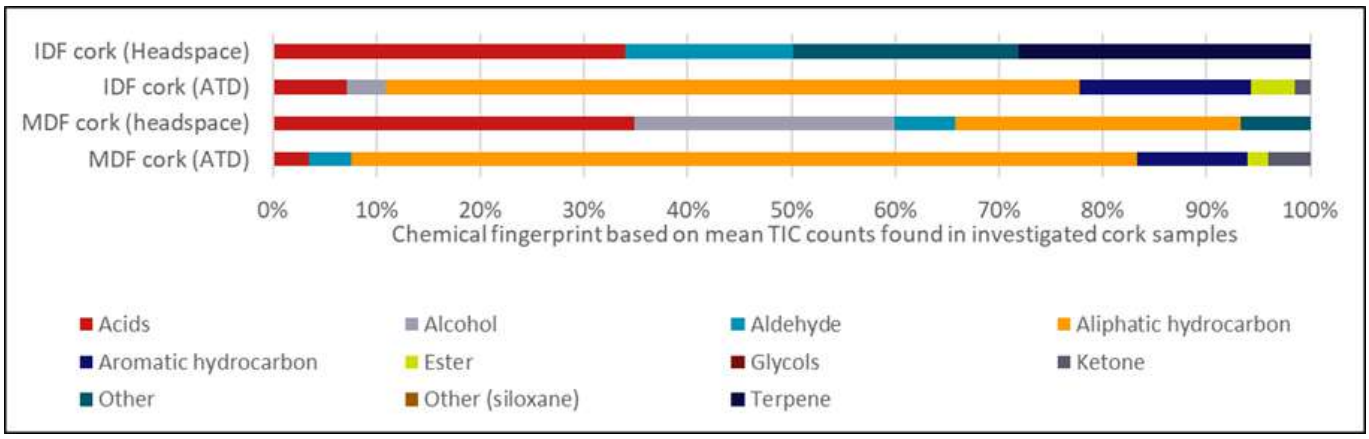

Figure 5. Duration and total number of gazes towards the window for each theme. The number of single outliers is shown in grey.

of VOC emissions between C6 and C14/15. Furthermore, a relative standard deviation (RSD) is calculated per material to show the uncertainties of the results. It should be kept in mind that AIR toxic tubes were used for the measurements, meaning that not all TVOC emissions between C6-C16 were included, but that the limit of detection was set to C15.

The results are compared with previous research on VOC emissions performed by Maskell et al. [7] and are evaluated by a part of the AgBB scheme focussing on LCI (lowest concentration of interest) values, carcinogenic compounds and TVOC emissions after 3 and 28 days. What can be stated is that expanded cork emits less VOC emissions then the measured emissions of particle board and EPS insulation. What also can be seen is that expanded cork emits a slightly higher amount of VOCs at both day 3 and day 28 then other biobased materials investigated by Maskell et al. [7], except for wood fibre/ wood wool.

Finally a risk assessment was performed using the AgBB scheme. It can be stated that expanded cork and particle board can be considered as healthy as they meet the set of requirements. EPS insulation did meet the requirements for TVOC emissions and LCI-values, but did emit elevated levels of benzene after 28 days, which means that the requirements concerning carcinogenic emissions were not met.

CONCLUSION

This study addressed the qualification and quantification of VOC emissions from expanded cork and various non-biobased building materials. Two different methods were used for identifying VOC emissions and one method for quantifying emissions to ultimately identify the effect of VOC emissions from biobased and non-biobased materials on the indoor air quality.

First it was concluded that information was lacking in the field of VOC emissions from biobased materials and VOC emissions in general. By performing the literature study key parameters were found that provide guidelines on how to measure VOC emissions in a way that results of the experiment can be compared with other literature studies.
Then research was carried out into the qualification of VOC emissions from biobased expanded cork as shown in figure 1. It was concluded that the harmful substances furfural and phenol were not found at room temperature, but acetic acid, toluene and acetone were. At 45°C phenol was found as well, which leads to the conclusion that an elevated temperature does have an influence on the emitted VOC emissions of expanded cork.

After the qualification of single components, long-term measurements were performed on VOC emissions from expanded cork, particle board and EPS to quantify the amount of VOC emissions emitted by these materials. It was found that expanded cork and particle board did meet the requirements, but EPS insulation didn't. Furthermore, expanded cork emits higher TVOC emissions after 3 and 28 days compared to other biobased materials studied in the research of Maskell [7].

Finally, during the quantitative measurements it became clear that VOC emissions were underestimated when applying the toluene equivalent approach. This mainly has to do with the response of the GC-MS device on the various chemical groups. By using group equivalents, more realistic values were obtained for aliphatic hydrocarbons, alcohols, terpenes, aldehydes and ketones. ■

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Kuijpers

Resultaat door betrokkenheid

Kuijpers & Mollier

Robert Snoeren, trainee Kuijpers
Wouter Flach, recruiter Kuijpers

Kuijpers is een technisch dienstverlener, actief sinds 1921. We zijn altijd op zoek naar jong talent. Daarom bouwen we heel bewust aan contacten met studieverenigingen, scholen en technische opleidingen van alle niveaus. Robert Snoeren (voormalig lid van Mollier) studeerde building physics and services aan de TU Eindhoven. Stage lopen hoort er daar helaas niet bij. Om toch ervaring op te doen, deed hij mee aan de meet & greets met bedrijven, georganiseerd door Mollier. Zo kwam hij bij Kuijpers terecht, één dag in de week. Die ene dag per week werd na Roberts afstuderen (in 2016) een tweejarig traineeship bij Kuijpers. En dat door de meet & greet met Wouter!

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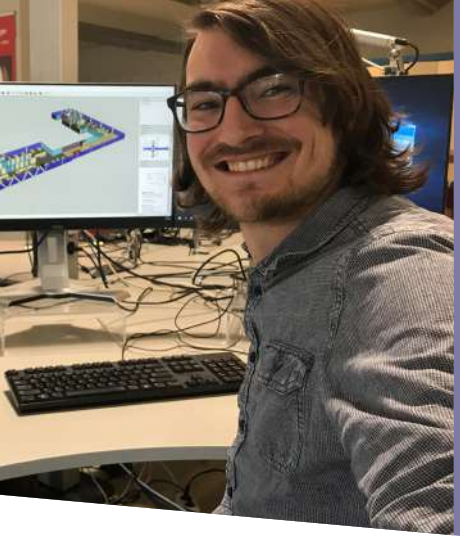


Alumni at Work

C. (Chris) van Loenen MSc

Hello, my name is Chris van Loenen. I'm 30 years old and currently living in Eindhoven on the most expensive street in the Netherlands (Kalverstraat, or Boardwalk for the English Monopoly players).

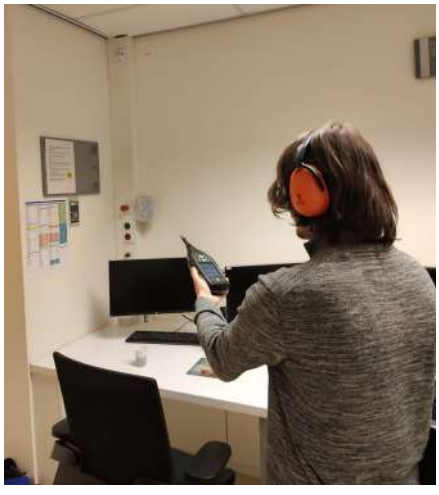
Born in the far east in Enschede and after playing a lot with Lego and Sims, I decided to become an architect. After visiting both the universities at Delft and Eindhoven, I chose Eindhoven because it was much gezelliger.

I started Bouwkunde in 2010. It only took half a year to realize becoming an architect wasn't gonna work out, but I kept going with the study anyway. I ended up in the Building Physics department, where a certain C. Hak lured me into building acoustics, which became my favorite part of Building Physics and the main subject for my master's and graduation research.

My first introduction to Mollier was the infamous, legendary first Cocktail Party, where I met so many members I couldn't remember them all afterward. During my years at Mollier, I joined the best committee ever (Lunch Lecture committee!) and took part in organizing the 4th Lustrum party. In the summer of 2017, we started the Summer Board '17 – '17 as a protest against the actual board not being there to organize events for the people hard at work during the summer break. The highlight of my Mollier-career was the honor of getting a fish named after me. Archibald Zeegers enjoyed his time with Koenfish in the Mollier fishbowl.

After/during my graduation I joined the Building Physics team of Deerns Nederland in Eindhoven and almost five years later I'm still with Deerns. At Deerns, I quickly learned that the professional world is quite different than the academic world. Still, I must say that a lot of knowledge I picked up during the courses came in handy (also, no TVVL course is required if you start at Building Physics!).

At Deerns, I work on a lot of different projects with a lot of different clients. They range from small houses to giant building blocks, from monumental museums to high-tech cleanrooms and from swimming pools to theatres. The subjects on which I consult with our clients covers the complete range you also come across during the Building Physics master track.



During my master, I also performed a whole bunch of different types of measurements. These skills I still get to apply during my work. I do not have to sit at the office the whole week, but also get out to investigate problems our clients face and perform measurements on-site to help find solutions. You get to let out your inner Sherlock when solving some of the problems on-site.

I also get a chance to further expand my knowledge in the areas I'm interested in. We are encouraged to follow lecture days and I recently finished the course Milieugeluid (Environmental Acoustics). This course was very interesting, since, compared to our research focused master, this course taught me a lot about acoustics in the professional environment.

I wouldn't still be at Deerns if the atmosphere wasn't great and I can say it really is. At Deerns there's a nice mix of young starters and more experienced seniors. Next to the work, there are a lot of activities being organized, such as the fun PV-activities (co-worker activities), Outdoor Weekends and the Acoustic Sailing Weekend.

If you're interested in Buildings Physics and looking for an internship/graduation project/job, feel free to contact me. Also, as a board member of the Mollier alumni board Schoone Leij, I am taking this opportunity to inform you that all Mollier members are welcome at our quarterly drinks/activities, hope to see you there! ■

Studying at the Danmarks Tekniske Universitet

Laurens Castenmiller

Hej, my name is Laurens, and you might know my name as chairman of Mollier last academic year. I have been in this role for 1.5 years. After the first semester last year, Pam took over my role as chairman and I went for a semester abroad. In this article, I will explain how I came to the idea of going to Denmark, how I experienced this exchange, and above all, what I mainly did during this semester.

In high school, I was not good at English, and choose this study in Eindhoven because the study was held in Dutch. After 3 quartiles in my bachelor, I was hit by a car and ran into a study delay. After I recovered and continued with my study the university told me that the study was held in English and that they wanted to encourage students to get experiences abroad. When I heard this I was thinking to go abroad to Belgium and still continue speaking Dutch. However, I now write about my experiences at the DTU, in Denmark, so how did this happen? To improve my English I accepted the challenge of becoming a board member of Mollier, and because I am interested in sustainability I accepted the challenge to improve my English even more in Denmark since they are performing well in terms of sustainability.

On the 20th of January, I had my master project presentation, and after the presentation, I needed to empty my student room and get ready to fly to Copenhagen, since my plane took off the next morning at around 11.30. At this time there were a lot of uncertainties due to the COVID-19 pandemic if everything could happen, luckily my exchange could happen! During the first week, I had an offline introduction week instead of a previously reported online introduction week. During this introduction week in Copenhagen, or more precisely in Lyngby, I made lots of contacts with other international students and also partied a lot with my introduction group (Figure 1). Due to the many parties in the student dorms, some outbreaks of COVID happened, but luckily I stayed safe!

Figure 1. My introduction group in one of the student dorms before a party.

After a very successful introduction week the serious part started, which meant that I needed to follow some courses. I followed 5 courses, 4 of which were given during the period February - May, and 1 course was given during 15 continued workdays in June. 1 of the 4 courses, called Indoor Climate, was a practical course and a lot of experiments were performed. When we sat together one day I handed out some Mollier stickers, and my group mates attached them to their notebooks, to promote Mollier all over the world (Figure 2)!

Figure 2. Promotion of Mollier on notebooks of other exchange students.

During the Indoor Climate course, we needed to write a report about the air quality at home and the light perception throughout the day concerning the sleep quality during the night. To be able to measure and analyze sleep quality several parameters need to be measured. The majority of the measurements occured during night time, and a FLOW sensor measures the $PM_{2.5}$, PM_{10}, VOCs, and NO_2 levels while a HOBO logger measures the temperature, relative humidity, and CO_2-concentration at home. Perceived light levels were measured during the time the person was awake, and was measured by a LYS sensor. The LYS sensor is a wearable device that measures the vertical illuminance in Lux and captures the intensity of the light in the red (R), green (G), or blue (B) spectrum. The sleep quality of a person is dependent on various variables and was being measured with the help of Fitbit. The Fitbit measures the sleep length, time in bed, number of awakenings, and the length of different sleep stages. The sleep stages are awake after sleep onset, REM sleep, light sleep, and deep sleep. Based on the HOBO, LYS, FLOW, and Fitbit data several plots were made, and conclusions were drawn about what the effect of these parameters against sleep quality. The data from the LYS sensor were manipulated into circadian stimulus values which showed the effectiveness of the spectrally weighted irradiance at the cornea. .

For the same course, the thermal environment was determined for 2 meeting rooms to analyze the effect of improvement or deterioration in newer buildings compared to older buildings. an Indoor climate analyzer by Brüel & Kjær 1213 (Figure 4) was used to take some instant measures in both rooms which measures the relative humidity, air temperature, and air velocity (Figure 5).

The results showed that the relative humidity in the older building (blue) was slightly higher than in the new building (orange) in Figure 3. In between those lectures, I had some spare time and I celebrated my birthday in Malmö and bought myself as a gift

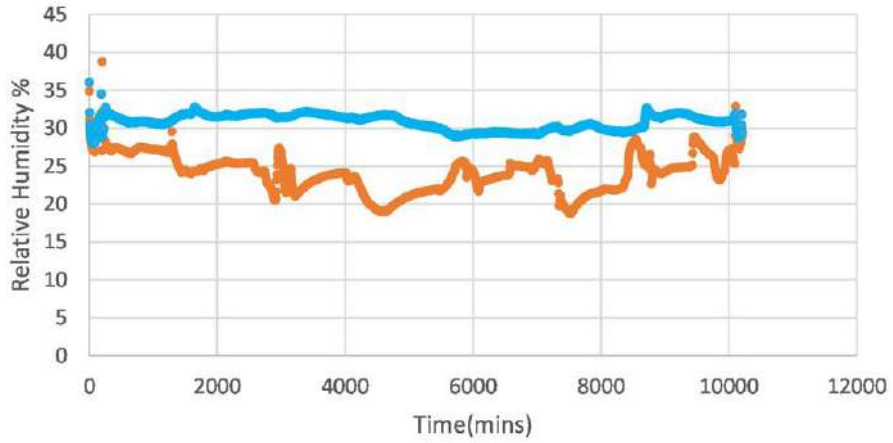


Figure 3. Relative humidity percentage of both rooms.

a visit to the Europe League game FC Copenhagen - PSV (Figure 6). I went to the game with many other exchange students, some from The Netherlands, and some even from Eindhoven as well as other international students to just visit a game of FC Copenhagen. PSV won the game easily with 0-4 and after the match, some of us still went to the city center to celebrate ST. Patrick's Day.

After being 2.5 months in Denmark it was time to go back to The Netherlands for a weekend to visit the postponed lustrum gala of Mollier. After coming back to Copenhagen it was almost easter break,

Figure 4. Indoor climate analyzer by Brüel & Kjær 1213.

Figure 5. Measurement device that measures the relative humidity, air temperature and air velocity.

and plans were made to visit Bergen, Norway, as a holiday with some friends (Figure 7). We hiked in Bergen itself, and also we went to other amazing places in Norway and saw a lot of the beauties the earth still has, like the amazing mountains, crystal clear lakes (Figure 8), beautiful skies, and the nice waterfalls.

After the holiday in Bergen, I continued my studies at the DTU, and my exchange ended after the 3-week course in June. In this course, called Smart Cities, I had to

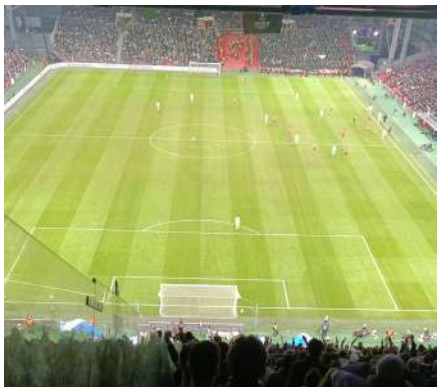


Figure 6. Matchday, FC Copenhagen - PSV

Figure 7. Group picture at the top of Fløyen with Bergen at the background.

Figure 8. Enjoying the amazing silent waters combined with the beautiful nature.

come up with some innovative options, and include technological options to ensure the well-being of citizens. In this project, we choose the city of Warsaw since there are some struggles with a very high level of air pollution. The objective of our project was to improve well-being, as well, as to raise awareness of the problem which can be very beneficial for the sake of tackling it. In this project, we introduced Smart Air Pollution Shelters, which is a sustainable solution consisting of zero-energetic indoor gardens to provide citizens with green space with clean air instead of the air pollution currently occurring in Warsaw. In the shelter, some smart screens are located to educate the citizens to shelter from the high level of air pollution. Which the citizens will receive via a text message on the phone. The shelters look like the image in Figure 9, and at the end of the three weeks, a presentation with a poster was given together with providing a report about the idea and the innovative ideas.

After the 3-week course, my exchange ended but I still paid for my student dorm in Lyngby till the end of July, so this meant that I had 1 month of holiday in Denmark. To start with this holiday, I watched the Tour de France start in Copenhagen, and my friends from high school and the TU/e visited me, so I showed them around Copenhagen! Finally, I had some days to enjoy with my exchange friends and cycled around Denmark en also had many days chilling at the beach, while sitting next to a campfire (Figure 10) and enjoying the last hours of the day, or even the first hours of the day, and take pictures of the sunrise in the early morning.

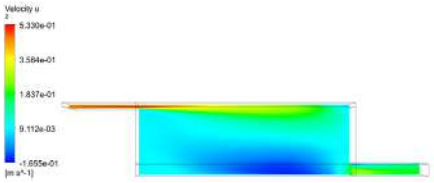
It was nice to study abroad, and I really can advice people to go abroad, and get the same kind of experience. ■

Figure 9. Smart Air Pollution Shelters.

Figure 10. enjoying the warmth of my new Erasmus friends at a campfire.

Ice Breaker
Natasha Stamler

Hi everyone! My name is Natasha and I am 22 years old. I'm from New York City and just finished my bachelor's degree in Mechanical Engineering and Urban Planning at MIT, right outside of Boston, Massachusetts. I'm researching ventilation simulation and occupant comfort in Atlas until June through a program called Fulbright, which aims to build positive relations between the US and other countries, including the Netherlands. I will then return to MIT to complete my MS/PhD in Mechanical Engineering.



Nielsen CFD validation case in Ansys Fluent.

"Two questions probably come to mind"

1. How did you end up studying building physics?
2. What are you doing all the way in Eindhoven, 5 500 km away from Boston?

Good questions! At MIT, I spent 3 years as a researcher with the Digital Structures group, part of the Building Technology program, the closest we have to BPS. There, I studied how we can change the shape of concrete ceiling slabs to minimize both embodied and operational energy. I wrote my mechanical engineering thesis with the group, modeling urban-scale outdoor air pollution using CFD. I enjoyed this work and saw it as a great way to combine the technical engineering skills I had from mechanical engineering with the design and urban systems thinking I had from planning to improve well-being and climate resilience in cities. I decided to come to TU/e because of its strength in BPS and because Atlas is an excellent case study for building energy retrofits, something that the US has been slower to adopt than Europe. I hope to learn as much as I can about BPS, energy, and the Netherlands while I'm here, as well as share what I've learned at MIT, so I'm excited to hear about your work and answer any questions you may have!

Pusphaira Dames 3 team photo.

At TU/e I am a part of Mollier and Pusphaira. I broke my wrist during the first soccer match but will hopefully be back soon!

In my free time I enjoy running, reading, and baking/cooking, especially dishes for my friends. I also sometimes build things for fun. The day before graduation in May, my friends and I had the crazy idea to build a remote-controlled, cow-themed kayak. Somehow, it worked, and we got to ride it on a beautifully sunny day on the Charles River.

Baking snickerdoodle cookies, a tradition I have with my friends to celebrate the end of the semester.

Riding the "Cowyak" with the Boston skyline in the background.

Onboard the Trans-Siberian Railway of Italy or "Ferrovia dei Parchi" (Railway of the Parks), the railway I studied in June.

At Preikestolen (Pulpit Rock), Norway with my twin brother in August.

Additionally, I'm a big train nerd – I spent a summer working for the Boston Commuter Rail – and have been greatly enjoying using the fantastic Dutch rail network to explore the country on weekends (seriously, ask me about regional rail planning and local energy policy). This summer I spent June in Abruzzo, Italy studying how improving last-mile connections to a historic rail line could revitalize depopulating small towns and then spent August traveling around Europe, mostly by rail. One of the highlights was hiking in Norway with my twin brother (admittedly the one flight I had to take).

I look forward to my remaining months in Eindhoven and hope it is both exciting and insightful. After finishing my university studies, I aim to bring what I learn back home to better adapt our cities to rising energy and environmental challenges. ■

FELLOW/fse Stichting Fellowship FSE WO² Eindhoven University of Technology

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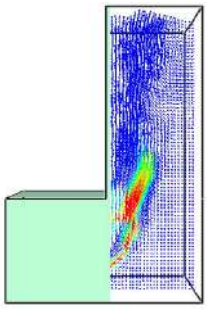
Engineering Fire Safety



Experimental research on fire and response of structures, separation constructions and building materials

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Circularity in Installation Technology: a Chain Solution

Author
Olaf Oosting, Director and Senior Advisor Sustainability and Circularity at Valstar Simonis

Editors
Marion Moerman
Marijn Braadbaart

Sustainability plays a major role at Valstar Simonis. It is not without reason that our mission is to use our knowledge to maximum effect in securing a healthy and sustainable world. Obviously the energy transition is an important driver behind our actions. With our advice and designs we do our utmost to ensure that the Paris Agreement goals are actually met. And preferably earlier than planned.

The subject of circularity was added to our agenda in 2015. Circularity is about preserving the value of products and materials used in the built environment and consequently minimizing the extraction of new raw materials. The latter depletes the earth, is highly energy intensive and causes considerable environmental pollution.
As the initiator of the TVVL Expert Group Circular Installations, we have been active for years in pushing this subject higher on the agenda of our industry. We see a continued interest in this topic and actively promote the subject in conversations with our clients.

CIRCULAR DESIGN

Within circularity, we distinguish three important impact areas: the design process, the product and the business model. At Valstar Simonis we can exert the most influence on the design process. We focus more attention on the impact of materials and we strive to maximize flexibility within a building. In this context, we have provided our input in the CB'23 circular design action team.

MATERIALS PASSPORT

The other impact areas are a circular product and a circular business model. Although we do not usually select suppliers ourselves, this is the focus point for the industry. The materials used in installations are provided by the suppliers. Little is known about the origin of products or the potential reuse of products and their constituent materials. Therefore we constantly emphasize to introduce a materials passport in our projects. As a consultant we see it as our job to emphasize the importance and to challenge parties involved on this aspect. Of course a passport itself is not an objective but a way to gain insight and a starting point to take further action.
Besides the passport, circular propositions are slowly emerging in our industry, such as the As a Service model or a buy-back guarantee. Not the holy grail of circularity, but it does put the responsibility and the possibility for reusing products or materials with the proper actor: the producer of the product.

ACTIVE KNOWLEDGE SHARING

Not only in new construction is circularity important. There is an enormous potential within existing building projects. Valstar Simonis has participated in the Framework for Circular Existing Buildings, an initiative of the Dutch Green Building Council. Together with other partners we wrote a pragmatic framework, in which the installation component has a clear spot and concrete guidelines have been formulated, such as the integration of a circular maintenance plan. We like to share knowledge about the lessons learned within our projects. For example, we provide expert lessons at the HIT-W training of Avans+ and (online) lectures via TVVL, the Dutch association for Installation Technology.

INTEGRAL TASK

The COVID pandemic and the IPCC report of early August 2021 have once again made it clear that stimulating circularity is an integral task. The interests can sometimes be contradictory and vary per client and situation. So there is a big challenge waiting for us, which we cannot and do not want to do on our own. We need the entire chain for that!

Impression Hogeschool Rotterdam (copyright: Paul de Ruiter Architects)

Projects we have worked on where circularity was part of the design / process:

HOGESCHOOL ROTTERDAM

After a European tender procedure, Valstar Simonis, together with DGMR, has been awarded the contract for the component 'Advisor Installations, Building Physics and Fire Safety'. Paul de Ruiter Architects has been selected for the architectural design. It is a beautiful new building at the Kralingse Zoom location, adjacent to Erasmus University Rotterdam. The client is the Hogeschool Rotterdam Business School.
One of the old buildings at the Kralingse Zoom, Rotterdam, no longer met current requirements and has been dismantled. Parts of the old building have been re-used at other locations of the Hogeschool in Rotterdam. At the current location, an energy-neutral building will be built, which forms a connection with the other, existing buildings.
The complex will be designed to at least the BREEAM-Excellent sustainability level, with the aim of creating a healthy indoor climate in a very energy-efficient manner; for example, triple glazing is used. There is also a lot of attention for plenty of fresh air, pleasant room acoustics and well-controlled temperature conditions that are regularly monitored. Daylight can enter through the atrium roof and glass facade in a controlled manner. On the roof of the fifth floor is a green roof with plants that support birds and butterflies.

SOUTH HOLLAND PROVINCIAL HOUSE

Within the consortium 'Hollands Licht' (Main contractor Kuijpers, Kraaijvanger Architects and DGMR for building physics), Valstar Simonis is responsible for the design of all technical installations for the renovation of the Provincial House.
The sustainable transformation concerns the renovation of an office and meeting building (event hall and Statenzaal). The Final Design (DO) was completed and approved at the end of 2019.
We designed the electrical and mechanical installations for this project, beyond the required DO level. The design is at BREEAM-Excellent level. We employ certified BREEAM experts for this. Furthermore, the building is energy neutral and uses 100% renewable energy sources for the heating and cooling supply. This ATES system was also designed by us. We employ a BRL6000-21 certified system designer for this.
The third floor will be replaced by a sustainable roof structure, which filters natural light into the building, but at the same time keeps direct sunlight out. Insulation of the existing facades and triple solar control glazing help to prevent heating and contribute to a reduction of the cooling load and heat loss. In addition, solar panels on the roof, in combination with energy storage in the ground, ensure that all building-related energy (including heat and cold generation) is generated sustainably and locally. Furthermore, materials are reused as much as possible and any new materials have a responsible (circular) origin. ■


Inside the South Holland Provincial House

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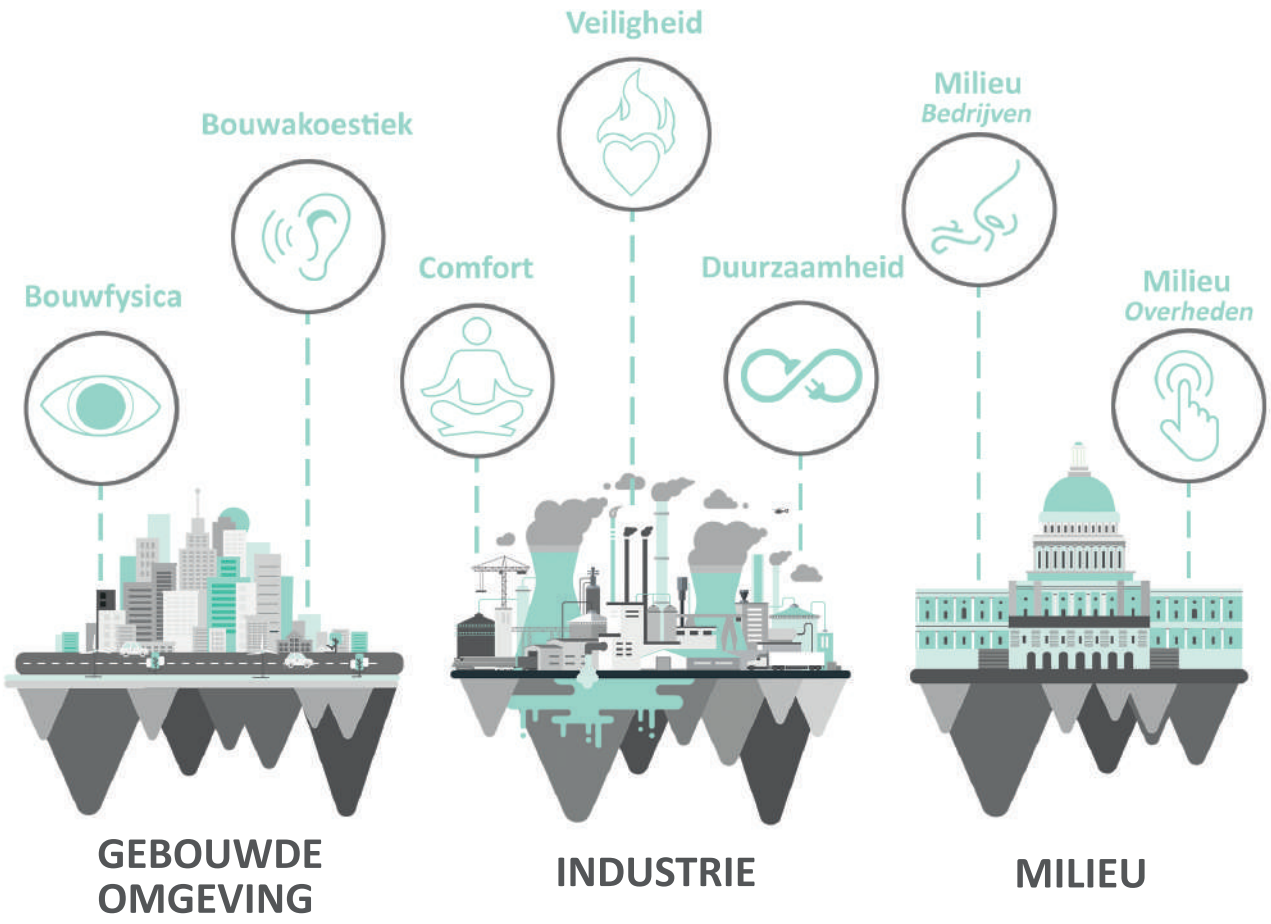

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Quantifying the Trade-offs Between Virus Exposure and Energy Consumption for Classroom Ventilation Strategies

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INTRODUCTION

The COVID-19 pandemic highlighted the importance of proper ventilation. The result has been that in many schools over the past two years, windows have been open very often, even in winter. This was necessary because ventilation was often not working properly. From a virus exposure risk point of view, this is positive; from a comfort and energy perspective, it is less optimal. Extra energy is needed to compensate for the extra heat losses through the open windows. Besides being undesirable from a sustainability point of view, because of the increase in energy consumption, the extra costs of this are also less bearable for schools. So, there is an optimisation trade-off: health versus energy consumption. At societal level, a choice for health seems obvious. For this, we only have to look at the costs of the COVID-19 pandemic for the Dutch society. At school level, those health care costs are not reflected, but those of the energy consumption are.

In the end, the key principle should be that health comes first. But it is nice when we can achieve that in a responsible way, i.e., with limited use of energy. Therefore, in this study, we looked at energy consumption versus benefits in terms of a reduced virus exposure risk in classrooms. The aim was to investigate the relationship between additional energy costs in winter by ventilating more, possibly in combination with purging, versus a reduction in infection risk. This ratio is considered to depend mainly on the type of ventilation system and insulation level.

The study focused on quantifying the trade-offs between reduced virus exposure and increased energy consumption for various classroom ventilation strategies. We investigated this for two types of ventilation systems (see Figure 1): Type A (naturally ventilated) and Type D (mechanical balanced ventilation with heat recovery). The idea behind this is that Type A is a very common type of ventilation solution for classrooms in existing school buildings, while Type D is used more often in new buildings. For the sake of completeness, Type C (mechanical extraction) can be compared energetically to Type A and in terms of virus exposure to Type D. For the insulation level, the construction types of old, new and passive buildings were considered.

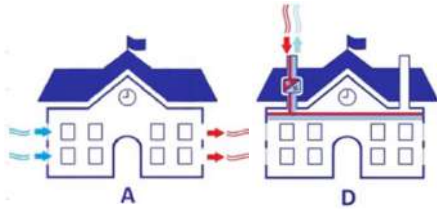

Figure 1. Ventilation system A (natural) and D (balanced ventilation with heat recovery).[1]

METHOD

Several cases have been studied in order to compare the influence of ventilation strategies on the virus exposure and the energy consumption. The scenarios focus on construction methods, ventilation systems, fresh air supply and exhaust, and the influence of opening windows, also referred to as purge ventilation. Simulations were performed using DesignBuilder [2], addressing one day with a low outside temperature, to gain more insight into the energy consumption due to heating per construction method and ventilation strategy. Purging is always through natural ventilation. The basic ventilation in the classroom assumes one of the two types mentioned (A or D). The scenarios include the effect of purging during the entire day, in-between class hours and during breaks, or not. In addition, the effect of the amount of ventilation (flow rate) and the amount that can be purged has been assessed. For these values, we used values defined in the 'Frisse Scholen' programme of requirements [3]. The values of the constant ventilation rate (V) and purge ventilation (P) are specified Table 1. The ventilation rates are indicated based on Frisse Scholen [3] class A, B or C as VA, VB and VC. The cases with purge ventilation are indicated as PA, PB and PC; the cases without (purge) ventilation are indicated by 0. To illustrate whether there is a schedule (S) for the purge ventilation or not, the numbers 0 (no schedule implemented) and 1 (schedule implemented) are applied.

Then the infection risk was calculated, using the Wells-Riley formula [4]. The amount of inhaled quanta was determined based on an integration of the inhaled quanta over time. This value was included in the Wells-Riley equation to calculate the infection risk over time.

RESULTS AND DISCUSSION

Table 2 summarises the calculated values for heating energy demand for the classroom as a function of the scenario's considered, type of ventilation system and construction.

Key figures were used to estimate the average energy consumption for heating a classroom for a day [5, 6]. This is estimated at 29.7 kWh. The comparison with the results obtained in Table 4 shows that the calculated values are in order of agreement with this value. Therefore, the calculation is considered sufficiently valid.

Figure 2 shows an illustrative example of the evolution of CO2 concentration,

Table 1. Ventilation combinations per scenario: Ventilation rate (V), Purge ventilation (P), Schedule (S) combined with class A, B or C and presence of purge ventilation.

	Ventilation rate V [m³/h]	Purge ventilation P [m³/h]	Purge schedule [-]
VCP0S0	670 (VC)	0 (P0)	no (S0)
VCPBS1	670 (VC)	1058 (PB)	yes (S1)
VBP0S0	949 (VB)	0 (P0)	no (S0)
VCPBS0	670 (VC)	1058 (PB)	no (S0)
VCPAS1	670 (VC)	1588 (PA)	yes (S1)
VAP0S0	1339 (VA)	0 (P0)	no (S0)
VCPAS0	670 (VC)	1588 (PA)	no (S0)
VCP0S0	670 (VC)	0 (P0)	no (S0)

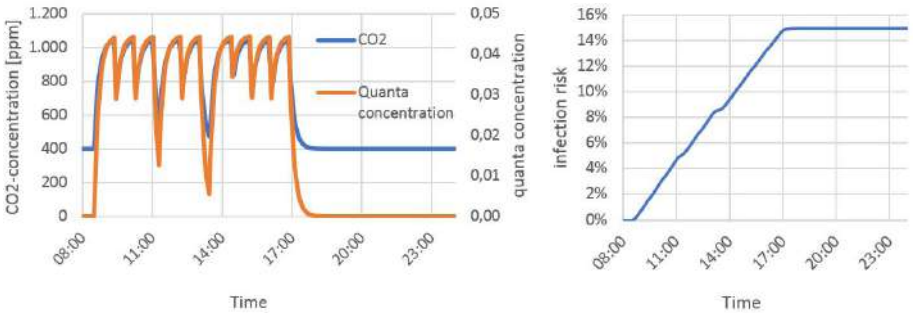

Figure 2. Example course of CO2 and quanta concentration over the day (left) and the increase in infection risk over the day (right) for scenario VCP0S0.

Table 2. Results energy demand for the different scenarios, ventilation type and construction type.

	Old + type A [kWh]	New + type A [kWh]	Old + type D [kWh]	Passive + type D [kWh]
VCP0S0	68,4	48,3	12,8	7,1
VCPBS1	73,9	53,9	29,0	23,5
VBP0S0	83,7	63,5	12,9	7,1
VCPBS0	91,0	70,6	69,5	61,9
VCPAS1	95,1	74,9	37,5	31,7
VAP0S0	105,2	84,7	13,0	7,2
VCPAS0	120,7	99,9	100,0	91,1
VCP0S0	68,4	48,3	12,8	7,1

quanta concentration and infection risk over the day in the classroom (CO2 production: 0.0039 l/s/person). The representation of CO2 concentration is illustrative and also used to check that the model was set up correctly. This was also done by comparing with a stationary situation in terms of virus exposure probability (after 3 hours) at the different ventilation flow rate classes [4]. The difference found was less than 1%.

In Figure 2a, the moments in-between classes and breaks are clearly visible. Figure 2b shows how the infection risk probability builds up over the day. This probability increases consistently for a person who is constantly present in the classroom, assuming that, if students are in the classroom, there is always one student present who is infected.

However, from here on the results are presented relatively because when calculating the risk, there is a relatively large uncertainty in the quanta production. Furthermore, we are interested in a comparison between the cases. The scenario VCP0S0 Type A (Old) was used as a reference, both for energy consumption and infection risk.

Figure 3 shows the overview of how the energy consumption relates to the relative infection risk. This is split up by construction and ventilation type. The dots in the graph, for a given construction and ventilation type, refer to the different scenarios investigated. It is clear that the construction type, for the same type of ventilation system, only affects energy use. For the ventilation system type, besides a clear difference in energy use, there is also a small difference in the relative infection risk for some scenarios. This is the case when purge ventilation is used. In Type D, this is added to the available mechanical flow rate, while in Type A natural ventilation is maximised on this. It is clear from the figure that when using a Type D ventilation system, a similar relative risk can be achieved as for Type A, but at an energy demand that is approximately 75% lower.

CONCLUSION

Of the scenarios studied, scenario VAP0S0 (Type D), with a high basic ventilation flow rate and no purging, appears to score best when considering both energy demand and infection risk. However, scenarios have been studied where the infection risk is lower. It is a difficult trade-off, energy use versus health. It is clear that with a good ventilation system with heat recovery and a high ventilation flow rate, energy consumption can be reduced, while the virus exposure can also be reduced. Besides this lower exposure, a higher ventilation flow rate will also contribute to better air quality in general.

Because the quanta concentration quickly builds up again during a class, the effect of purging during breaks is clearly less when considering the infection risk. Therefore, purging should not be the design principle of a classroom ventilation strategy to reduce infection risk. This should be seen as an additional measure when the ventilation flow rate is not up to date and for occasional situations (emissions). It is better to have sufficient basic ventilation. Purging is then additional.

What risk is regarded acceptable is not stated in this study, hence we have expressed it relatively. Again, this is a consideration to be made by the end-users/responsible parties. A relatively low value for quanta production has been calculated. With a more infectious virus, as we have already seen with the variants of SARS-CoV-2, the quanta production will be higher and thus the infection risk. The question is whether in that case ventilation alone will solve the problem. The starting point will have to remain that basic ventilation must be properly taken care of. A further reduction of the virus exposure can then be achieved with, for instance, additional air cleaning. ■

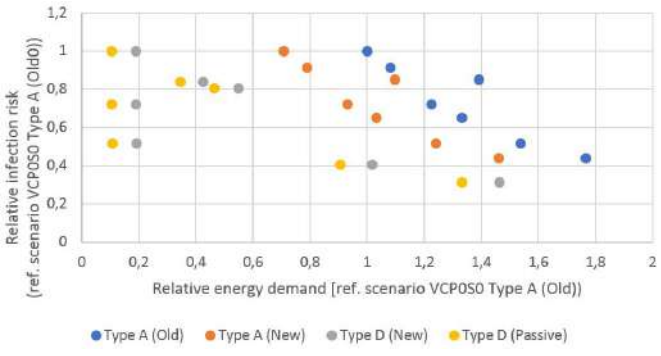

Figure 3. Relative energy consumption versus relative infection risk, split up by construction and ventilation type. The reference case has ventilation type A, with an old construction and scenario VCP0S0, (ventilation class C, no purge ventilation and therefore no purge ventilation).

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Risk of Heatstroke in Residences

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Royal HaskoningDHV

Recently temperature exceedances in residential buildings are gaining attention. Since January 1, 2021, a limit value for overheating of residences has been set under national regulations (TOjuli indicator). A study for the NKWK-KSB program on the risk of high temperatures for the health of vulnerable residents has identified which residences are at risk of temperature exceedances.

VULNERABLE RESIDENTS

This research focuses on vulnerable residents. This can be the elderly, but also people with chronic diseases or overweight are more vulnerable to heatstrokes. However, most studies are based on the 'standard' human being. Research shows that older people are not necessarily colder or warmer, but that their perception is less sensitive [1]. As a result, they are unable to take measures, which puts them at a higher risk of heat stress. Certain diseases can also entail characteristics that make the body less responsive to heat (reduced sweating, higher heat production, abnormal blood pressure) [2].

RISK OF HEATSTROKE

TOjuli is currently used as an indicator of the risk of temperature exceedance when new residences are built. This is determined based on the calculated cooling requirement for the month of July in the NZEB calculation following the Dutch NTA 8800 standard. A weighted temperature exceedance (Gewogen TemperatuurOverschrijding, GTO) is a more accurate method that can be applied as an equivalent of the TOjuli.
In addition to national regulations, it is also important to what extent (vulnerable) residents run the risk of heat stress. The Indoor Stress Index (ISI), with associated survival time (τ_s), depends on the air temperature and relative humidity [3]. The survival time gives the maximum tolerance time before heatstroke occurs (body temperature 40.6 °C). Next, the number of hours of Heat Stress (NhHS) is determined by $\tau_s < 5$ days. Other variations on this parameter are [4]:

- Number of days of heat stress (NdHS): number of episodes during the summer period where during three sliding days:
  - the average of the daily maximal exceeds 32 °C and;
  - the average of the daily minimum exceeds 18 °C.
- Day Degree Hour (DDH): the day overheating intensity between 7:00 - 21:00 when T > 32 °C.
- Night Degree Hour (NDH): the night overheating intensity between 22:00 - 6:00 when T > 26 °C.

TEMPERATURE EXCEEDANCE

With the use of the brochure Example Residences of Agentschap NL [5], it has been established what a typical residence in the Netherlands looks like. Subsequently, a variant study was carried out on thermal insulation, window-to-wall ratio, infiltration, purge ventilation, blinds, Low-E glazing, orientation, and adjacent boundaries. Figure 1 shows the GTO for a standard row house, double-sided gallery apartment, and single-sided apartment. This shows that most residences meet the GTO < 450 hours requirement, except for apartments built after 2005. These residences have more thermal insulation, which makes it more difficult to lose the gained heat. The single-sided apartment has the additional disadvantage that it can only use purge ventilation on one side, which is less effective.
Reducing temperature exceedances is particularly important for new residences and existing residences that are being renovated. Various measures are proven to be effective, of which the result in the living room (where the highest exceedances occur) is shown in figure 2. Limiting solar gain is particularly important as a building-related measure. This can be an outdoor blind, Low-E glass, or an overhang. In addition, many of the exceedances can be reduced by wearing lighter clothing, being less active, and turning on a fan (personal measures).
To get an indication of whether GTO is a good limit value for vulnerable residents, a comparison was made with the heatstroke parameters (NhHS, NdHS, DDH, NDH). Night Degree Hour (NDH) is a key parameter that deviates from

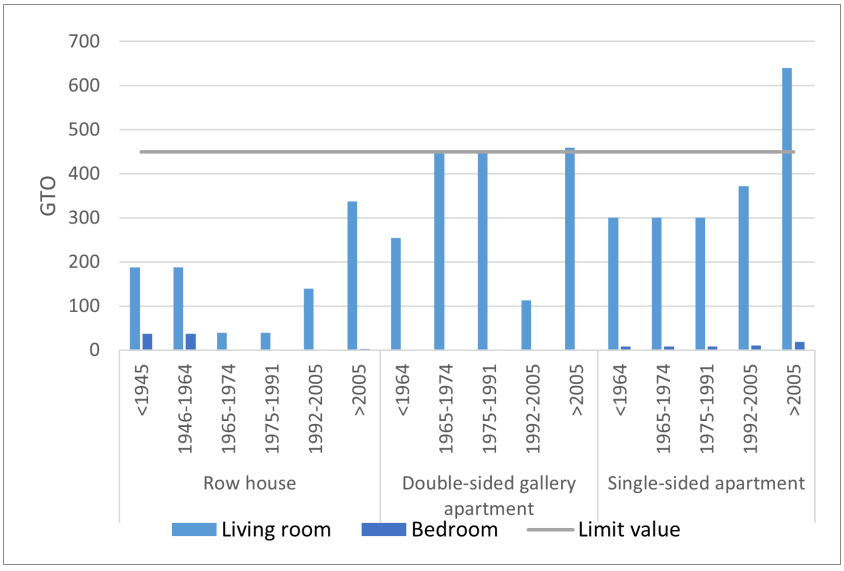

Figure 1. GTO of standard residences in the Netherlands

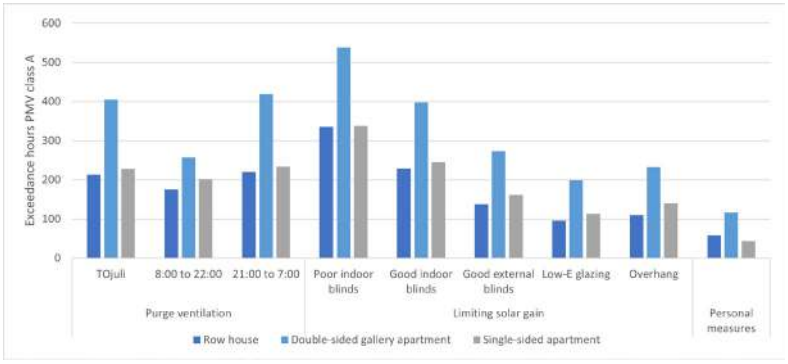

Figure 2. Effect of measures to reduce temperatures in the living room

GTO, which indicates that residences are insufficiently cooled during the night. The body must have the opportunity to cool down so that the heatstroke process is interrupted. The amount of time this takes depends on the temperature [6]. The number of hours of heat stress (NhHS) was always zero for all typologies. The number of days of heat stress (NdHS) and the Day Degree Hour (DDH) varies and gives an indication of the suitability of the residence for vulnerable residents. The research shows that row houses with a low thermal insulation value with good blinds are most suitable to prevent heatstrokes for vulnerable residents. Next to that, it is also important to optimally use purge ventilation to cool down during warm periods.

CLIMATE CHANGE

Meteorologists predict a change in our climate, in which higher temperatures also play a role. In addition, the Netherlands is a highly urbanized country, and the difference between the city and the surrounding area can be more than 5 °C [5]. Due to these two influences, it is expected that temperatures in the future could be much higher than the climate scenarios on which the standard is based. In this study, the effect of various climate scenarios on temperature exceedances in residences is researched. Figure 3 shows the results of the different scenarios, where UHI represents the current temperature in an average city and 2050 is the predicted temperature increase compared to the standard climate scenario.

The results show that the urban heat island effect means that many residences no longer meet the GTO requirement. The risk of temperature exceedances is particularly high in apartments, the most common type of housing in cities. When the temperature increases in the future, no standard residence will meet this requirement anymore. In this scenario, we see that Low-E glazing is necessary to meet the GTO requirement. In addition, good blinds and purge ventilation are important. When considering the good thermal insulation necessary to limit energy consumption, only row houses still meet the GTO requirement.

CONCLUSION

Attention to temperature exceedances in residences is of great importance for the comfort of residents. Now that residences are better insulated and airtight, they cool down less quickly, increasing the risk of overheating. Although insulating buildings is necessary for the energy transition, overheating is a problem for vulnerable residents who are extra sensitive to heatstrokes. Measures such as good blinds and purge ventilation, but also personal measures help to keep the residence cool. These measures are particularly important for residences in cities due to the urban heat island effect and will become increasingly important in the future due to climate change. ■

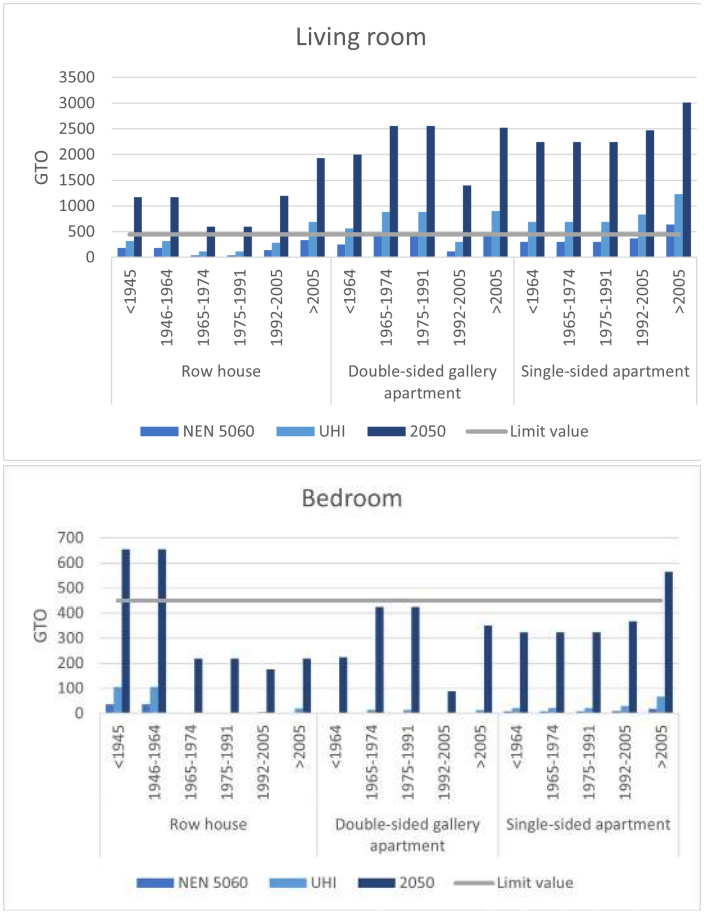

Figure 3. Future scenario GTO for standard residences in the Netherlands.

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Can We Predict Healthy Daytime Lighting for Home Office Workers?

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Dr. ir. M.P.J. Aarts
Dr. ir. J. van Duijnhoven

INTRODUCTION

Since working from home became part of our daily life due to the covid-19 pandemic more focus was created on the quality of home workplaces. The quality of good workplaces consists of several factors such as available work equipment, ergonomic working posture but also lighting. There are certain requirements that lighting should meet related to visual performance such as task illuminance levels but recently there are also recommendations defined for non-visual performance (healthy daytime lighting) expressed in melanopic equivalent daylight illuminance (EDI) [1], [2]. The recommended illuminance level is related to the performed task and additional so-called common context modifiers [1]. For offices, an illuminance of 500lx is required at the work plane when no common context modifiers are applicable. For non-visual performance, a melanopic EDI level of 250lx is recommended during the day in the vertical plane at a height of 1.2m. The level of melanopic EDI depends on the amount of the representation of the blue part (~480nm) of the light spectrum which triggers the photopigment melanopsin [3]. Melanopsin is found to correlate with the production of melatonin which is produced by the body to induce sleep [4]. The α-opic Toolbox designed by the International Commission on Illumination was used to convert the measured spectral power distribution to melanopic EDI and illuminance [5]. With the growing interest in working more from home after the pandemic than before, it is important that also for workplaces at home, lighting requirements are met as well.

This research tried to identify the quality and quantity of the lighting when working from home and in the offices. As an indicator for visual performance, the task illuminance levels were measured while for the non-visual performance the melanopic EDI levels people receive during the daytime when working at different indoor work locations were measured. The main research question was: "To what extent can someone's illuminance levels and melanopic EDI levels be predicted based on location characteristics?". Three sub-questions were formulated to contribute to answering the main research question;

1. "What are the differences regarding illuminance levels and melanopic EDI levels for people with different work locations (e.g., home office and office)?",
2. "To what extent do (home) offices meet criteria for visual performance on the working plane and non-visual performance (healthy daytime lighting) at eye level?"
3. "What is the connection between vertical illuminance levels, melanopic EDI levels and home- and office workplace characteristics?".

METHOD

To answer the research questions an exploratory field study was performed between November 30, 2021 and January 7, 2022. The measurement period consisted of four consecutive days containing continuous lighting measurements, an intake questionnaire to make an inventory of the characteristics of the workplaces, and a logbook to track work locations during the day. Figure 1 presents the study design. Additional static light measurements of the electrical lighting were carried out at the office workplaces

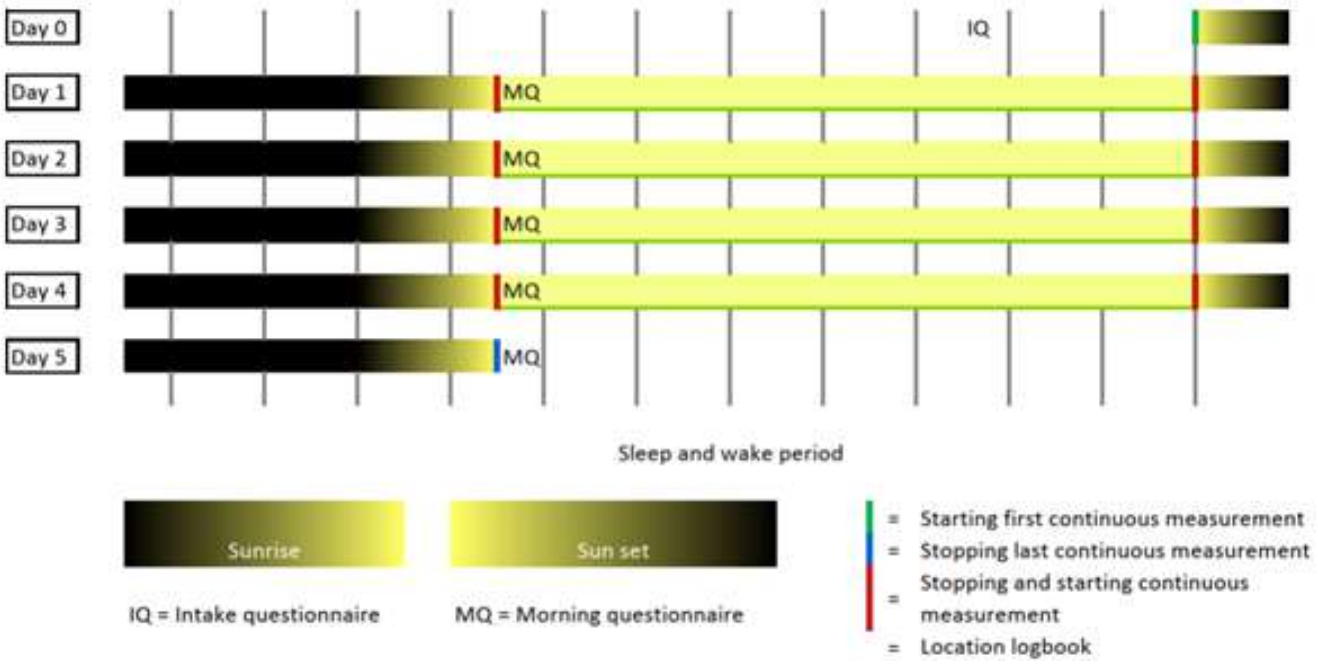

Figure 1. Study design.

Of the participants. The participants were asked to wear the spectroradiometer as a necklace during the entire day.
All measurements have been performed with the NanoLambda Spectrometer XL-500 BLE Spectroradiometer with a range of 10 to 10,000lx. The NanoLambda sensors have been calibrated for the directional response linearity. The directional response of the NanoLambda devices are classified as low to medium quality equipment. The linearity of the NanoLambda meter is classified as medium quality equipment in the range between 10 and 1,000lx and as high quality equipment in the range between 1,000 and 10,000lx.

Figure 2. NanoLambda Spectrometer XL-500 BLE Spectroradiometer (image source: NanoLambda).

In total seven office workers from two different offices in the Netherlands participated. Office A has a lighting installation with the Zumtobel LIREL-L LAY LED of 16W with a color rendering index of >80 and a correlated color temperature of 3000K. Office B has a lighting installation with the Philips Master TL5 HO of 49W with a color rendering index of >80 and a correlated color temperature of 3000K. Two female and five male office workers participated between the age of 26 and 62 years old with an average of 44.43 years. The measured spectral data set was converted into illuminance and melanopic EDI values with the CIE S 026/E:2018 Toolbox [5] and based on the logbook data, all locations and office characteristics were added. For the analyses, only the data that contained working hours between 10.30 – 12.00 (morning) and 13.30 – 15.00 (afternoon) were included. These timeframes were selected based on the average reported work locations and working hours of the participants.

RESULTS & DISCUSSION

The results of this study show that the range is larger and the median value is higher for both the illuminance levels for task performance and melanopic EDI levels for non-visual performance at home, see figure 3.
The minimum for healthy daytime lighting recommended melanopic EDI of 250lx was met 38% of the time when working from home and 17% of the time when working in the office. The amount of time this recommendation is met can be influenced by several factors. For example, the usage of sun shading. Since this has not been tracked over time, its impact can't be related to the results. Another factor is the time of the year. This study was performed during winter when the days are short and the sun's position over the day is low. It is expected that higher values will be found when performing this study during summer.

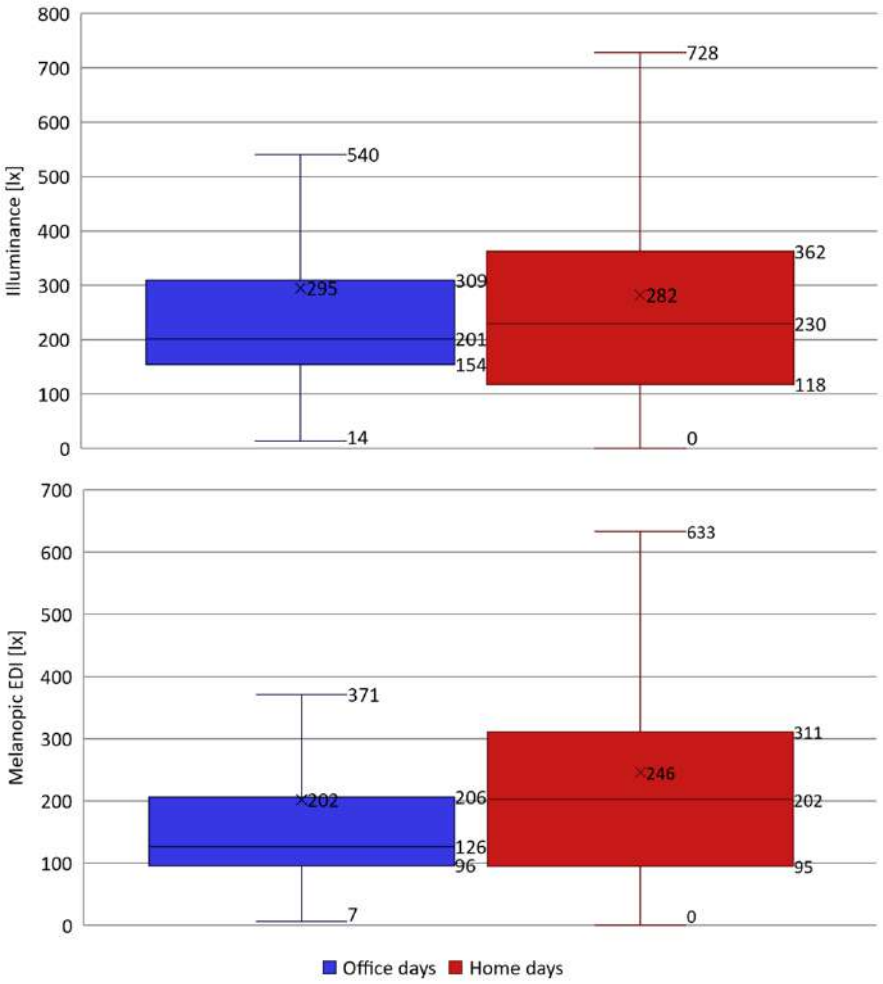

Figure 3. Boxplot of the illuminance and melanopic EDI vertically at eye level of all participants working form home and working in the office.

The minimum illuminance level on the working plane for visual performance of 500 lx is met for two out of seven participants' office workplaces based on static measurements. Only one working place meets the recommended 750lx when the context modifier for age is applied.
The influence of the window distance to the working place can be seen in the results of the home workplace, see figure 4. At home with the increase of the window distance from 0.6m and larger the level of illuminance and melanopic EDI decrease. This can also be seen at Office A from a window distance of 2.5m and larger. The results also show that for some measurements the illuminance and melanopic EDI levels are lower with a smaller window distance compared to larger window distances. This might be caused by the missing information on the window size and position of the sun shading.
A substantiated relationship between illuminance, melanopic EDI, and indoor home- and office workplaces characteristics combined could not be defined based on the study results.
The workplace questionnaire that participants were asked to fill in contained several questions about the characteristics of the closest window to their workplace. Instead of asking for the dimensions, the window type was asked based on figures. This does give an idea of the window type, but the dimensions might have been different for each participant's workplace. If this data was included, it would be possible to verify if there is a relation between α-opic EDI values or illuminances and window size.
The logbook did not ask the participants to keep track of the position of the sun shading and the view direction is not recorded. This information would have been useful in analyzing the relations between workplace characteristics, illuminance levels and melanopic EDI levels as they are expected to influence each other.
Another important piece of information that would have been useful, is the start and stop times of the workday. This was not included in the logbooks which resulted in the uncertainty of the starting and stopping of the workdays when participants worked from home.
So the main reason for not being able to answer the main research question

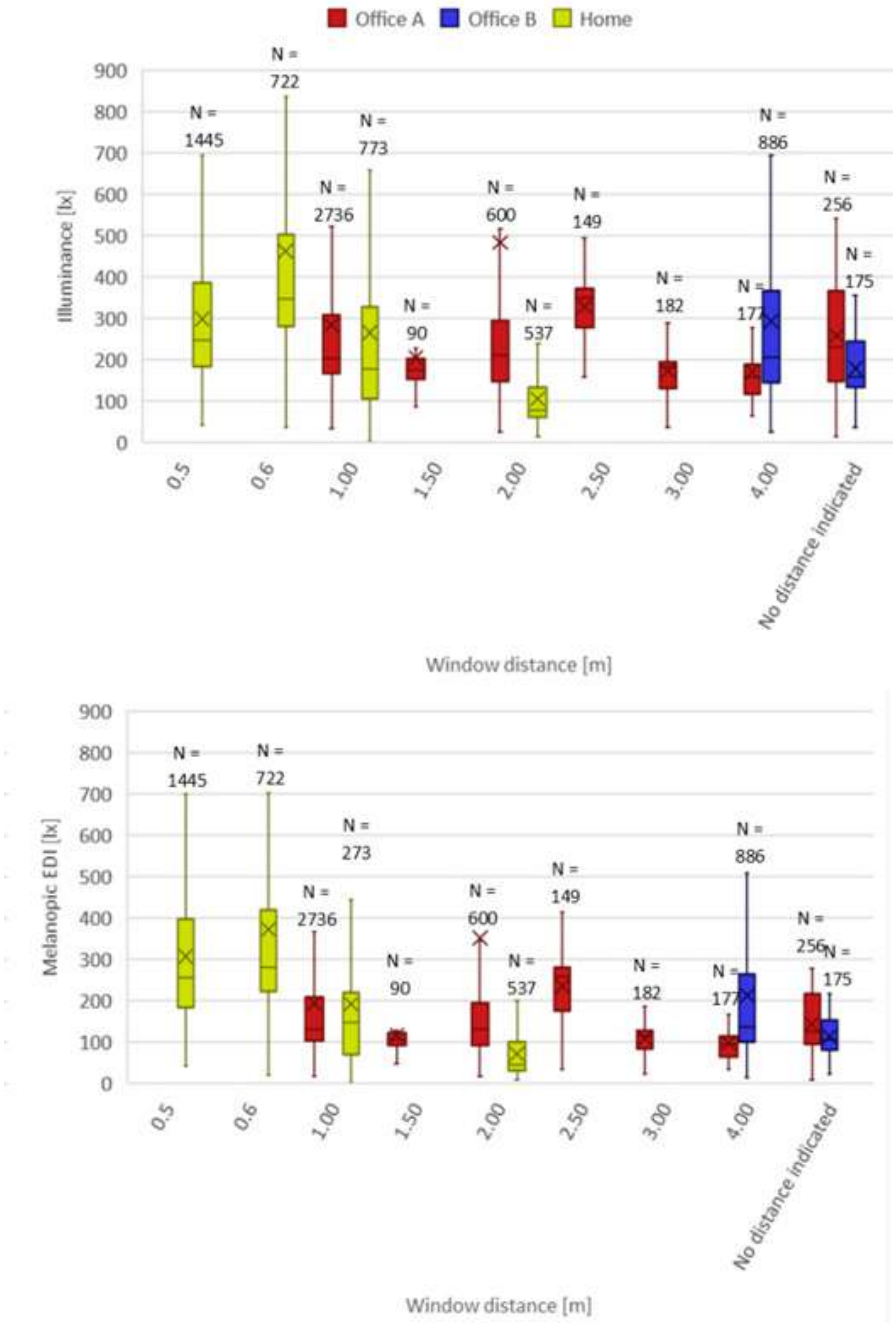

Figure 4. Window distance relative to illuminance and melanopic EDI levels.

is the missing information on window dimensions and position of sun shading, but also the limited number of data due to the low number of participants in this study.

LIMITATIONS

The NanoLambda has a convenient size which makes it easy to use as a wearable. But the device does have some negative aspects too. Because of the low performance on directionality the data that has been collected might have been negatively affected by this. Currently, it is not yet possible to correct measurement values for the directionality. The obstruction of the casing on the sensor might be a considerable influence on the performance. For future use of the NanoLambda where directionality is of importance, it is sensible to verify if the performance of the sensor improves if the depth of the sensor into the casing is decreased.

CONCLUSION

From the results of this study can be concluded that there is a difference in the median value of illuminance and melanopic EDI levels between the home workplace and office workplace. The median is respectively 29lx and 44lx higher at home than at the office even though the office has a larger range. This answers the first sub-question "What are the differences regarding task illuminance and melanopic EDI at eye level between office workers working from home and working in the office?".
The recommendations of 500lx on the horizontal working plane are met for two out of seven office workplaces and only one working place meets the recommended 750lx when the context modifier for age is applied. The recommended melanopic EDI of 250lx for healthy daytime lighting during daytime was met 38% of the time at the home workplace and 17% of the time at the office workplace. This answers the second sub-question "To what extent do (home) offices meet criteria for visual performance on the working plane and for non-visual performance (healthy daytime lighting) at eye level?".
The third sub-question "What is the connection between vertical illuminance levels, melanopic EDI levels and home- and office workplace characteristics?" has been explored and the expectation about the decrease in illuminance and melanopic EDI levels with increasing window distance is confirmed by the results. Other characteristics did not show substantiated connections.
With the results from this study, the main research question cannot be answered for the population of office workers that work at home offices and offices due to the small sample size and missing information, but it can be concluded that in this study the range of illuminances and melanopic EDI values are larger and the levels of illuminance and melanopic EDI are higher at the home working place than at the office. To be able to predict illuminance and melanopic EDI levels at home and office workplaces more participants are needed but also more detailed information about the workplace characteristics in relation to light is required, especially to daylight.

For future studies that make use of the NanoLambda sensors, it is recommended to get a good understanding of the performance of the device. ■

[1] NEN-EN, "NEN-EN 12464-1:2021," 2021.
[2] T. Brown et al., "Recommendations for Healthy Daytime, Evening, and Night-Time Indoor Light Exposure," Dec. 2020, DOI: 10.20944/PREPRINTS202012.0037.V1.
[3] P. Khademagha, M. B. C. Aries, A. L. P. Rosemann, and E. J. van Loenen, "Implementing non-image-forming effects of light in the built environment: A review on what we need," Build. Environ., vol. 108, pp. 263–272, Nov. 2016, DOI: 10.1016/J.BUILDENV.2016.08.035.
[4] C. Papatsimpa and J. P. Linnartz, "Personalized office lighting for circadian health and improved sleep," Sensors (Switzerland), 2020, DOI: 10.3390/s20164569.
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Airflow Visualisation with Acoustic Sensors

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Innovation Handling

Willem van der Spoel

INTRODUCTION

Visualising airflow patterns in-situ can help understanding various flow phenomena in buildings. Traditionally, a qualitative technique using smoke is often used, sometimes complemented with laser illumination to provide a visual picture of the flow in a plane. For quantitative measurements, particle image velocimetry (PIV) can be performed, where the velocity of tracer particles is measured to provide a 2D or 3D vector field of the flow. This technique is usually applied at scales in the order 0.1 - 1 m. PIV at a larger scale requires a tailored line-up of cameras and lasers, which makes the technique time-intensive and inconvenient to apply in practice where information about the airflow in many cross-sections or several rooms may be requested.

For these applications, an alternative technique developed by Innovation Handling in Veldhoven may be used that measures air temperature, velocity with direction, and turbulence based on sound propagation in air [1]. The temperature and velocity are acoustically measured simultaneous, which allows the determination of energy flows. Basically, the method uses a pair of lined-up transducers at a fixed distance that send and receive sound and measures the time required for the acoustic waves to travel from one to the other transducer in both directions. It is fast, accurate, inaudible, insensitive to maintenance, dust, aging, and contamination. Given other state variables such as humidity, pressure, and CO_2-concentration the spatial air velocity vector can be calculated from the measurements in the three separate directions [2].

With a trajectory length of 20 cm, one can measure the air velocity with an accuracy of some mm/s. The complete velocity vector can be reconstructed by combining the information from the three pairs of transducers, usually placed in an orthogonal configuration. A picture of such a probe head is shown in Figure 1. By subsequently placing a set of linearly lined-up probe heads at distinct positions in a plane, the 2D vector field of a steady flow can be obtained. By doing so at several parallel planes successively, the 3D flow field may be reconstructed.

ABT has entered into a partnership with Innovation Handling to apply and further develop this method for spatial indoor climate measurements. In this article, we show a few practical examples where the technique has provided valuable insight into the flow pattern in buildings. In addition, recent and planned developments will be discussed.

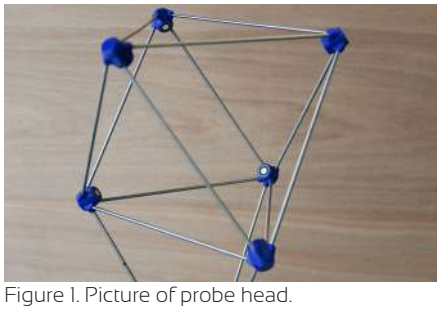

Figure 1. Picture of probe head.

Figure 2. Town hall reception hall. Imposed coordinate system is indicated in red.

RECEPTION AREA TOWN HALL

Employees working at the reception of a town hall, see Figure 2, complained about cold and draft in the area behind the counters. As a first step in the investigation, the airflow field in this area was mapped in 3D. The results did not clearly show suspicious areas with higher air velocities. However, at closer inspection, it was noticed that the airflow pattern at each individual counter systematically showed higher air velocities just above the counter surface, with the airflow directed from the public area towards the employee area. It was speculated that this phenomenon is caused by high heat losses at the opposing glass façade of the public area in combination with cold air infiltration through the tourniquet and the floor heating, resulting in a significant air temperature difference between the area in front of and behind the desk. This was substantiated by an exploratory CFD calculation that indeed showed such a directed airflow over the counter, shown in Figure 3. Advised measures aimed at reducing or at least compensating the heat losses at the façade of the public area.

THEATRE

The phenomenon of spread of viral airborne particles by air movement is well known. A directed airflow from an infected person towards a susceptible person should preferably be avoided. During the lock-down due to Covid-19, a theatre requested an investigation into the airflow field at the grandstand at one of their halls. Figure 4 shows the stand and used measurement pole with the lined-up probe heads. The measurement results in Figure 5 revealed that at the lower part of the stand, strong airflow currents occurred parallel to the seat

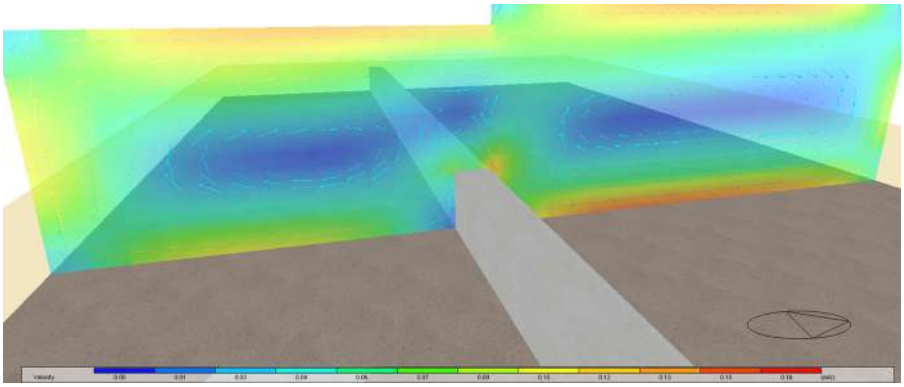

Figure 3. CFD results for air velocity in y-z plane. Employee area is left, public area is right.

Figure 4. Theatre stand with measurement pole.

rows. The theatre was advised to alter the ventilation into a displacement type by supplying the air from below the seats.

OPERATING ROOM

The ventilation in a hospital's operating room is based on a laminar downward airflow from a plenum above the operating table, with a square area of approximately 3.0x3.0 m^2. The area outside the operating area is referred to as the periphery. Here ventilation air is supplied through several swirl diffusers in the ceiling. To support the downward air displacement in the central area, the air supply temperature here is lower than in the periphery. The possibly contaminated air in the periphery should directly return to the ventilation system and should not mix with the downflow in the central area. To avoid such air entrainment from the periphery, as a rule of thumb the difference in air temperature between the operating area and the periphery must be within 1.0 to 3.0 °C. This temperature difference is continuously measured by the control system and subsequently used as a proxy to warn for unfavourable airflow conditions. The exact measurement locations to consider when evaluating these temperatures are not defined.

As part of the investigation, air velocities and temperatures were measured in a vertical plane partly covering both central and peripheral area. Personal was present and several auxiliary equipment was switched on during the survey

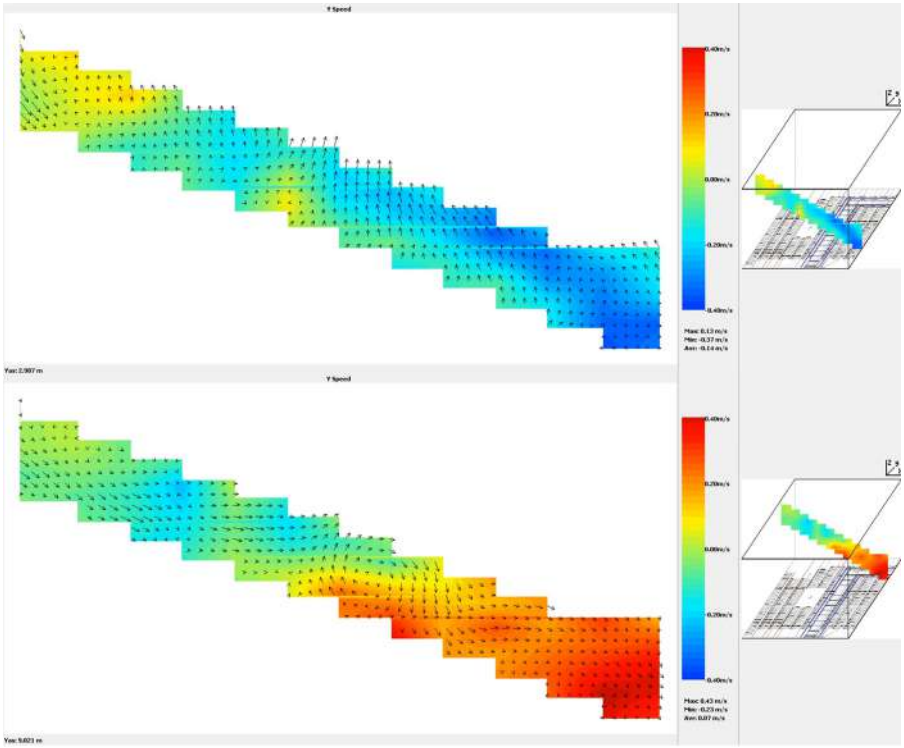

Figure 5. Measured velocity in two vertical planes across the stand. Color legend refers to velocity component parallel to the seat rows. Arrows are projection of velocity vector in the plane.

to mimic a realistic situation in terms of heat production, see Figure 6. The measurement results in Figure 7 show a neat downward airflow in the operating area above the table and hardly any air entrainment from the periphery. When positions below the operating table are disregarded, the temperature differences between the centre of the operating area and the periphery meet the conditions laid down. However, since closer to the ceiling the differences are near 3.0 °C, a false alarm could occur when temperatures would be measured here. The investigation shows that the selection of the control system's temperature measurement locations should be assessed with care.

OUTLOOK

Recently, a new slender probe head has been developed with miniature transducers at a smaller mutual distance of 10 cm, shown in figure 1. The shorter distance comes with a reduced accuracy, but this is well compensated by less disturbances of the airflow field and extended application opportunities where space is confined. In the near future, a revision of the acquisition system will enable a much faster processing of the measured data. Eventually, with a set of probe heads simultaneously positioned on in-plane lattice points, it should enable us to visualise the time-dependent flow field in this plane in real-time. Further developments relate to automating the localisation of the probe heads, allowing a fast three-dimensional scan of the geometry under investigation. The obtained vector field may subsequently be used as an imposed velocity field in particle tracking simulations to gain insight in the dispersion of tracers, dust particles or exhaled droplets. ■

Figure 6. Operating room.

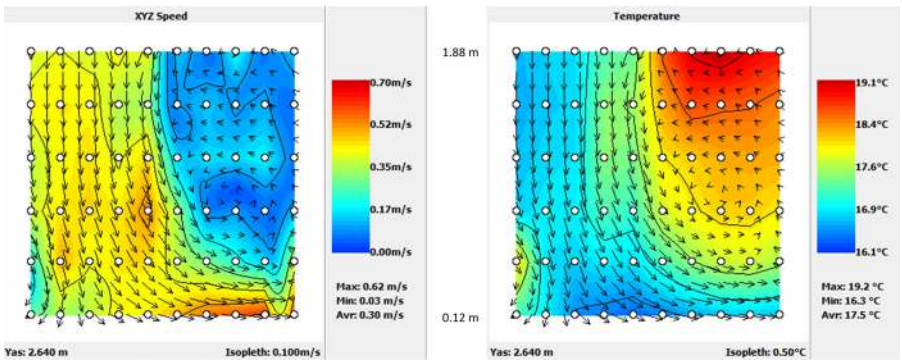

Figure 7. Measurement results in a vertical plane. Left shows air velocity, right air temperature. The operating area is left in each plot, the periphery right. The bottom-left region in each plot is located below the operating table.

[1] Mao, X. (2005). Acoustic techniques for temperature and flow velocity measurements. [Phd Thesis 1 (Research TU/e / Graduation TU/e), Applied Physics]. Technische Universiteit Eindhoven. https://doi.org/10.6100/IR597647

[2] Schaik van W.H.J., Schaik van M.P.G.E (2018). https://docplayer.nl/221147856-Luchtige-aspecten-in-de-bouwfysica.html

ECODAMI: Ecologically Optimal and Sustainable Material for Artificial Reefs

Supervisor
Dr. M. (Marc) Antoun

Authors
R.R.T. (Roeland) in 't Veld
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Roeland in 't Veld

INTRODUCTION

Reefs are large marine ecosystems that are the home for a large variety of species. They are among the most productive and bio-logically diverse eco-systems on Earth. Millions of people depend on reefs as primary food source and for their livelihood. Additionally, coral reefs can support shorelines, by acting as a buffer for severe storms. However, there is a huge problem, the constant severe degradation of reefs around the world. This degradation is both present in coral reefs in the Caribbean near Saba and Sint Eustatius, and in the North Sea in the Netherlands. The continuous degradation of coral reefs in the Caribbean started in the 1980's, due to deceases, the rising water temperature, and hurricanes [1]. In the Netherlands there use to be an abundance of oysters, which was exported to other countries in large quantities. Due to over-fishing, diseases, and destruction of shellfish reefs by fishing nets, they disappeared around the 20th century.

Artificial reefs design can help by acting as a hard substrate for reef development and it has the potential to enhance fish abundance and biomass. These artificial reefs can be made from relatively simple materials including stones, shells, and shipwrecks. However, artificial reefs with more complex shapes are made as well, such as concrete reef domes and 3D printed concrete structures. In a lot of cases ordinary Portland cement (OPC) is used as binder for the concrete [2]. However, the Ordinary Portland cement (OPC) used is not suitable due to its high pH and has a large amount of embodied carbon. The aim of this research is to find an alternative cement, which is durable, has lower CO_2 emissions and can be applied in marine environment for making artificial reefs.

Figure 1. Coral reefs (top) and artificial reefs (bottom)[1].

METHODOLOGY

Three cement types are tested, CEM I, CEM III type B and CSA. Due to their different composition, CEM III and CSA potentially have a lower pH and embodied carbon compared to CEM I. Additionally, 25% of the volume of the CEM III is replace with recycled fines to lower the embodied carbon further and lower the material cost. Furthermore, half of the cement samples are carbonated. Carbonation is a process, by which CO_2 enters the cement through pores in the material and reacts with calcium-hydroxide ($Ca(OH)_2$). This lowers the pH of the cement and as an added benefit stores CO_2 [3]. Several methods (shown below) are used to research the differences between each of the cement types, the effect of seawater and carbonation on the cement types and the effect of the cement on seawater.

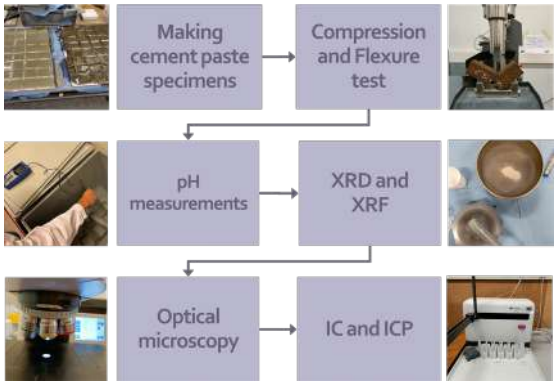

Figure 2. Research methods

CONCLUSIONS

Based on the pH measurements, the seawater surrounding the CEM III and CSA samples have a lower pH, compared to seawater around the CEM I. Carbonation lowers the pH of the cement types, except for CEM I which does not show a clear decrease in pH. The carbonation can have negative impact on the mechanical properties. However, all cement types remain strong enough for making artificial reefs. When observing the samples under the optical microscope, there are no visual signs of degradation due to the seawater. Furthermore, based on the IC and ICP results, there are no signs of leaching of chemicals in the water after 180 days. According to the department of Marine Biology of the University of Applied Sciences Van Hall Larenstein in Leeuwarden, CEM III and CSA show promising results for promoting the growth of marine species. ■

[1] Top photographs: XL Catlin Seaview Survey, bottom left: ReefSystems, bottom middle: Hinatuan Mining Corp & bottom right: Ude van Dongen, Bureau Waardenburg.

[2] Hylkema, A. O. Debrot, R. Osinga, P. S. Bron, D. B. Heesink, A. K. Izioka, C. B. Reid, J. C. Rippen, T. Treibitz, M. Yuval, and A. J. Murk, "Fish assemblages of three common artificial reef designs during early colonization," Ecological Engineering, vol. 157, 10 2020.

[3] K. Didderen, T. "van der Have", J. Bergsma, H. "van der Jagt", W. Lengkeek, P. Kamermans, A. "van den Brink", M. Maathuis, and H. Sas, Shellfish bed restoration pilots Voordelta, Netherlands: Annual report 2018. Wageningen Marine Research, 2018. 1

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			1		2			
	5						9	
				6				
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		8				4		
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We assume you all know the basic sudoku rules, so to make it more interesting we ask you to solve a chess sudoku. In addition to the normal sudoku restrictions, you cannot have the same number within a knights move. A knight moves in an L shape (two over and one across)

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Fire Safety in the Tallest Building in the Netherlands

Author
Arjen de Kort

With the completion of the Zalmhaven Tower last spring, high-rise buildings in the Netherlands reached a new milestone. At 215 metres, the tower is even the tallest (residential) building in the Benelux. But high-rise buildings are complex and have many rules, including fire safety. And because the Zalmhaven Tower towers well above the 'sprinkler limit' of 70 metres, more additional facilities were required, such as an overpressure installation.

De Zalmhaven is a high-rise project consisting of three residential towers in Rotterdam. The complex contains 452 apartments and penthouses, 33 townhouses, a four-storey car park with 456 spaces, offices, commercial spaces and a restaurant. Zalmhaven 1 has 61 floors and a height of 215 metres, making it the tallest building in the Netherlands and Benelux. Construction of the Zalmhaven was in the hands of BAM Bouw en Techniek - Special Projects. In terms of fire safety, the biggest challenges were the sprinkler and overpressure installation.

SPRINKLER INSTALLATION

The sprinkler system in the 215-metre-high Zalmhaven Tower was installed in the residential and commercial areas and the restaurant of the highrise building as well as in the 4-storey car park. A dry and wet fire-extinguishing system was also installed, with dry pipes being chosen for the car park and Zalmhaven 2 and Zalmhaven 3, to which the fire brigade can immediately connect its water supply in case of fire. A wet fire-fighting system with three pumps was installed in Zalmhaven 1.

PRESSURE RELIEF INSTALLATION

The other additional feature to optimise the fire safety of the Zalmhaven Tower concerns an ingenious overpressure installation. Project manager Leon Bik (BAM), who with his team was responsible for fitting the installations into the constructions such as walls, floors, technical shafts and technical areas, explains why this installation was necessary: "The Zalmhaven Tower is subject to more stringent fire safety requirements, because the enormous height increases the time needed to escape in the event of an emergency. And fleeing should, of course, be possible safely."

DE ZALMHAVEN IN KEY FIGURES

- 61 floors (including technical floor)
- Per layer 2 locks at overpressure 50 Pa and a guaranteed air speed over the opened door of 0.75 m/s
- 4 pieces, positive pressrue fans 6.600 m3/h 850 Pa static pressure.
- 4 pieces, exhaust fans 6.600 m3/h 850 Pa static pressure.
- 232 pieces multi-compartment fire-resistant smoke dampers in accordance with EN12101-8.
- 116 pieces of fire-resistant pressure relief dampers.

The importance of safe escape confronted Marc Noordermeer, consulting engineer Fire Safety, Building Acoustics and Building Physics at Peutz, at an early stage of the project. "At the start of the design process in 2014, escape was one of the first aspects advised on. Research was already carried out at that time on how a timely and safe escape could be realised." The outcome led to a recommendation for a pressure relief system for the front portals of the stairwells.

ESCAPE SAFETY

Asked about the importance of a pressure relief system in relation to escape safety, Noordermeer, who was also De Zalmhaven's project consultant for fire safety, building physics and acoustics from 2018-2022, is clear: "Keeping the stairwells over which people escape smoke-free is essential in high-rise buildings. Because more people use the stairwells in high-rise buildings, doors to vestibules and the stairwells will also open and close more often, as well as remain open longer. The risk of smoke in stairwells is therefore also higher, but should be minimised. Both because of safe escape and from the point of view of fire-fighting repression. Pressurising the stairwells is then an option to prevent smoke in the stairwell."

FRONT PORCHES ON POSITIVE PRESSURE

Cooperation with HC TS was chosen for the overpressure installation. Hugo Dorsman, manager Sales & Engineering was closely involved in this project on behalf of HC TS. And although he had experienced many a high-rise project up close, the Zalmhaven Tower proved to be of a different order. Dorsman: "In high-rise buildings, the stairwell is often pressurised in accordance with EN 12101-6. In the case of the Zalmhaven Tower, with its enormous height of 215 metres, Peutz and the competent authority chose to put the front portals on overpressure. All in accordance with the SBR 'Handreiking Brandveiligheid in hoge gebouwen' (Guide to Fire Safety in Tall Buildings). This describes

STAIRWELL OVERPRESSURE SYSTEM

An overpressure system is a smoke control system that keeps the stairwell free of smoke through overpressure. This system ensures that people can escape safely and provides the fire brigade with a protected route of attack.

REGULATIONS

Buildings taller than 20 metres should be fitted with a vestibule/smoke lock.

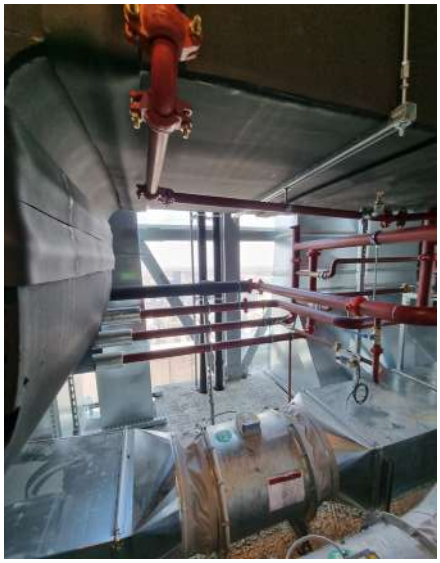
- For buildings between 20-70 metres, an overpressure system can serve as an equivalence instead of a vestibule.
- An overpressure system is mandatory for buildings above 70 metres.
- If the escape route does not comply with the Building Code, an overpressure system can serve as equivalence.

STAIRWELL OR VESTIBULE ON OVERPRESSURE?

With a continuous flow of fleeing persons to the stairwell, a smoke lock offers too little protection against smoke. In this situation, one can also choose to put the smoke lock on positive pressure instead of the stairwell. This increases the safety level of the stairwell.

THE SYSTEM

The overpressure system is generally composed of pressure sensors connected to the control box with frequency regulators. The valves are motorised from the



View from the technical space on the 60th floor, with the admission overpressure fans (bottom center)

Pressurising the vestibule or lock as a similar solution to pressurising the stairwell. The advantage of this is that there is no influence of height and temperature differences that can occur in tall stairwells due to the chimney or stack effect. Overpressurising the locks on the fire floor and ensuring an air flow over the opened door prevents smoke from entering the lock in case of fire. This keeps the entire stairwell free of smoke in the event of a fire, allowing the building to be evacuated safely in the event of a fire."

PRESSURE RELIEF VALVE

But there are more details, Dorsman continues. "To increase the control speed of the system, a fire-resistant mechanical pressure relief valve is fitted at each lock. As soon as there is a fire alarm on a building floor, the overpressure system is activated in the locks on the fire floor. The fire-resistant smoke dampers on the fire floor are then sent open. All other fire-resistant smoke dampers on the other floors remain closed, ensuring fire and smoke separation to the other floors. After the appropriate dampers are opened, overpressure is switched on between the lock and the corridor adjacent to the flats. Also, due to the supply and return of air, the mechanical pressure relief valve is automatically opened, so there is already an air flow between the lock and the corridor. The moment people on the fire floor flee to the airlock, the door to the airlock next to which the mechanical pressure relief valve is located will open. This will close immediately, so the air velocity will now flow directly through the opened door. Also, both the supply and exhaust fans will rev up a little further, so that the desired air velocity of at least 0.75 m/s is achieved. After the door closes, the excess air will immediately flow out through the mechanical pressure relief valve. As a result, the pressure in the lock does not rise too high, so that the door opening force does not exceed the maximum prescribed 100 Newtons."

Fire-resistant smoke damper, in accordance with EN12101-8 multi compartment: when open, on the fire floor during fire

OVERPRESSURE SYSTEM CUT IN HALF

"Halfway up the tower, around the 30th floor, the overpressure system is also cut in two," Dorsman concludes his account of all the details of the overpressure system. "The lower part of the system is supplied and discharged from the ground floor and the upper part from the roof. As a result, we have two completely separate systems and the ducts are up to 100 metres long, which benefits activation and control speed."

Overpressure ducts and fans on the 60th floor (red pipes = sprinkler, also other installations.)

CAN HIGH-RISE BUILDINGS BE FIRE-SAFE?

High-rise buildings are now also an irreversible trend in the Netherlands. But with the Grenfell Tower fire in mind and a government that is lagging behind when it comes to laws and regulations, experts regularly express concerns about fire safety. Concluding, then, the question for Bik, Noordermeer and Dorsman is whether high-rise buildings can be fire-safe?

"Yes it can," Bik kicks off. "With the right plans and taking into account the requirements set in other countries where high-rise buildings have been built for a long time, we can also achieve this in a fire-safe way in the Netherlands." Noordermeer adds: "There is a huge shortage of affordable housing, and cities like Rotterdam and The Hague therefore face a very large densification challenge. To meet this, high-rise buildings will be realised even more in the coming years, and this can most certainly be done in a fire-safe way." Dorsman agrees and concludes: "By jointly following the regulations regarding fire safety and opting for an integral approach, high-rise buildings can certainly be built in a fire-safe manner. It is precisely with high-rise buildings that so many additional facilities and certifications are needed, that in my view these buildings are even safer than buildings that just meet the requirements of the Building Code. ■

This article was previously published in Brandveilig.com, issue 3, September 2022.

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The long awaited Lustrum Gala finally took place on the 19th of March 2022, at the gorgeous venue of Het Ketelhuis. Everyone looked exceptionally fine in their smokings and dresses and had the time of their lives. It was truely a night to remember.

We'd like to thank our lustrum partners (Johnson Controls, bba binnenmilieu, NVBV and LPB|SIGHT) and the attendees of all our lustrum activities!

Yours sincerely,
The 5th Lustrum Committee of s.v.b.p.s. Mollier

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