Academic year 2018 - 2019 #1 | December

MOLLIER

Study Association
Building Physics and Services

INSIDE INFORMATION

MOLLIER | UNIT BPS | STUDENTS | ACTIVITIES | MEMBERS

Improvement of Vertical Axis Wind Turbines using Boundary Layer Suction

ir. E.M. (Marissa) Vos

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TRANSITION TO GASLESS BUILDINGS STILL HARD WORK IN 2018

Foreword

Marc Tavenier

Dear reader of this amazing magazine,

With great honor, I present to you the first edition of this year's INSide Information for the year 2018-2019!

For our new readers, this is the biannual magazine of the study association Mollier, in collaboration with the Unit Building Physics and Services of the Eindhoven University of Technology. This year, I have the pleasure of serving as the Chairman of the study association.

This edition will feature interesting articles with an icebreaker by a new student, an alumnus at work, recently completed graduation projects, an introduction to the new board of Mollier, the Mollier activity calendar and more. You can also read about our sponsors and their projects in the professional field!

In addition to publishing the INSide Information, this year, Mollier will organize several excursions, lunch lectures, workshops, a study trip, and last but not least, a renewed version of the Meet & Greet! This event will be combined with a BPS exhibition to make it a week-long BPS extravaganza! This exhibition is still in its beginning stages of planning, but will most likely take place in March 2019, so save the date! The main intention is to bring industry and academics under one roof, and provide a platform for the demonstration of the various innovations and undertakings of the Unit BPS. We would love for you to join us at these activities!

Above all, I would like to thank the INSide Committee for their efforts that made the publication of this edition possible.

Lastly, I hope that this is an interesting read for you readers, and I look forward to seeing you around at our activities!

Yours sincerely,

Marc Tavenier
Chairman, 23rd board of s.v.b.p.s. Mollier

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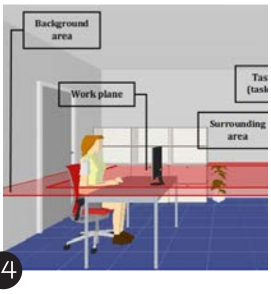
This INSide



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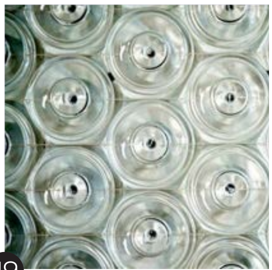
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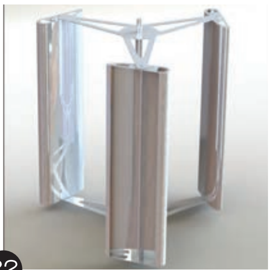
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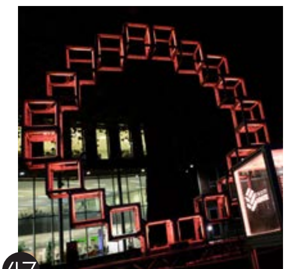
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MOLLIER & MEMBERS

BUILDING PHYSICS & SERVICES

COMPANIES

Introduction to the 23rd Board of Mollier

MARC TAVENIER, CHAIRMAN

Hey my fellow BPS-er, I'm Marc Tavenier, 23 years of age and happy to tell you that this year, I will be the Chairman of Mollier! In my earlier years, I always wanted to be an architect, just like my uncle. But, as more of you probably have experienced, I found out that architecture was not to my liking, and I preferred the more technical aspects of the built environment. I did my bachelor in Building Engineering at the Avans University of Applied Sciences in 's-Hertogenbosch, where I specialized in Building Technology. Since I felt like I could do more than just my bachelor, I decided to do a masters at the TU/e in the field of Building Physics and Services. This field I thought to be the most interesting because, in my opinion, it relates closely to my bachelor.

Besides academics, I work one day a week at a building physics and services firm to acquire some experience in the field. But also, one weekend a month, I work as a supervisor at a company that provides weekends and vacations for kids with a developmental disorder (autism, ADHD, ADD, etc.). In my spare time I sometimes have left, I play the piano, play around with computers and gadgets and work out.

I hope that this year I can make Mollier even better than it already is. My focus will mostly be on getting not only Mollier, but the entire BPS study on the map to strengthen Mollier's more distant future. If you want to get to know more about me, please do visit me and/or the other board members on Floor 5, where we usually work on either Mollier related things or are (trying to) make progress on our master's degree!

MEGHANA KULHALLI, SECRETARY AND COMMISSIONER EDUCATION

Hello, I'm Meghana Kulhalli. I am 24 years old and I come from the South Indian city of Bangalore. This was also where I studied to become an architect in my bachelors. Having worked in architectural studios during my studies and thereafter, I realised there was a need for architects to also have a more strong, technical foothold in the built environment. There on, I started my studies at the Unit BPS of the TU/e. I am now in my second study year. How time flies!

During this past year, I have tried to keep myself busy with an active student life. From designing installations for a sustainable home with student team VIRTUe for the Solar Decathlon in Dubai, co-organizing the Mollier study trip to Chicago, to being in the editorial team of this very magazine- I have been quite an active member of Mollier. Having picked up some Dutch, some decent cycling skills and a palate for some cool brews, I like to think I have integrated well into the society with its *gezelligheid* in the Netherlands. I even went skiing and ice skated for the very first time! Needless to say, I have thoroughly enjoyed my time here! So when I had an opportunity to serve on the board, of course I said yes!

I like to travel and read in my free time and I thoroughly enjoy cooking! I also love writing, though I don't do it enough. From first writing the Icebreaker as a new student to now writing an introduction as a board member, this year-long journey has been one of the most interesting, exciting, inspiring and uplifting times of my student life! As I now take up my new responsibility as the Secretary and Commissioner of Education in the board, I am ready and all in to make the study and the student life more exciting for everyone in the Unit!

DAAN VAN ROOIJEN, TREASURER

Hello, My name is Daan van Rooijen, 23 years old. I come from a small city named Wijk bij Duurstede located south of Utrecht. Here, I completed my HAVO degree and that is when I noticed that I enjoyed mathematics and physics the most. So I searched for a education which included both subjects and I eventually ended up choosing Architectural Engineering at the Hogeschool Utrecht. Nearing the end of the study, I was split between two specializations either Building Physics or Structural Design. During my internship at Nieman, I decided that I wanted to continue with building physics, as it was an easy step to also do my graduation project with them. After graduating, I felt that it was too early to start working full-time and I still really enjoyed studying. Since I graduated halfway through the school year, I needed to wait half a year for the pre-master to start. Hence, I ended up working for half a year which I enjoyed, and it also further enforced my decision to continue studying.

In my free time, I enjoy playing games with friends. It could be either board, card or computer games - I'm pretty much always up for anything. I'm also teaching myself to play the piano, and I also really enjoy reading.

During my first year at the TU/e, I wasn't very involved with Mollier. I went to a couple of activities, but I was more focused on finishing the premaster and passing courses. Since the few activities I did go to were a lot of fun, I decided that I had to become more active. So this year I will be fulfilling the role of Treasurer in the 23rd board of Mollier. If you wish to talk to me, just come by and find me on Floor 5 of the Vertigo building. You will find me there most workdays.

WESLEY VAN DER SOMMEN, COMMISSIONER ACTIVITIES

Hi everyone! My name is Wesley van der Sommen and I am 24 years old. I was born and raised in Veldhoven and only recently moved to Eindhoven. Ever since I started my HAVO education, I was sure I wanted to become an architect. After the HAVO, I went on to study Engineering at the University of Applied Science in Tilburg, which is where I got an idea regarding the kind of work architects do. This is when I changed my mind and started focusing on building physics.

Eventually, after completing my study at the University of Applied Science, I was not ready to work yet. This is why I started studying in Eindhoven. Doing the master Building Physics and Services means that you come into contact with Mollier one way or another. I liked the nice people of Mollier and the many activities they organized, so I became more and more involved in the study association.

Last year, I was asked if I might be interested in being the board of Mollier. Since I was already active and enjoyed the time I spent with the people in the association, I decided to become the new Commissioner Activities.

Life without Mollier is hard to imagine, and I am happy to be a part of this amazing association! Besides my studies and Mollier, I like to go cycling occasionally and travelling the world is something I can't get enough of!

Oh, and before I forget! Feel free to join us in our educational activities and leisure throughout the year!

MARGO VAN DEN EIJNDE, COMMISSIONER EXTERNAL RELATIONS

Hello! My name is Margo van den Eijnde and I'm 23 years old. I grew up in Beek en Donk (a small village close to Eindhoven) and since I started my premaster, I moved to Eindhoven. I did my HBO at the Avans University of Applied Sciences in Tilburg. During my graduation there, I got more enthusiastic about the subjects of Building Physics and Services. So after I graduated, I started my premaster BPS last year at the TU/e. This year, it is time for a new challenge so I will, together with Stephen Abraham-Reynolds, fulfill the function of Commissioner External Relations of the 23rd board of Mollier.

After joining the studytrip to Chicago last year, I got more involved and enthusiastic about Mollier. I decided to join the board because I wanted to get to know more people not only within Mollier, but also in the work field of BPS.

In my free-time, I like to make music. I play the saxophone in different bands and I also hang out with my friends over there. I also have some hobbies which I want to do more often, like working out or travelling, but unfortunately, these things do not fit in my current (student) lifestyle.

I hope to learn a lot during my time as a board member, in both my personal and professional skills. Besides that, I am really excited about this upcoming year with a lot of activities and I would like to get to know you all a bit better.

STEPHEN ABRAHAM-REYNOLDS, COMMISSIONER EXTERNAL RELATIONS

My name is Stephen Kofi Obo Abraham-Reynolds but you can call me Steve (not Stefan please). I am a 27 year old *"Rotterdammer"*, but I moved to Eindhoven with my girlfriend in 2016 to start the master Building Physics and Services at the TU/e.

After a long obsession with building design, mostly designing and building scale models in Duplo, Lego, Mechano in my pre-teens, studying Architectural Engineering at the Hogeschool Rotterdam was a natural choice. At the HRO, I specialized in Project Management and Sustainable Building Design. My graduation project focused on the performance evaluation of green roof integrated PV systems. In the process of validating my model with an experimental set up, I fell in love with building physics.

Just after graduation, I started working as a freelance Technical Draftsman and assisting the tutor at the SUS-Atelier of the HRO. A year later, I switched jobs and started working in a commercial role with a contracting company. I learned a lot, but ultimately, I missed the engineering. So I said goodbye to Rotterdam and hello to Floor 5 of Vertigo at the TU/e in Eindhoven.

As a board member, I hope to further develop my skillset, get to know as many (ex-)members and partners of Mollier, and leave a legacy for the years to come! ■

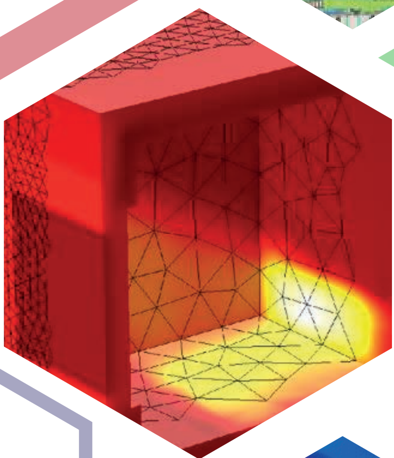
MOLLIER
Study Association Building Physics and Services

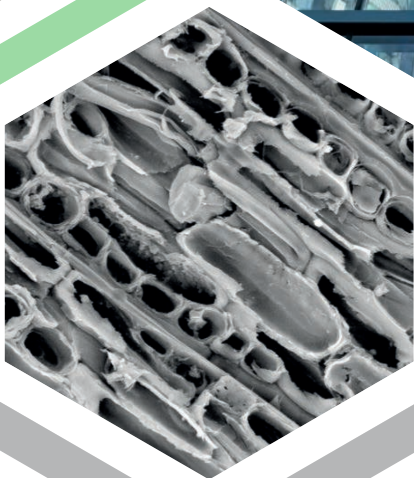
Innovation Week

An Exhibit of Developments in the Built Environment

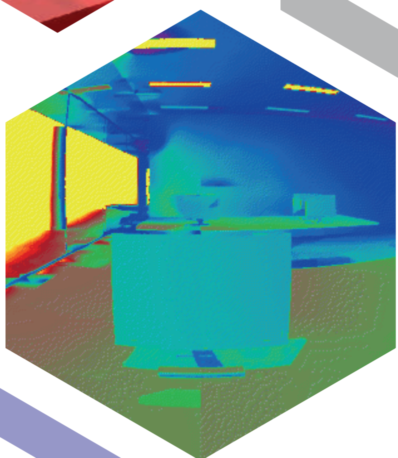
In collaboration with Unit BPS, Mollier is organizing an innovation week to showcase the research and development in the field of Building Physics and Services. By bringing industry and academia together under one roof, we look forward to a valuable learning experience for everyone in the Faculty!

Acoustics
Lighting
Building **Physics**
Materials
Building **Services**
Performance





Wanted!
Ideas, innovations, projects, research and technology for display!
Write to us at
exhibition@mollier.nl



11th - 24th March 2019
Vertigo Floor 1
TU/e Campus

TU/e
EINDHOVEN UNIVERSITY OF TECHNOLOGY

Mollier Activity Calendar

MEET THE BOARD DRINK

To break the ice, the 23rd Board of Mollier organized a Meet the Board Drink on the 3rd of October, in the very festive purple party tent! The members got a chance to interact with the new board in an informal environment, enjoy a few beers and snacks. The members were also encouraged to find a committee of their choice to serve on for the year. The outdoor fun did attract some welcome attention towards the board! New members signed up with us, which made it a roaring success!

START ACTIVITY

The weekend of the 19th to the 22nd of October, Mollier organized the Start Activity of 2018 to kick off the activities of the year! The committee set out the activity to be the best Start Activity of Mollier EVER. Friday afternoon we drove out to Bergkamen, a village close to Dortmund. Most of us arrived around 7 PM, so we made ourselves some nice curry that we consumed while being overloaded with beautiful disco lighting. After dinner and the customary shot of Jäger, we had a nice night with some chats, beers and most of all, lots of 'gezelligheid'.

The next day, we were up quite early, so we could leave to the first activity for which we had to bring our swimming suit. We drove to the AquaMagis, a big indoor swimming pool where we had a nice day of going down slides, waddling in pools and chilling in bubble baths. On the way there, it turned out that the German police had made a lot of snappy shots. That evening, we played some Mollier special Werewolves of Millers' Hollow, stresspong and card games. On Sunday, we visited Zeche Zollverein, a huge coal mine from the 1840s that is now a UNESCO World Heritage Site. After that, we went to Alpincenter Bottrop to go down some slides on pieces of wood as everyone picked skiis and snowboards and had a gala time. While some of us enjoyed the food and banter, Daan unfortunately broke his wrist and had to go to the hospital. After some glorious falls and laudable stunts, everyone had their share of fun, making the Start Activity ta grand success!

SUSTAINABILITY DESIGN CHALLENGE | ROYAL HASKONINGDHV

Five groups which had four members of Mollier along with one RHDHV employee worked on proposals to make the legendary PSV Stadium more sustainable. Over a period of 2 weeks, the teams conceptualized some ideas, some technical interventions, some architectural modifications, but all in the interest of sustainability. It was presented to a jury consisting of RHDHV employees and a representative from the Municipality of Eindhoven. The winning team enjoyed a luxurious 3-course dinner at 'De Verlenging' in the PSV Stadium!

OCTOBER

GLOW GOLF

On the 14th of November, Mollier went on a glow in the dark adventure. In the middle of colorful animals, various themes and obstacles, members of Mollier tried to get a ball in a hole using a long stick (sometimes called "Mini-Golf"). In each group, with some fair amount of luck, the balls were putted into the holes, although some missed the target and hit some other team members instead. All in all, everyone had a lot fun, and some of us continued the evening at Stratumseind for a drink together, as a nice closure to an adventurous evening!

LUNCH LECTURE #1

The first lunch lecture of the year was kicked off by lectures from Voort and Kuijpers on the 20th of November. Ex-Mollier members presented their experiences in their transition from their student lives to professional lives in a humorous and relatable style. After devouring some lip-smacking delicious sandwiches, members had the chance to get an insight into the company and their projects, and also ask questions regarding responsibilities, expectations and the work environment. The large turnout was also a great motivation for the board to keep going! It also was an opportunity for the old members to come say hello to Mollier since their graduation!

BOUWKUNDE BEDRIJVENDAGEN CAREER EVENT

The career event at the annual Bouwkunde Bedrijvendagen was held on the 21st of November. Mollier led two tours visiting the stands of companies that are of interest to students of BPS. The Building Physics and Building Services tours were helpful in giving students a peek into the working world of BPS. The companies gave a short overview regarding the future career opportunities like internships, part-time jobs and graduation projects. Besides, it was also a great opportunity to talk to old Mollier members to hear about their journey in the business world!

CAUBERG-HUYGEN PARAMETRIC DESIGN CASE STUDY

In collaboration with Cauberg-Huygen, Mollier organized a parametric design case study which involved exploring the feasibility of building the Pontsteiger on Mars! With the use of parametric tools like Grasshopper, Ladybug and Honeybee, groups of Mollier members showed off their parametric design skills (or lack thereof). Over lunch, we learnt more about the various applications of these software in daily professional work of the company which inspired many to take more interest in the subject. Everyone presented their case studies at the end of the day. Thereon, we headed to a cafe to talk more about the company, their projects and just casually chatted over some drinks and snacks. It was a fun and inspiring day which would not have been possible without the cooperation and enthusiasm of everyone at Cauberg-Huygen!

RICHARD'S BIRTHDAY DRINK

After a series of educational activities, Mollier decided to change it up a bit. In memory of our father Richard Mollier's birthday, a drink at the SkyBar! was organized in celebration! Members had an opportunity to stand next to their idol on the 30th of November for a picture, for the first time in the history of the association! Some beers were drunk, cake was eaten in an overall fun environment. Instagram and Snapchat posts were in abundance! All in all, a grand celebration ensured everyone was in good spirits for the upcoming holiday season!

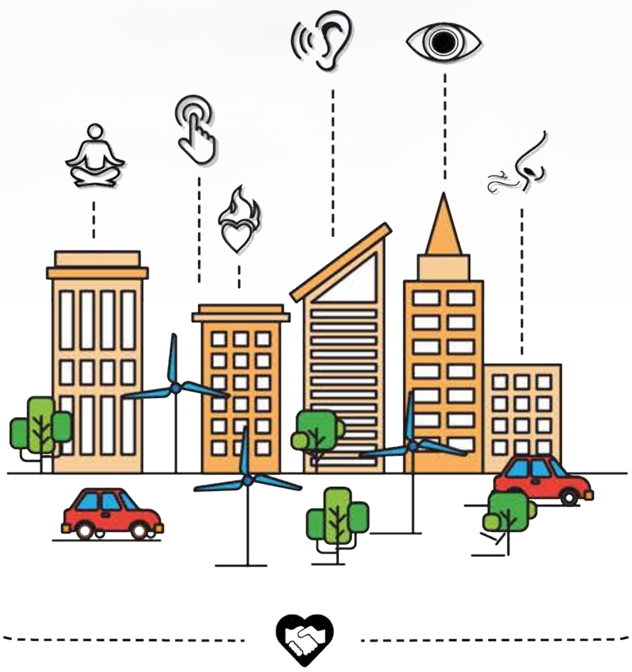
NOVEMBER

EXPERIENCE ENGINEERS

WANTED!

WIE ZIJN WIJ

Wij zijn DPA Cauberg-Huygen. Onze 120 ingenieurs bundelen dagelijks hun krachten en werken samen met onze klanten aan de uitdagingen van morgen. We zijn een onderscheidend ingenieursburea dat net even anders aankijkt tegen de uitdagingen waar wij als samenleving voor staan. Uitdagingen zoals klimaat-verandering, uitputting van grondstoffen, verduurzaming, digitalisering, vergrijzing en verstedelijking hebben namelijk impact. Impact op hoe wij ons voelen, bewegen en manifesteren. Op hoe wij de wereld om ons heen ervaren.



WIE BEN JIJ

Jij kan niet wachten om je kennis uit je studie eindelijk in de praktijk toe te passen. Iemand die graag zijn steentje bijdraagt aan de toekomst van de gebouwde omgeving. Als experience engineer zorg jij er samen met je team voor dat gebouwen veilig, comfortabel en toekomstbestendig zijn voor de eindgebruiker. Wij vinden het belangrijk dat iedereen bij ons in zijn kracht staat, van jong tot oud. Vakinhoudelijke kennis staat daarom net zo centraal als jouw persoonlijke ontwikkeling. Klaar om verder te groeien? Bel, mail of nog leuker... kom gewoon eens langs voor een kop koffie om de mogelijkheden te bespreken.

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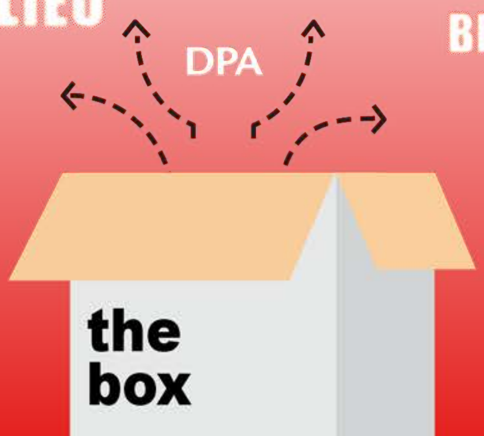

Probabilistic Approach of RSET for Bedridden Building Occupants

Author
ing. B. (Bram) Dorsman

Supervisor
R.A.P. (Ruud) van Herpen MSc. FIFireE

INTRODUCTION

Evacuating building occupants who are bedridden is a difficult time-bound task because these occupants need help evacuating. At least two assistants need to be available to guide the bedridden building occupants to a safe spot. This means that with a minimum capacity of two assistants, only one bed can be evacuated at a time, which results in a longer Required Safe Egress Time (RSET), i.e. a longer time is required for the occupants to evacuate to a safe area.

In research, the chance of a successful evacuation is expressed as the Available Safe Egress Time (ASET), i.e. the time that is available before the circumstances make it impossible to evacuate, minus the RSET. In multiple reports, an ASET-RSET ratio is determined for different circumstances, for e.g., for a varying occupant density or for a case study in a supermarket. However, no report is known of a probabilistic calculation of the RSET-ASET for the evacuation of bedridden occupants.

METHODOLOGY

The goal of this research was to calculate the probabilistic ASET-RSET for a bedridden occupant when a defend-in-place concept is executed. This concept means that only the room where the fire starts will be evacuated, while the bedridden occupants in the adjacent rooms will stay in their place. For this concept to work, the adjacent rooms must not be affected by the fire in such a way that the air quality or heat gets above or below pre-set limitations.

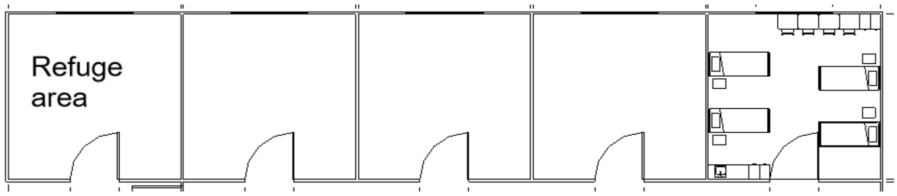

Figure 2. The lay-out of the case study

The air quality and temperature was obtained by simulations run by Pathfinder and CFast. Figure 1 shows the scheme of the used methodology to calculate the RSET and the ASET. CFast is used to calculate the detection time of the fire. This detection time is implemented in Pathfinder, giving the RSET and the time slots that the doors of the burning room are open. The latter information is then put into CFast, which calculates the ASET. Using data derived from [1], the failure probability based on the RSET is determined.

Figure 2 shows the layout of the case study, based on the dimensions given by [2]. As can be seen, there are four bedrooms and one refuge area. The room where the fire starts is situated on the far right. In the study, when the fire starts , two assistants evacuate the four bedridden occupants in the room to the refuge area. This simulation has been done twice- one time the mattresses are made of latex, the other time the mattresses are made of polyether. This is done to be able to evaluate the possible differences between the two kinds of mattresses on the ASET-RSET.

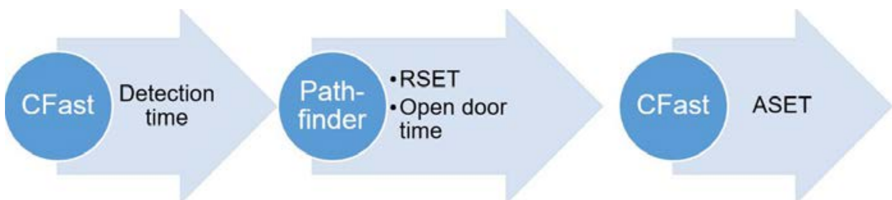

Figure 1. The scheme of the methodology to calculate the RSET and the ASET

In order to calculate the probability of the RSET, the variances of multiple variables, the detection time, the uncoupling time of the bed and the walking speed is simulated.

RESULTS

The main result of this research is that in both simulations, only one occupant could be evacuated in time using a latex mattress. In simulations with a polyether mattress, no evacuations were possible in time. However, in both cases, the adjacent rooms had air quality which remained within the pre-set limitations.

The probabilistic RSET has been calculated, however, more research has to be conducted to give meaning to the probability with which the occupants can be evacuated.

CONCLUSION

Since only one occupant could be evacuated, a conclusion can be drawn that single-bedrooms for bedridden occupants are, in a fire situation, more safe. Also, when having a choice between a latex or a polyether mattress, the first option increases the chance of survival compared to the latter option. However, in both cases, the defend-in-place was successful.

Further research has to be carried out to validate these results. It should contain the pre-movement time, and the effect on tiredness and panic on the RSET. There is also the need for more research on the probabilistic approach of the ASET, to be able to calculate the probabilistic ASET-RSET. ■

[1] Strating, N. (2013). Evacuation of bedridden building occupants, 67

[2] Idema, W. J. (1995). Ruimte rond (grotere) bedden. Report STAGG-Studiegroep, 94.

Correlations between Daylight Quality Aspects in Offices

Supervisors
ir. T.W (Thijs) Kruisselbrink
prof. Dr.-Ing A. (Alexander) Rosemann

Author
F. N. (Nikou) Nikoudel

INTRODUCTION

Daylighting is an effective factor to achieve comfort in office buildings, as it contributes to the visual and thermal comfort and productivity of occupants. Successful daylighting design should guarantee a sufficient quality of light [1]. Daylighting quality in buildings deals with user satisfaction from daylighting, the amount of light for a task, and the degree to which lighting hinders the individual from performing a task [2].

Visual performance and visual comfort are two factors which represent aspects of daylighting quality. Visual performance is an objective matter representing the ability of performing a task. In this research, the visual performance is indicated by the illuminance and uniformity on the task area. Visual comfort is a subjective matter affected by the degree of perceived discomfort glare - a sensation of annoyance caused by viewing a light source directly or a reflection of the light source from a specular surface without impairment of the ability to see. Daylight Glare Probability (DGP) is a way to evaluate the discomfort glare. This research focuses on measuring the daylighting quality and the relation between the different factors representing it.

METHODOLOGY

The daylighting quality is impacted by the design of windows in the buildings and their orientation. Two different window configurations – small and large – are considered in a standard South-oriented office room located in Eindhoven, the Netherlands. Two task areas are positioned near the windows, and a third one is located at the back of the room, perpendicular to the window. To study the daylighting quality, computer simulations using Relux-Pro are carried out during working hours on three different days: June 21st, September 21st, and December 21st, representing the seasonal variations throughout the year. Measurements are done on several reference planes at work and eye level, at the height of 0.75m and 1.20m respectively (Figure 1). Quality parameters such as illuminance level (horizontal and vertical), illuminance uniformity, and simplified daylight glare probability (DGPs) are measured and the relations between them are analyzed.

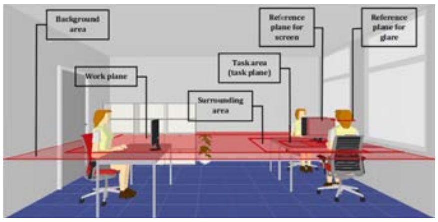

Figure 1. Reference planes at work plane level and at eye level

RESULTS

Increasing the average illuminance on the work plane reduces the illuminance uniformity, meaning that a good uniformity does not guarantee a sufficient illuminance level. The uniformity is higher when both direct and indirect daylight are considered. Moreover, it is observed that in addition to sun elevation angle, window configuration can impact the uniformity. Figure 2 indicates that uniformity and its trend related to the illuminance of task areas near the window (Desk 1 and Desk 2) depends on the size of the window (in this setup).

In office spaces, reflection of light from different surfaces causes glare and affects the visual performance. Thus, the relations between the DGPs and illuminance on the task area, on the monitor and at eye level are studied. The results indicate that although the illuminance on task area and monitor can cause glare, the correlation – in this case study – between illuminance and glare on those surfaces is not very strong. That is, a higher horizontal illuminance at the eye level or at the work level does not necessarily cause higher DGPs. In other words, only the amount of vertical illuminance reaching the eye matters for the glare. However, there are cases – in our study for a person sitting at the end of the room perpendicular to the window – where a linear relation between DGPs and horizontal illuminance at the eye level is observed as well, which is not the case for other users.

CONCLUSION

Some daylighting quality aspects have strong correlations between each other. For e.g., horizontal illuminance and uniformity, vertical illuminance and glare. Some barely show a relation – for e.g., horizontal illuminance and glare, and vertical illuminance and uniformity.
Depending on the position and quality aspects under study, different users in the same office space could experience different daylighting qualities. ■

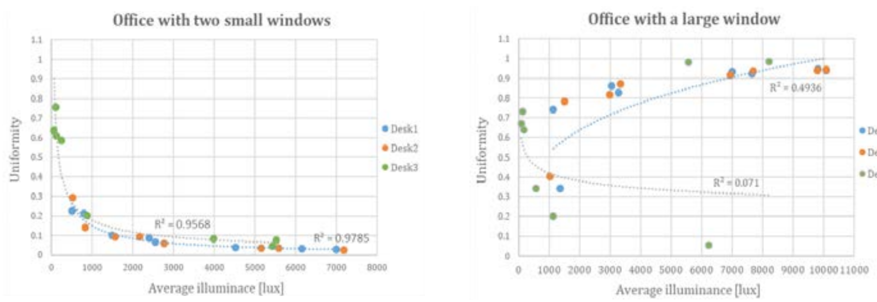

Figure 2. Uniformity on task area for office with different window sizes (December, 21st)

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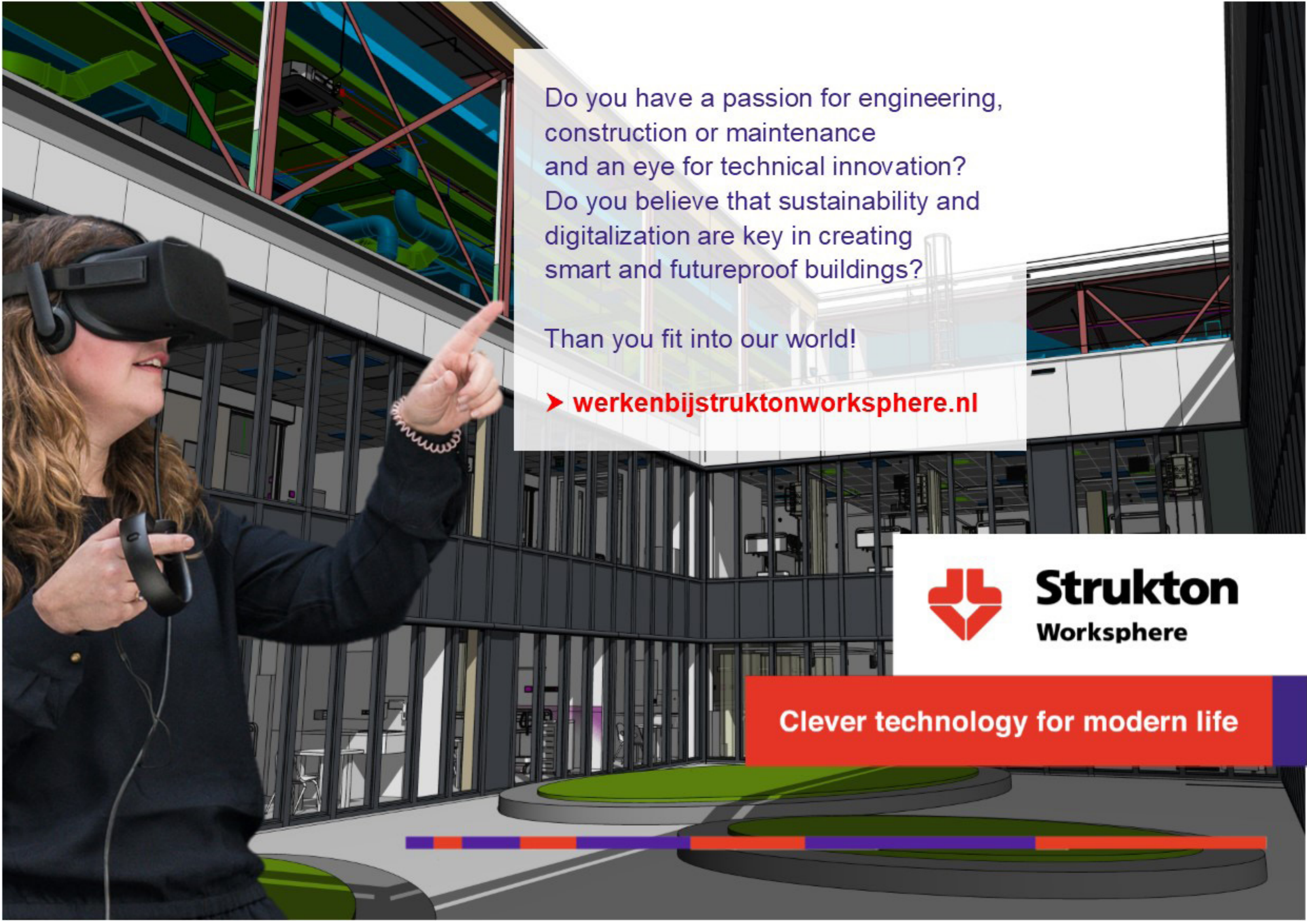
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Optimizing Existing Office Buildings to label A with ATES

Author
ing. P.M.J. (Paul) Gerats,
Energy Consultant at Sweegers en de Bruijn

There are several reasons why our building stock should become more sustainable. The main reason is stricter building regulation, but others are higher demands on our indoor climate, improving productivity, increasing building value, and financing requirements of banks. In particular, our government is increasing demands regarding the sustainability of our existing and new real estate. This can be related to the evolution of the Energy Performance Coefficient (EPC) requirements towards *BENG*, as can be seen in Figure 1.

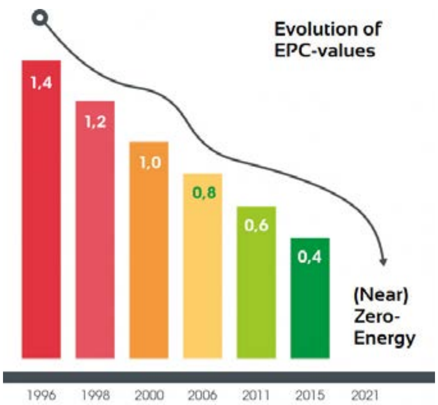

Figure 1. Evolution of the EPC requirements towards BENG for new built office buildings

	High efficiency								*Low efficiency*
Label:	A++	A+	A	B	C	D	E	F	G
EI:	0.5 or less	0.51 to 0.70	0.71 to 1.05	1.06 to 1.30	1.31 to 1.60	1.61 to 2.00	2.01 to 2.40	2.41 to 2.90	2.91 or more

Figure 2. Energy label and underlying Energy Index (EI)

As part of the Energy Agreement (or the Paris Agreement) we try to achieve an energy neutral built environment by 2050. An intermediate step is the ambition that all buildings have on average at least energy label A. By law, all office buildings must have label C by 2023. The energy label reflects the energy performance of a building with a rating (from A++ to G) and underlying energy index (EI). This can be seen in Figure 2. A valid energy label is mandatory at sale, lease and completion of non-residential buildings. If these conditions are not met, fines can be imposed by the Inspectorate of Life-environment and Transport (ILT).

The energy label reflects the energy performance of a building, but is no guarantee that the calculated energy performance will be achieved. When a building is used differently or incorrectly, the energy performance may differ and be disappointingly worse than calculated. The energy label will be valid for 10 years.

The mandatory energy label (label C or better in 2023) for office buildings puts real estate owners to the task to examine a large part of their building stock. About 53% of the existing office buildings currently does not meet label C [1]. These buildings have an Energy Index greater than 1.60 (label D or worse).

The requirements for energy label C concerns 53% of the total surface area of office buildings in the Netherlands. In total it concerns 67,000 buildings with an office function and a total surface area of 85 million square meters. Improving those office buildings to label B means that 66% needs to be adjusted. When improving these existing buildings to label A this even means that 75% needs to be adjusted [1].

Most owners want to know now if their building conforms to the requirements of a C label and A label. And if not, what investments lay ahead of them in order

Table 1. Costs per Energy Index point (€/0.01 EI) per Energy Index improvement (Δ EI) relative to the reference (EI = 4.32)

Study case: Office building from the 70's/80's with energy label G (EI = 4.32)			
	Energy saving measure	**Δ EI**	**€/0.01 EI**
A	Replacement of central heating system	0.14	€ 5,143
B	HR++ glazing	0.45	€ 4,556
C	New window frames with triple glazing and high quality (high qv;10 value ≤ 0. 4) crack and seam seals	0.52	€ 10,577
D	Insulate roof and facade	0.77	€ 1,883
E	Replace roof, facade and window frames	1.79	€ 16,760
F	LED lighting	0.48	€ 4,375
G	Direct current (DC) pumps and fans	0.44	€ 1,136
H	Low temperature heating and high temperature cooling	0.16	€ 43,750
I	ATES in combination with heat pumps, low temperature heating and high temperature cooling	1.13	€ 9,912
J	PV panels (200 in total) with 290 Watt peak power per panel	0.31	€ 2,419
K	Heat recovery ventilation	0.18	€ 2,778

Table 2. Various combinations of potential measures per Energy Index improvement (Δ EI) and energy label improvement

Options	Measures	Δ EI	€/0.01 EI	EI	Energy label
I	ABDFGK	2.46	€ 2,976	1.86	D
II	ABDFGJK	2.67	€ 3,022	1.65	D
III	BDFGHIK	2.78	€ 6,403	1.54	C
IV	EFGHIJK	3.48	€ 12,945	0.84	A

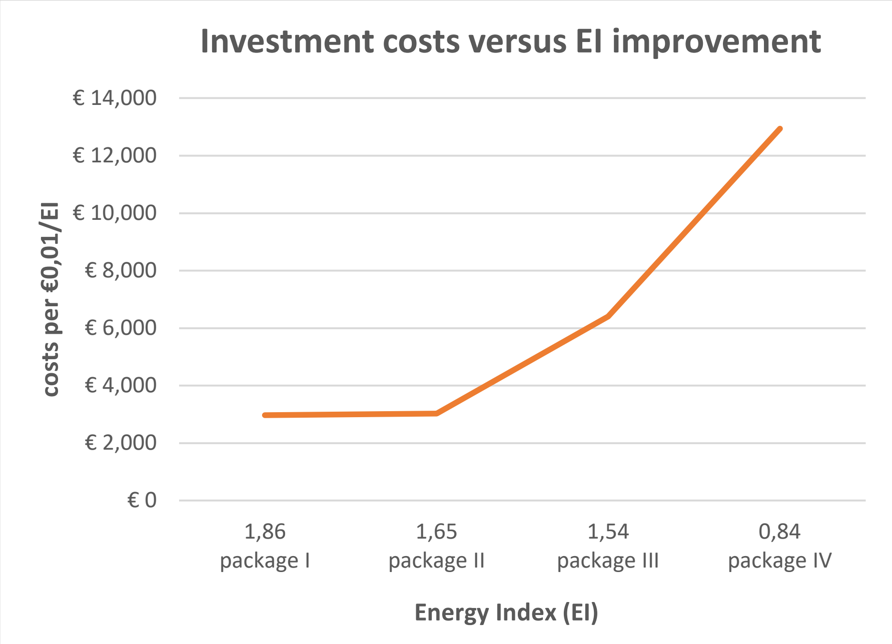

Figure 3. investment costs versus Energy Index

to meet the requirements? Research [1] shows that a better energy label leads to lower CO_2 emissions, increases property value, considerably increases rental income, and lowers energy and service costs.

To clarify the impact of a mandatory energy label Sweegers en de Bruijn conducted a research study. Here, a fictional building was used as study case. The building used in this study dates back to the 70's/80's and has a surface floor area of 7,000 m^2. No energy saving measures are implemented, in the building; and therefore, the building has the lowest energy label (label G, EI = 4.32). Table 1 shows the impact of a single measure on the energy index.

Table 1 shows that a combination of measures is required to go from a G label to a C or A label. Table 2 shows which combination of measures can be taken and what the costs per package per energy index point are.

From Table 2 and Figure 3, it can be concluded that the investment costs for an improvement of the Energy Index increase exponentially.

It is also clear that the application of Aquifer Thermal Energy Storage (ATES) in combination with heat pumps is inevitable as the ambitions become higher. For this particular study case, it is even necessary in order to achieve label C. In other cases the necessity for ATES and heat pumps will only occur in order to reach label A. When applying ATES and heat pumps, it is also necessary to adjust the system for central heating and chilled water, because the temperature range will change. For central heating , this will go from a high to low temperature range while for chilled water the temperature range will change from low to high temperatures. It is important to take this into account with installation replacements as normally included in a Long Term Maintenance Plan (in Dutch abbreviated as MJOP).

It is highly recommended to combine the investments from the MJOP (based on the life cycle of building services) with the Long Term Housing Plan. By commencing timely with the optimization, adjustments and modification of building services money will be made (due to lower energy costs) which can partially cover the investments in sustainability. So it is time to revive the MJOP in the context of sustainability and energy label improvement and identify which replacement investments can be linked to sustainable measures.

WHAT IS EPC?

The Dutch building code sets requirements on the energy efficiency of new built office buildings. This is written in the Dutch standard (NEN 7120) which is called 'EnergiePrestatie van Gebouwen' (in Dutch abbreviated as EPG) or translated into English 'Energy performance of buildings'. Within the standard the measure for energy efficiency is the well-known Energy Performance Coefficient (or EPC). This standard will be replaced by BENG from 2020. According to the governments original policy the EPC requirements should be zero in 2020. However, in order to comply with European standards buildings will be assessed according to the BENG from 1-1-2020.

WHAT IS BENG?

BENG stands for 'Bijna Energie Neutrale Gebouwen' or translated into English 'Nearly Zero-Energy Buildings'. The energy performance of BENG-buildings is determined based on three requirements that consider building-related energy flows:

- The maximum power demand in kWh per m^2 usable surface floor area per year;
- The maximum fossil energy consumption for primary energy in kWh per m^2 per usable surface floor area per year;
- The minimum required share (in percentages) of renewable energy.

DISTINCTION BETWEEN EPC AND BENG

The EPC only considers the total sum of energy in relation to building services, where BENG considers three separate building-related energy flows. Buildings that meet BENG requirements generally have an EPC of -0.2 to 0.2 or lower. In general, BENG is not feasible for buildings older than 10 years due to the combination of BENG requirements. In particular, BENG requirement are only feasible for those buildings when the building physics and building services are being renovated on a large scale. ■

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Performance of a BICPV Façade System with Daylight Control

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INTRODUCTION

Daylighting plays an important role in achieving high-performance buildings by providing an opportunity to reduce the energy demand of the building. It not only reduces the dependency on artificial lighting to achieve desired illuminance levels, but also aids positively in the perceived comfort of the occupants. Increased exposure to daylight is also associated with higher productivity, health and well-being of the occupants. The recent interest in developing highly glazed façades is a direct consequence of this importance. However, large glazing areas can also negatively affect the energy performance of the building by admitting unwanted solar gains along with the daylight. Glare discomfort is another issue that needs to be tackled when designing buildings with glazed façades. Although external static shading solutions such as overhangs and fins can keep direct sun away under specific circumstances, it comes at the cost of insufficient indoor illuminance on overcast days and reduced view to the outside. Manually operated shading systems such as venetian blinds and roller shades are rarely deployed efficiently, due to large dependence on user interaction [1]. Hence, there is increasing interest in dynamic shading systems such as automatically controlled blinds, switchable glazing, etc. [2] [3]. A missed opportunity that is shared by the majority of shading systems is that solar radiation is either absorbed or reflected, but not turned into something useful. The application of thin film solar cells with dynamic shading system allows simultaneous production of electricity [4], but it limits penetration of useful diffuse light into the building. Fresnel lenses with solar tracking have been suggested for capturing direct solar energy while allowing diffuse radiation to illuminate the interiors [5 & 6]. However, these systems tend to be bulky for façade applications due to the presence of a focal distance between the lenses and receivers. To overcome this issue, Lumiduct, a solar-controlling dynamic façade system based on planar light-guide solar optics (Figure. 1) was developed that only permits only diffuse radiation inside the building [7]. It has a series of concentrating photovoltaic (CPV) modules that track the sun's movement throughout the day in order to block direct radiation and produce electricity from it (Figure 2). Each module has a number of planar optic receivers, as shown in Figure 3, which consist of a 4x4cm planar focusing optic, a 1.3x1.3mm TJ III/V solar cell, a bypass diode, a heat sink and integrated wiring [8]. These CPV modules are installed within the cavity of a double-skin façade, as shown in Figure 2, in order to prevent the influence of dust and other outside environmental agents on the optical properties and the solar tracking mechanism.

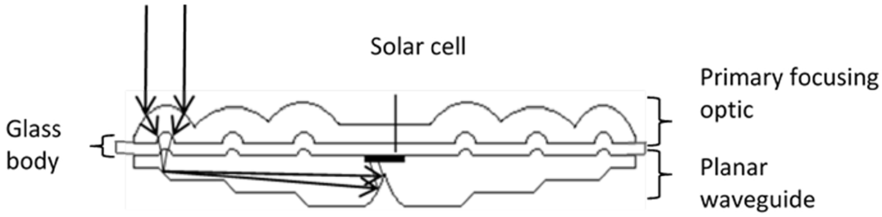

Figure 1. Schematic representation of the optical element of the receiver of the Lumiduct

Figure 2. Inside view of the façade mounted with Lumiduct CPV modules

Figure 3. Concentrating photovoltaic (CPV) module's planar optic receivers

RESEARCH OBJECTIVE

Since Lumiduct is a new and complex dynamic façade system, the current default capabilities of building performance simulation (BPS) tools do not support its performance prediction. Therefore, the aim of this research was to develop a model using existing BPS tools to assess thermal, daylight and electrical performance of Lumiduct and to then compare its performance with conventional glazing systems.

MODELLING AND SIMULATION METHOD

ASSUMPTIONS

In this modelling approach, the Lumiduct system, with dynamic CPV modules installed in the cavity of the double skin façade, is instead a 3-layer glazing system. The outer and inner panes represent thermal and optical properties of the outer and inner glass façade, while the middle pane represents CPV modules, and is modeled as a glass layer. This layer blocks direct solar radiation while transmitting only diffuse radiation.

THERMAL AND DAYLIGHT MODEL DESCRIPTION

An integrated thermal and daylight model was developed by taking advantage of the TypeDLT TRNSYS type. This type uses Radiance's 3-phase method for daylight predictions and can be coupled with TRNSYS' multi-zone thermal model (Type 56). In this 3-phase method, the incident light flux is divided into the following three phases for autonomous simulation, wherein each phase is represented by a matrix:

1. Phase 1, from the sky to the exterior of the fenestration, given by the Daylight matrix (D), which relates sky patches to incident directions of the fenestration.
2. Phase 2, from exterior of fenestration to the interior of the fenestration, given by Transmission matrix (T) which contains outgoing flux coefficients in all directions for each incident direction which is a Bi-directional transmission distribution function or BTDF.
3. Phase 3, from interior of fenestration to the sensor points, given by the View matrix (V), which relates outgoing directions from the fenestration to desired results at the interior points.

The illuminance at a given point in time is obtained by multiplying each of the above matrices with a sky vector (s) which contains sky luminance values from patches representing sky directions. As Lumiduct blocks direct solar radiation, for the daylight model, the outgoing flux coefficients in the transmission matrices which represent direct sun directions for any given hour were blocked using the daylight matrix and the sky vector.

In the TRNSYS' thermal model, the component of the direct solar radiation transmitted into the building is determined by the coefficients of the angular transmittances while the diffuse solar component is determined by the hemispherical transmittance. Therefore, in order to block direct solar radiation while allowing diffuse radiation to pass through, the angular transmittances for the solar and visible spectrum were reduced to zero. For quality assurance purposes, the optical properties of the model were further calibrated against measurements from the test-site of the pilot project at Alblasserdam, the Netherlands.

ELECTRICAL MODEL DESCRIPTION

As CPV modules track sun, their rotation and tilting induces shading over nearby panels. This self-shading of the modules reduces the electricity generation. Therefore, a self-shading factor (SF) of the modules is considered when evaluating the electrical output of Lumiduct. SF is considered to be equivalent to the fraction of the vertical façade, which becomes uncovered by the modules due to their rotation when viewed from a direction normal to the façade. For a south-oriented façade, it is given by Equation 1 and its variation over different seasons of the year can be visualized by Figure 4.

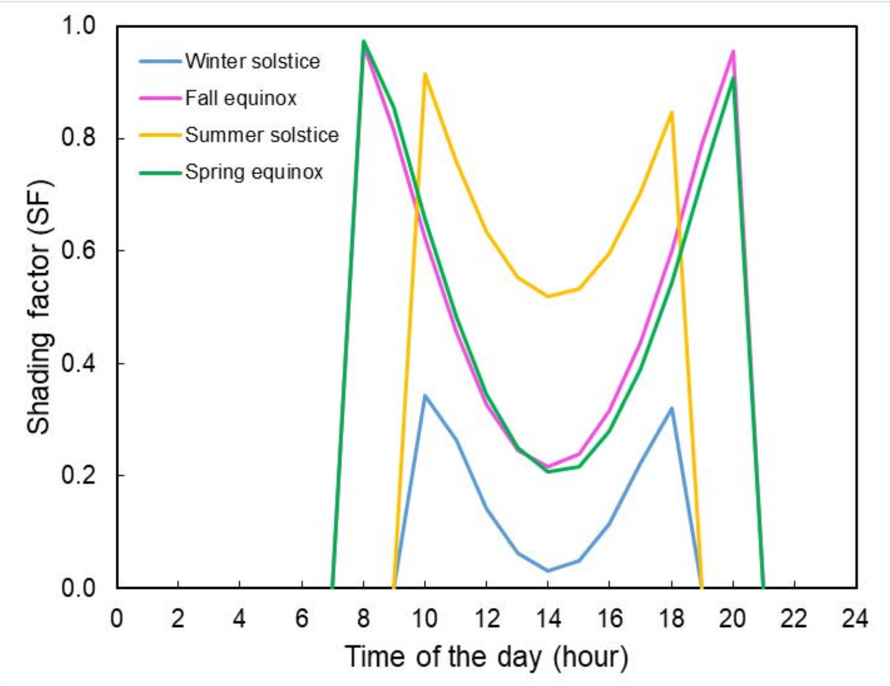

Figure 4. Diurnal variation of shading factor of the CPV modules when installed over a southward facing facade in Amsterdam on equinoxes and solstices dayst

$$SF = 1 - \left(\cos \gamma_s * \sin \theta_z\right)$$

Equation 1. Self shading factor (SF) where, γ_s is the solar azimuth angle and θ_z is the solar zenith angle.

A previous experimental study found a linear decrease in the maximum power output for an increasing shading factor of this flat CPV system [14]. Assuming a linear decrease in the maximum power output and considering a constant conversion efficiency (η) of 30% with no interconnection losses between receivers of the modules, the total electrical energy generated by the CPV modules was computed by Equation 2.

$$Electrical\ energy = DNI_{track} * T_{sol\ (0)}\left[1 - tan^4\left(AOI/2\right)\right] * \left(1 - SF\right) * \eta$$

Equation 2. Where, DNI_{track} is the direct normal irradiation over a dual-axis tracking surface, $T_{sol(0)}$ is the solar transmittance of the outer glass façade of Lumiduct at normal incidence and AOI is the angle of incidence over the vertical façade

CASE STUDY BUILDING

For an annual performance comparison of Lumiduct with conventional façade systems, a single-person perimeter space with dimensions 3.6m (width) x 5.4m (depth) x 2.7m (height), located at an intermediate floor of an office building having identical neighbouring office spaces and a south-facing exterior façade (with 87% window-to-wall ratio) in an Amsterdam climate was chosen as a case study. The external wall had a U-value of 0.35W/m^{2}K. The installed lighting power density was 7.5W/m^2 with continuous dimming control up to an indoor illuminance of 500lux, other equipment gains were 10W/m^2 (working hours are 9 AM-5 PM). Artificial lighting was controlled using a sensor placed 2.7m away from the façade and 1.8m from the side walls. The thermal environment was controlled using an HVAC system having a COP of 4 with unlimited capacity based on the indoor air temperature, the set-points for heating and cooling during working hours were 20°C and 24°C respectively, while during non-working hours, they were 14°C for heating and 32°C for cooling. Infiltration was assumed to be constant.

COMPARATIVE SOLAR CONTROLLING FACADES

The annual performance comparison was made against the following transparent façade systems for the aforementioned case study building:

- High-performance window with no shading - triple glazing system with low-emissivity coating near the rear glass pane.
- Internal roller shades (openness factor 4%) with automatic control applied over the case (a). The shades are pulled down fully when the incident solar radiation on the window exceeds 250W/m^2.
- External roller shades (openness factor 2.5%) with automatic control applied over the case (a). The shades are pulled down fully when the incident solar radiation on the window exceeds 250W/m^2.
- Lumiduct in the sun-tracking mode

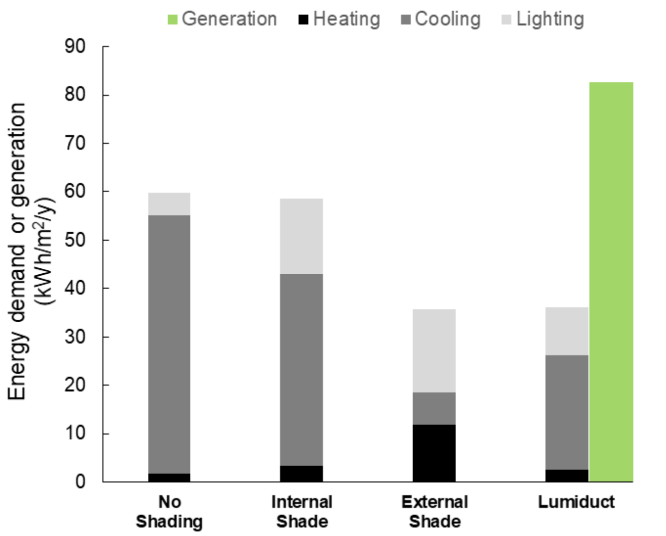

Figure 5. Comparison of annual primary energy consumption and generation of a building during the operational phase of a building for five different façade configurations investigated

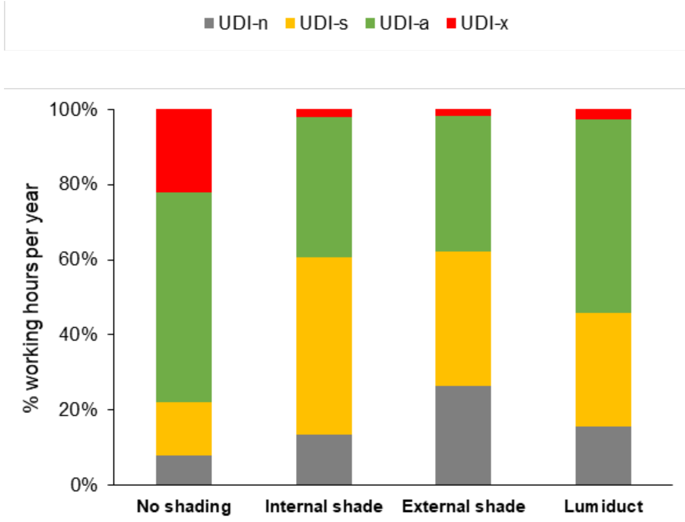

Figure 6. Daylight performance comparison of the investigated cases based on UDI for a south-oriented facade in Amsterdam

PERFORMANCE INDICATORS

The energy performance is assessed by investigating annual primary energy use intensity [kWh/m²/y] considering heating, cooling and artificial lighting energy and annual electricity generation potential. The primary energy conversion factor for electricity is taken as 2.56. For daylight performance assessment, useful daylight illuminance (UDI) is used. UDI categorizes the indoor daylight illuminance into four different ranges - 0-100 lux (UDI-n for non-sufficient), 100-500 lux (UDI-s, for supplementary), 500-3000 lux (UDI-a, for autonomous) and above 3000 lux (UDI-x, for exceeded). UDI-n represents the percentage of hours when the daylight is insufficient to meet the illuminance requirements while UDI-s corresponds to the percentage of occupied hours when daylight partially meets the illuminance requirements and artificial lights are to be used in combination. A higher amount of UDI-a represents the percentage of hours when only daylight is able to achieve the minimum required illuminance levels, and is still visually comfortable for the occupants. Daylight illuminance higher than 3000lux is often considered to impart more visually uncomfortable conditions with possible occurrences of glare, which is represented by UDI-x in this metric.

RESULTS AND DISCUSSION

A comparison of the annual primary energy use intensity and UDI categories for the five cases investigated are shown in Figure 5 and Figure 6 respectively. The results suggest that the total primary energy demand can be reduced by nearly a factor of two when a high-performing window with no shading is replaced by Lumiduct (see Figure 5), while still comparing well on the percentage of working hours in the UDI-a range. The results further suggest that though external roller shades are able to reduce the total primary energy demand also by a factor of two, the percentage of working hours when daylight remains insufficient (UDI-n) to be the sole source of illumination increases by more than three times, while in the case of Lumiduct, it remains nearly the same with a negligible increase of 20 hours over the occupied hours of the whole year (see Figure 6). In terms of UDI-x, Lumiduct performs well in comparison to the internal and external roller shades, thus reducing occurrences of excessive daylight that are likely to cause glare.

Additional to serving as a solar-control façade, Lumiduct's capability to generate electricity gives it an added advantage over conventional shading systems. Its annual electricity generation potential is estimated to be 74 kWh/year/m² of the window area which is nearly 1.5 times the electricity consumption of the building installed with Lumiduct, combined for heating, cooling and artificial lighting.

CONCLUSION

In this article, a modelling and simulation approach to evaluate energetic and daylighting performance of Lumiduct, a multi-functional façade with selective daylight transmission is described. The results indicate that considering Lumiduct as an alternative to conventional shading systems can provide an energy efficient solution for achieving both thermal and visual comfort requirements, while also generating electricity, fostering comfortable and net energy positive buildings. ■

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Improvement of VAWTs using Boundary Layer Suction

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INTRODUCTION

The shortage of energy and global warming have emerged as major problems. Development of renewable and sustainable energy is becoming more and more important. Nowadays, one of the common sustainable energy sources is wind energy technology, which provides sustainable and renewable energy by wind turbines. Wind turbines are generally classified in two main categories: horizontal axis wind turbines (HAWTs) and vertical axis wind turbines (VAWTs) [1]. The two types of wind turbines are presented in Figure 1.

For large-scale wind turbines, the market has adopted HAWTs, as the efficiency and the energy production is higher compared to VAWTs [2]. For small scale wind turbines, VAWTs have several advantages over HAWTs. VAWTs need less maintenance because the turbines consists of fewer and slower moving parts, the rotation speed is lower and no awning mechanisms are present to turn the blade. VAWTs also produce less noise as the tip speed ratio is lower and are omnidirectional which means that turbulence and wind speeds from all directions can be used effectively [3].

As the energy production and efficiency of VAWTs are nowadays too low for adoption in the commercial market, the need for the improvement of the overall performance of VAWTs is high. One of the possible improvements in the performance is the usage of passive or active boundary layer control. Passive boundary layer control methods are based on using geometrical effects, for instance, by integrating additional passive attachments to the airfoil. However, active boundary layer control is proven to be more effective due to an increase in profile losses for passive boundary layer control and the possibility of deactivating the control method. Active boundary layer control methods consist out of two main systems, which are based on injection (a. blowing) or extraction (b. suction) of a small amount of energy into or out of the system. The biggest advantage of suction compared to blowing is a larger and lower pressure zone on the upper side of the airfoil that increases the maximum lift coefficient. However, the flow is more attached to the surface of the body and the drag of the profile decreases. The two types of active boundary layer control methods are presented in Figure 2.

Figure 1. Horizontal Axis Wind Turbine vs. Vertical Axis Wind Turbine [4]

The application of boundary layer suction is to prevent flow separation over the airfoil. The boundary layer over an airfoil typically separates near the trailing edge, while the separation point moves towards the leading edge by increasing the angle of attack. Additionally, at moderate angles of attack, a laminar separation bubble is formed near the leading edge. Boundary layer separation is almost always undesirable as it leads to great losses in energy [4]. Therefore, it is preferable to eliminate or delay boundary layer separation for many practical applications [5]. Prevention of boundary layer separation results in the effectiveness of lifting and the reduction of pressure drag on airfoils [2] [3].

The application of boundary layer suction is mainly applied to aircraft wings and various types of airfoils. However, the effectiveness of boundary layer suction is highly dependent on the location on the airfoil (Lj), the suction slot geometry (Ld), the suction amplitude (A) and the type of suction. Although many studies focus on the application of boundary layer suction on airfoils, only limited research is done under a relatively low Reynolds number (< 105). In addition, very limited research is executed for the application of boundary layer suction in VAWTs.

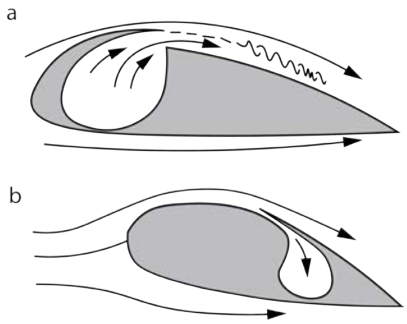

Figure 2. Preventing boundary layer separation by: a. blowing and b. suction [4]

Therefore, the objective of the study behind this paper is to investigate the implementation of boundary layer suction in VAWTs and the different parameters that influence the overall performance of a VAWT.

VALIDATION STUDIES

Validation is defined as the process to determine the accuracy of the computational model representing physical phenomena. Validation is carried out by a comparison between the performed numerical results and experimental studies including similar geometrical and operational characteristics, as well as similar boundary conditions. Validation by a comparison between performed numerical results and numerical studies is possible, but the accuracy and reliability of the numerical studies are of major concern. Statements on the accuracy of Computational Fluid Dynamics (CFD) studies with a certain turbulence model should therefore be based on CFD studies that have undergone solution verification, where numerical errors are limited and physical modelling errors are reported [7].

In this research, the validation study is realised for a static airfoil without suction, based on two experimental studies and two numerical studies that have undergone solution verification. For the static airfoil including suction, no accurate validation study was found that included appropriate boundary conditions for including the boundary layer suction method in the VAWT. Therefore, an additional validation study was executed to validate suction over a flat plate.

Extensive solution verification and validation for a VAWT without suction have been already performed and published:

• Rezaeiha, A., Kalkman, I., & Blocken, B. (2017). CFD simulation of a vertical axis wind turbine operating at a moderate tip speed ratio: guidelines for minimum domain size and azimuthal increment. Renewable Energy, 107, 373-385.

• Rezaeiha, A., Kalkman, I., & Blocken, B. (2017). Effect of pitch angle on power performance and aerodynamics of a vertical axis wind turbine. Applied Energy, 197, 132-150.

In this study, the same computational domain, grid and numerical settings have been used.

METHODOLOGY

To examine the suction boundary layer control method on the low-solidity single-bladed H-rotor Darrieus wind turbine with a diameter of 1m, a solution verification study for a suction location of 10% of the chord length (0.1c) is executed.

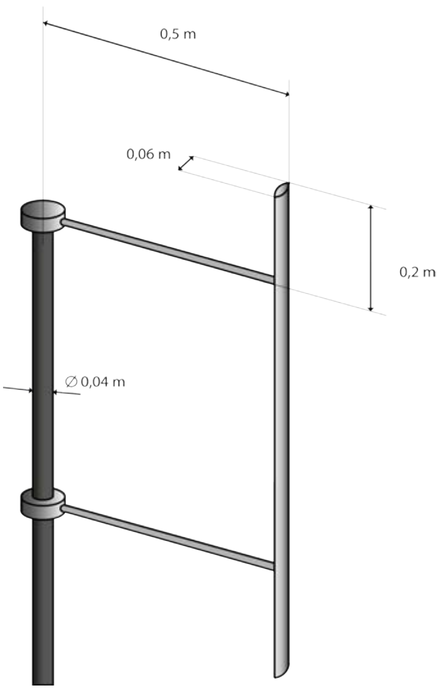

Figure 3. Single-bladed VAWT

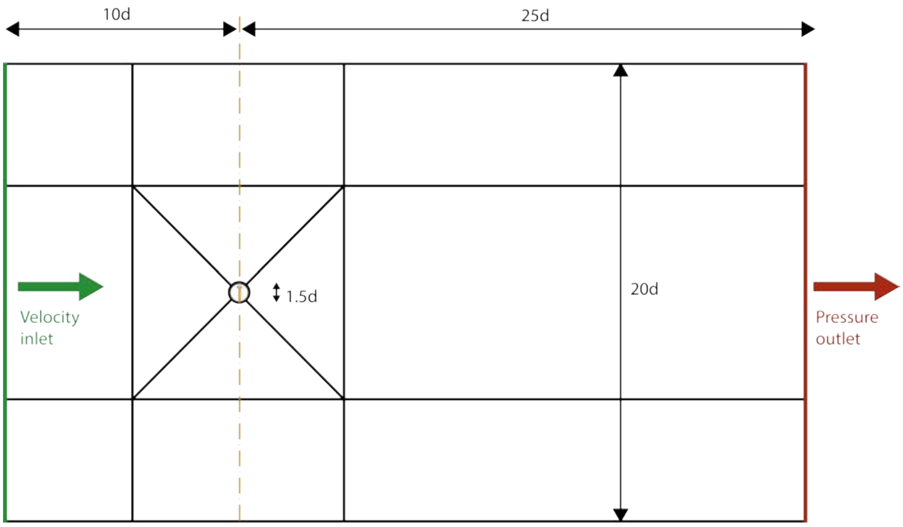

Figure 4. Dimensions of the 2D computational domain

The suction is applied at the inner blade of the turbine to affect the first 180° of the revolution of the VAWT. A single-bladed VAWT was chosen to reduce the computational time while introducing the suction method. The single-bladed VAWT including dimensions is presented in Figure 3.

The dimensions of the 2D computational domain are presented in Figure 4. The length of the computational domain is 35d and the height is 20d, which corresponds to a blockage ratio of 5%. A blockage ratio of less than or equal to 5% is required to minimise the effect of side boundaries on the results. The use of this 2D domain is based on the results of the study by Rezaeiha et al. (2017) [8] [9]. The length of the area behind the airfoil is 25d, which enables a better prediction of the wake behind the VAWT. The diameter of the rotating core is 1.5d.

The outer part of the domain consists of quadrilateral cells. The grid for the rotating core is generated using a multi-zone method including quadrilaterals and triangular cells to create a smooth transition from the rotating core to the outer area. The grid around the suction slot is created using 6 different interfaces that can be controlled independently of each other by which a fully quadrilateral grid around the suction slot is made. This is presented in Figures 5 and 6.

Calculations are initialised with the solutions of steady RANS simulation and continuation for 20 turbine revolutions without the implementation of a suction method. The URANS equations are used as governing equations, while turbulence is modelled with the 4-equation transition SST turbulence model also known as γ-θ SST turbulence model. The timestep chosen is 3.7534e-05s. This is the minimum required timestep of the URANS simulations driven by the time scales of the unsteady complex phenomena in the flow. For the case of VAWTs, it is usual to correlate the timestep with the turbine revolution and express it as the azimuthal increment. This azimuthal increment ($d\theta$) employed for the unsteady calculations is 0.1°. Each timestep consists of 20 iterations to have the scaled residuals < 1×10^{-5}. The

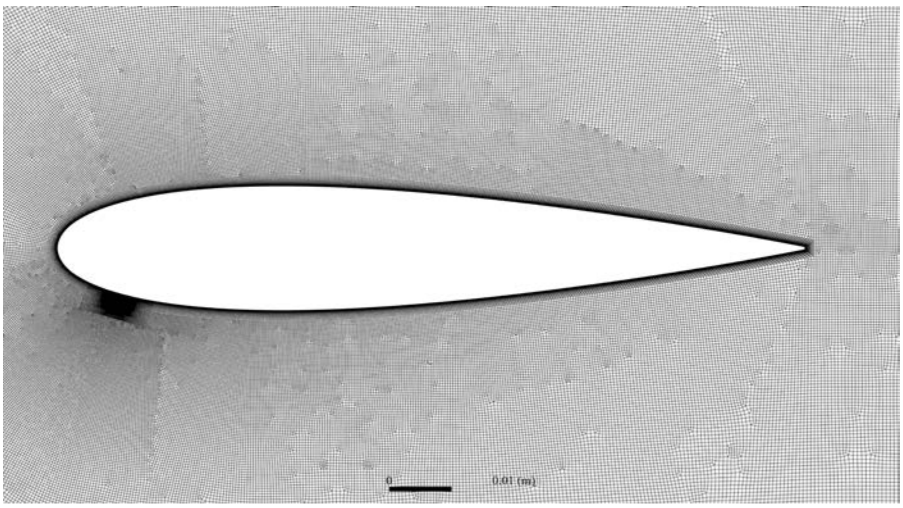

Figure 5. Grid near the airfoil

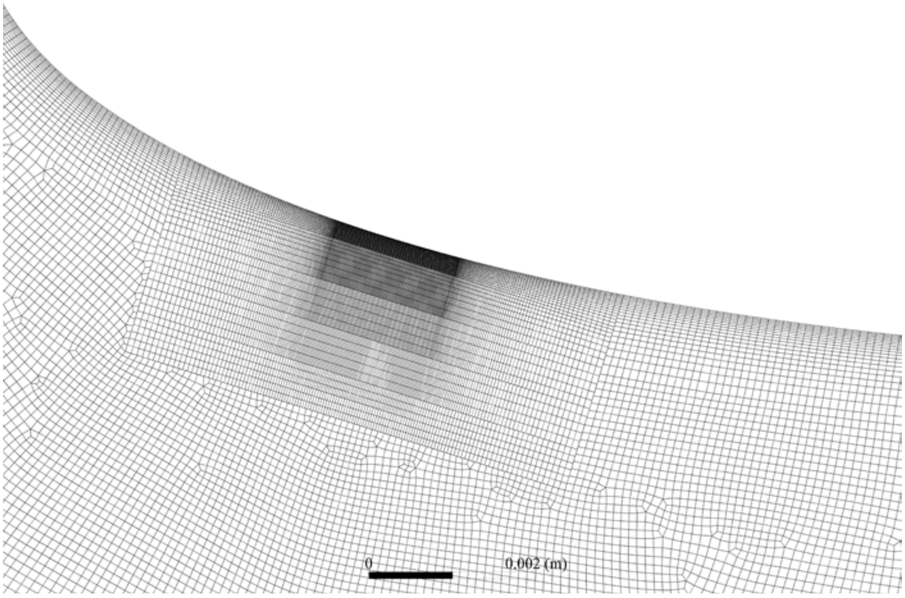

Figure 6. Grid near the suction slot

instantaneous moment coefficient is sampled after the third revolution of the turbine including the suction method, as the convergence study shows that the power coefficient is statistically converged after 3 revolutions.

RESULTS AND DISCUSSION

SUCTION LOCATION

The suction location (Lj) is very important to create a positive effect on the aerodynamic performance of the VAWT. If the suction slot is placed at a suction location after the location where the laminar separation bubble arises, the applied suction has a negative result on the overall power coefficient and is not effective. The application of suction near the location where turbulent trailing edge separation has already started, therefore has a negative effect on the overall performance of the VAWT.

The application of suction for a tip speed ratio of 2.5, 3.0, and 3.5 is the most effective for suction locations close to the leading edge. For a tip speed ratio of 2.5, the most optimal suction location found is at 0.1c. This is presented in Figure 7. For a tip speed ratio of 3.0 and 3.5, the most optimal suction location found is at 0.15c. The most optimal suction location per tip speed ratio is placed near the beginning of the laminar separation bubble for lower θ, and at the end of the laminar separation bubble for θ close to the stall angle. When the suction is applied at this location, a part of the laminar separation bubble is sucked away. Therefore, the transition of laminar flow to turbulent flow resulting in the growth of turbulent trailing edge separation over the airfoil is delayed. The usage of suction for the optimal location per tip speed ratio induces a shift in the stall angle of Δθ = 10°. Delaying the turbulent separation near the trailing edge and shifting the stall angle optimises the aerodynamic performance of the VAWT, and therefore induces an increase in the overall power coefficient.

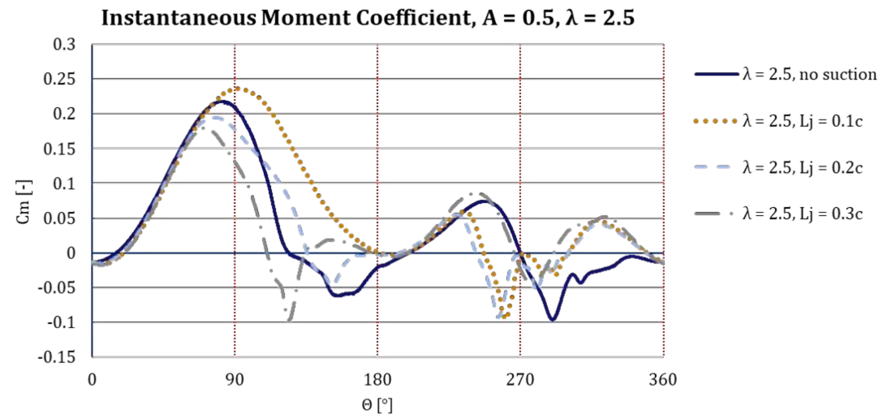

Figure 7. Instantaneous moment coefficient for different suction locations at λ = 2.5, A = 0.5 and Ld = 0.025c

SUCTION WIDTH

Another important parameter considering the aerodynamic performance is the width of the suction slot (Ld), which is chosen in accordance with literature between 0.02c and 0.03c. A suction slot width of 0.02c has a somewhat positive effect (+4.2% in comparison to a width of 0.025c) on the power coefficient, while a suction slot of 0.03c has a slightly negative effect on the power coefficient (-0.14% in comparison to a width of 0.025c). However, as the differences between the results are rather small, no distinctive conclusions can be made.

SUCTION AMPLITUDE

The most important operational parameter considering the aerodynamic performance is the suction amplitude (A) and the suction velocity divided by the free stream velocity. The optimal suction amplitude found is at 0.0175 for λ = 2.5, as presented in Figure 8. A larger amplitude results in a larger impact on the flow field around the airfoil during the first half of the revolution. However, a larger suction amplitude does not result in a more positive effect on the power coefficient. Values exceeding 0.1 manipulate the laminar separation bubble to a larger extent which results in an earlier transition of laminar flow to turbulent flow, resulting in growth of turbulent trailing edge separation over the airfoil. For smaller suction velocity amplitudes between 0.0175 and 0.025, a second laminar separation bubble is present over the airfoil between 0.3c and 0.4c for θ ≥ 80°. After this point, the flow is able to partly reattach to the surface of the airfoil and the turbulent separation near the trailing edge is delayed to a location further downstream compared to higher amplitudes.

The combination of the most optimal parameters considering the suction location, the suction width and the suction amplitude creates the highest improvement with respect to the averaged instantaneous moment coefficient, the delay in the stall angle and consequently, the overall power coefficient of the VAWT. The application of suction is the most effective for a tip speed ratio of 2.5, as the power coefficient increases by 104% in comparison to the case where no suction is applied. This is caused by earlier stall and a larger growth of turbulent trailing edge separation over the airfoil for a tip speed ratio of 2.5 in comparison to a tip speed ratio of 3.0 and 3.5. The applied suction shifts the stall angle by Δθ = 15° for λ = 2.5 and delays turbulent trailing edge separation over the airfoil, which creates the largest effect on the overall power coefficient.

For the tip speed ratios of 3.0 and 3.5, the application of suction is less effective. However, the power coefficient still increases with 21% for a tip speed ratio of 3.0 and 16% for a tip speed ratio

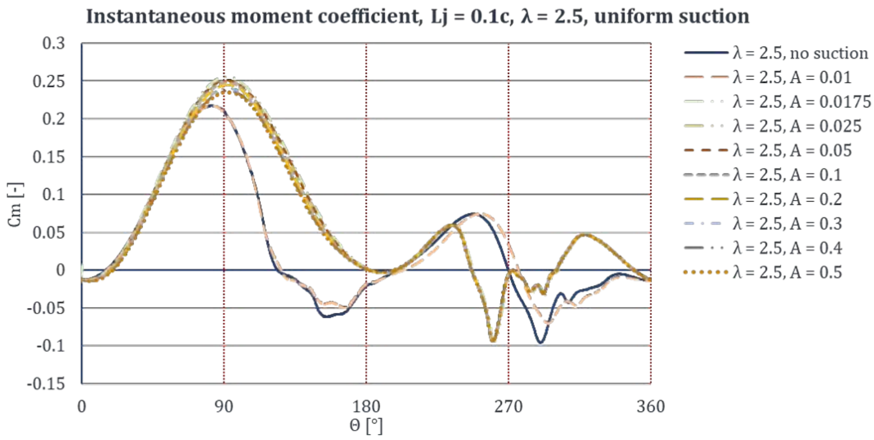

Figure 8. Different suction amplitudes for Ld = 0.025c, Lj = 0.1c and λ = 2.5

of 3.5. Although the increase is less in comparison to the increase for a tip speed ratio of 2.5, the application of suction is still effective and can lead to a much higher energy efficiency of the VAWT.

As very limited research is executed on the application of suction in VAWTs, a possible configuration should be considered to realise the suction system. In Figure 9, a schematic overview of a possible configuration for the application of suction in a low-solidity two-bladed H-rotor Darrieus wind turbine is presented. This application is based on an experimental study considering the application of suction in an airplane wing, and the blade is retrofitted with an array of microjet actuators that spans the entire blade. A solenoid valve is used to regulate the opening of fluid flow to ensure the right amount of suction is present at the suction slot [10]. The under pressure required to suck away the air by the microjet actuators is supplied by a miniature high-pressure air cylinder. However, the location of the miniature high-pressure air cylinder should be in the rotating part of the turbine tower to make sure the suction flow is able to be transported from the suction slot on the blade to the miniature high-pressure air cylinder.

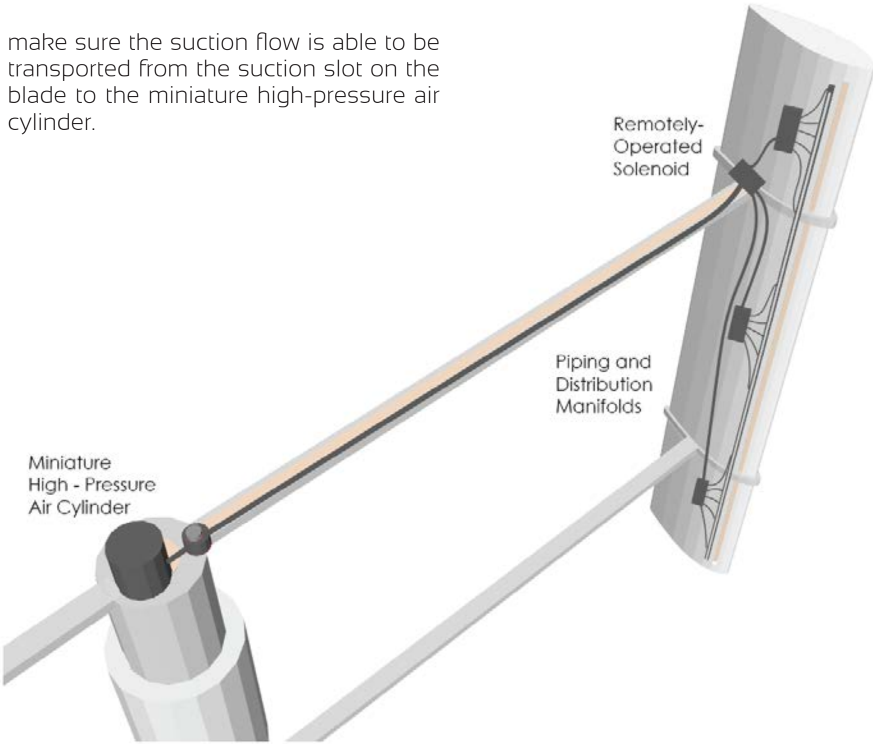

Figure 9. Schematic overview of a possible configuration for the implementation of suction in a vertical axis wind turbine

CONCLUSION

The current study examines the effect of suction and consequently the improvement of the aerodynamic performance considering numerical studies. The results are promising, and the investigation of boundary layer suction in experimental studies will contribute to the reliability and realisation of VAWTs including boundary layer suction methods. ■

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Methodology to Assess Energy Neutrality

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INTRODUCTION

The concept of energy transition is gaining traction globally, as various governments have set ambitious targets to move from the fossil-based energy systems towards systems using a considerable amount of distributed renewable energy sources. Most governments around the world such as EU-28 [1] plan to achieve 100% renewable energy generation by the year 2050. In the EU-28, the share of renewable energy in gross final energy consumption has grown rapidly from 8.5% in 2004 to almost 16.7 % in 2015 [2]. Towards attaining the goals of energy transition, in addition to increase in the share of renewable energy sources, great emphasis has been placed on improving the efficiency of production systems and improving energy savings and flexibility on the demand side.

On the demand side, a major emphasis is placed on the buildings. This is because buildings account for over 30% of the world carbon emissions and consume well over 30% of total primary energy [1]. As a result, there is a major focus on individual buildings for achieving reductions in consumed energy. Thus, energy neutral and CO_2 neutral buildings are being designed as options within the current energy framework. However, achieving energy neutrality is unfeasible with the current setup and composition of some of the existing buildings. Additionally, it is stated that waste heat can be harvested in a useful manner with collective options when moving the boundaries from a single building to the neighborhood level.

INFLUENCE OF ENERGY TRANSITION ON BUILDING NEIGHBORHOODS

At the moment, most buildings are planned to be constructed individually, despite of the energy characteristics of the prevailing neighborhood buildings. In addition to these new buildings, a considerable amount of buildings which are present today will also exist in 2050 [3]. However, the eventual disposal of fossil-based energy systems may demand alterations in both the external and internal design and operation of these buildings. For instance, currently in the Netherlands, more than 90% of the existing buildings' heating demand is fulfilled by natural gas-based energy systems [4]. However, the Dutch government decided to move towards a gas-free system for new buildings from 2018 onwards. Therefore, the existing building stock remains a greater challenge. The alterations with gas-free transitions are yet to be communicated to the building owners.

Intriguingly, the fossil fuel demand in existing buildings can be reduced with energy refurbishment measures or integrated energy branches [5]. Electrification of the heating demand for buildings might be a result of integrating energy branches. Electrically driven heat pumps are a point of interest in such a transition. Heat pumps have been identified as a low CO_2 emission technology. Thus, heat pumps could play a promising role in the level of individual buildings and neighborhoods. In conjunction, new forms of energy carriers like hydrogen could replace gas and gas operated equipment inside buildings. However, the willingness of the existing buildings to accommodate these changes is still debatable.

Apart from electrification of the heating division with the individual approach using heat-pumps, a number of area-specific collective measures also have been introduced with decentralized district heating, cooling networks and 4th generation low-temperature heating grids at the neighborhood level, in order to satisfy the thermal energy demand. Furthermore, buildings themselves are a viable option for providing flexibility to the demand side with the use of energy storage systems. Buildings can contribute to the needed energy flexibility [6] through energy sharing and exchange among themselves within a neighborhood. These techniques will claim additional platforms allowing interchange of energy options.

A building neighborhood can be compact as compared to an urban condition, or sprawling (rural). Likewise, a neighborhood can range from a cluster of buildings to the city level. The pace of transition and the necessary infrastructure developments vary depending on factors such as focused neighborhood status, population, geographical location and available resources. Since the term 'neighborhood' is unique in character, a clear boundary and a description are essential when studying a neighborhood.

EXISTING STUDIES ON ENERGY NEUTRAL NEIGHBORHOODS

Aggregating buildings and introducing community-level renewable energy sources with storage systems may make it possible to achieve the goal of zero-energy at the neighborhood level [7].

However, the analyses of energy infrastructure developments and the realization of energy neutrality at the neighborhood level are indeed still a challenge. Existing studies on neighborhood level energy framework have focused mainly on the optimal operation of renewable sources, intermittency of renewables, integrated decentralized energy systems, and integration of district heating into neighborhoods [8].

While some of these studies also address issues such as peak demand management with local level storage systems and increasing energy self-sufficiency, they are often most focused on the operational phase of buildings. As a result, they seldom reflect the overall impacts of decentralized energy systems at the neighborhood level. Even for the decision-making aspects of clean energy initiatives, only the operational phase of buildings and distributed energy sources are considered.

The overarching performance assessment of energy infrastructure developments including the production, operation and end-of-life stage have been seldom evaluated.

RESEARCH OBJECTIVE

This study evaluates the energy infrastructure development scenarios in the lifecycle perspective as a decision-support method to realize energy neutrality in the long run. This facilitates the possibility to estimate the effects of different transition scenarios and gives the opportunity to the decision maker to identify the best-value compromise or option for neighborhood-level energy infrastructure developments.

PROPOSED METHODOLOGY

The proposed methodology illustrated in Figure 1 consists of four steps, and are described below in detail [9]. The methodology is focused on the existing building stock and it can be used to analyze any type of building or any number of buildings ranging from very few buildings to a larger scale.

- Step 1: Identification: In the decision-making process, the first step is to define the neighborhood boundary with the included number of buildings. This selection is dependent on the stakeholder (decision-makers) inputs, interests and willingness of the building owners to participate. Then, according to the geographical area, distinguished area-specific measures, local knowledge and available resources, the realizable scenarios can be identified intrinsic to the neighborhood. In this context, scenarios define the different clean energy initiative options. Examples of different scenarios:

  S1 = Individual heat pumps for each building with solar PV on rooftops of all the buildings in the neighborhood

  S2 = Collective heat pump system for all the buildings in the neighborhood with a separate thermal grid and solar PV on rooftops of all the buildings

- Step 2: Computational analysis and calculations: In this step, the energy performance of the identified scenarios are estimated using simulation models.

Prior to estimating energy performance of scenarios, it is imperative to know the current energy consumption and demand profiles of the buildings. In general, two different modeling approaches are used to estimate the demand profiles of the buildings, namely classical modeling and data-driven modeling. Both of these modeling approaches can be applied in the computational analysis to estimate the current demand profiles of the buildings depending on the data available. Subsequently, the annual energy performance of candidate scenarios is estimated with an appropriate simulation tool (MATLAB, PVSyst, EnergyPlus etc.) using the above obtained energy demand profiles. For PV, energy storage, and heat pump related computational analysis, it is important to have smaller data resolutions such as hourly energy consumption to identify accurate energy performance.

- Step 3: Performance assessment using KPIs: This step introduces Lifecycle Performance Design based key performance indicators (KPIs) so that the decision-making process encompasses a lifecycle perspective of the energy infrastructure development scenarios. Some examples are shown in Figure 2.

The energy consumption, CO_2 emissions and associated costs of energy infrastructural components during the pre-utilization stage (production of equipment), operational stage (energy consumption of the buildings, and maintenance of equipment) and end-of-life stage (recycling or demolishing of equipment) is included in this analysis.

Table 1. Performance matrix

Scenario / Performance category	Life cycle energy	Life cycle CO_2	Life cycle costs
S_1	LCE_1	$LC(CO_2)_1$	LCC_1
S_2	LCE_2	$LC(CO_2)_1$	LCC_2
...	...	...	...
S_m	LCE_m	$LC(CO_2)_m$	LCC_m

Table 2. Opportunity loss matrix

Scenario / Performance category	Life cycle energy	Life cycle CO_2	Life cycle costs
S_1	$LCE_1 - B_1$	$LC(CO_2)_1 - B_2$	$LCC_1 – B_3$
S_2	$LCE_2 - B_1$	$LC(CO_2)_1 - B_2$	$LCC_2 – B_3$
...	...	...	...
S_m	$LCE_m - B_1$	$LC(CO_2)_m - B_2$	$LCC_m – B_3$

Here, equipment exemplifies boilers, chillers, PV panels, gas pipes, heat pumps etc.

The performance is continuously evaluated until 2050 using knowledge-based deterministic probabilities. The term 'knowledge-based' denotes the probabilities obtained with an accumulation of available facts and information. The final resulting performances of the scenarios can be represented by a performance matrix as demonstrated in Table 1 for the easy understanding of the decision makers.

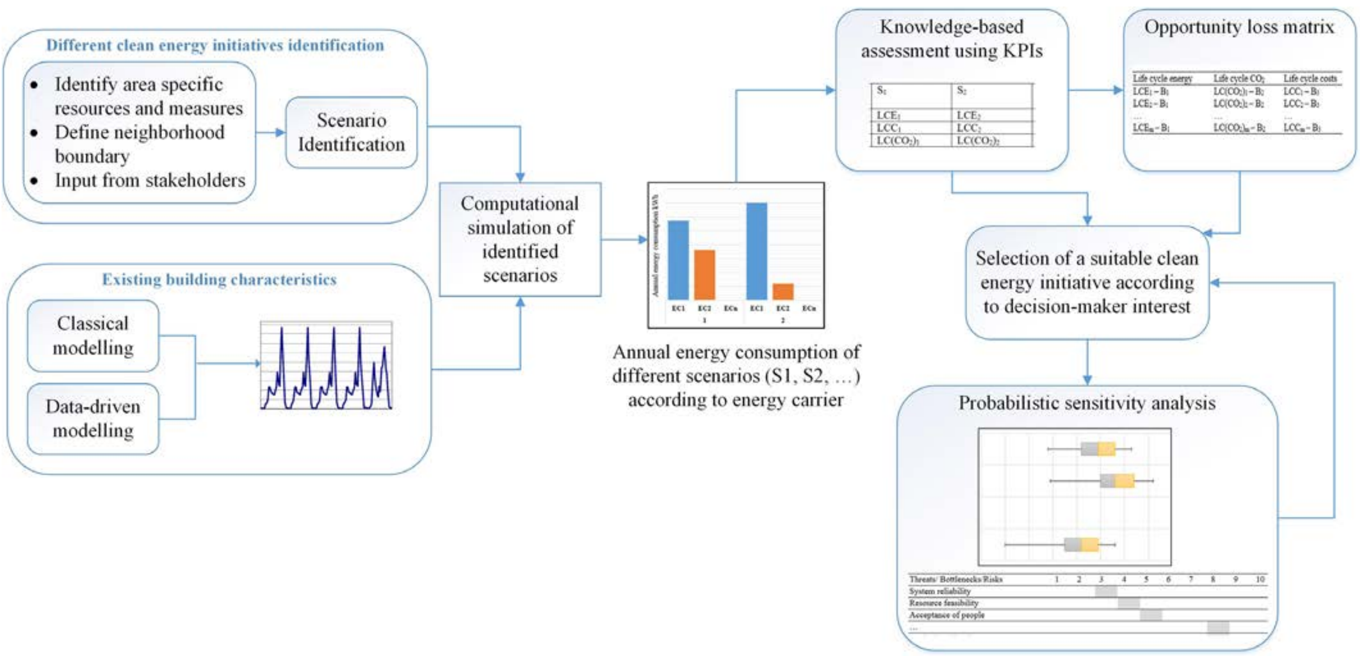

Figure 1. Illustration of the proposed methodology

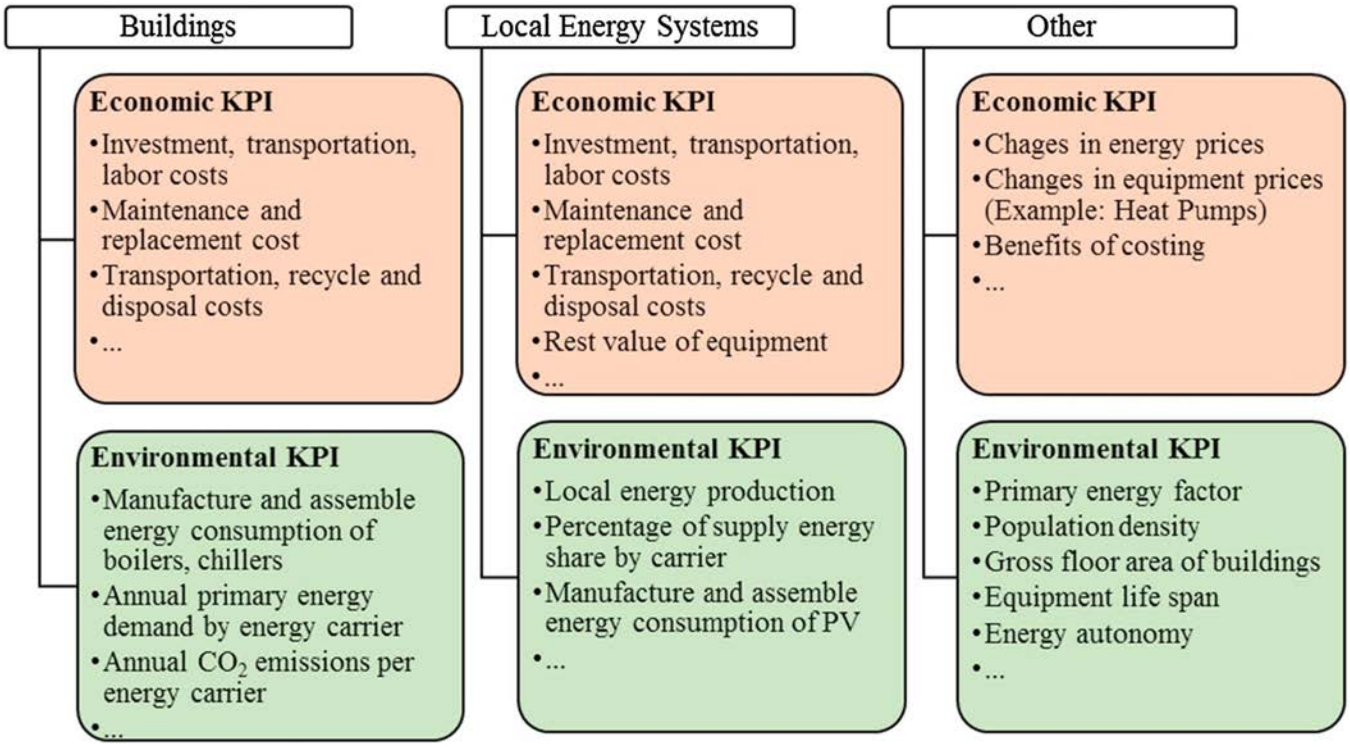

Figure 2. Categories and subcategories of LCPD based KPIs on assessing the neighborhood level energy systems with buildings

Applying the knowledge-based approach in this step allows the formation of neighborhood plans without going through time consuming processes and computational efforts.

- Step 4: Decision making: In order to choose a development scenario from among the set of other possibilities, the performance matrix is converted to the opportunity-loss (regret) matrix.

Using minimal performance in each category of the performance matrix, the regret matrix is obtained by applying the minimax regret method. By communicating the performance matrix with the opportunity loss matrix (Table 2), the decision maker is allowed to select a suitable development scenario.

Opportunity loss = |Best value – Actual value|

Best value (B_i) = Minimum value of each performance category
Example: $B_1 = \min(LCE_1, LCE_2, \ldots, LCE_m)$

In this manner, when all the scenarios are analyzed without giving a preference, the decision-maker is well-informed about what the scenarios are capable of and what the opportunity losses are. Most of the decision-making procedures found in the literature start with the decision-maker's interest. Thereby, some of the best value-compromise options could be exterminated.

The role of the decision-maker (building owners, consultants, policymakers) influences the acceptance of certain trade-offs and selection of the scenarios. For example, the building owners are most interested in the least cost scenario while policymakers are interested in the lowest CO_2 emissions scenario. Next, the robustness of the decision-maker selected scenario is identified by performing a probabilistic sensitivity analysis using Monte Carlo simulations. This implies the assignment of uncertainties to the knowledge-based probabilities.

CONCLUSION

The proposed methodology can be considered more than merely providential, since energy neutrality is an objective of the European building directives. It is easily used by decision makers to identify the robustness of the energy infrastructure developments at the neighborhood level.

When the pre-utilization and end-of-life stage of the energy infrastructural equipment are introduced in the decision-making methodology, it provides sufficient awareness to the decision-maker of how much energy, CO_2 emissions and costs are actually involved in the total transition process. This is rarely found in the currently available decision making methodologies. Additionally, the uncertainty assessment contributes to attaining robust energy systems in practice. ■

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On-site Energy Matching of NZEC District Energy Systems

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INTRODUCTION

BACKGROUND

The application of intermittent on-site renewable energy sources (such as solar and wind) in buildings leads to a mismatch between on-site renewable energy production and the local building load. European legislation dictates that all new buildings built from 2021 should be nearly zero-energy buildings (NZEB) [1].

This challenging legislation will lead to mismatches more severe than ever before. In order to meet the objective of NZEB annually, the on-site renewable energy systems must be enhanced significantly to reduce or compensate the energy imported from the grid. Taking the on-site photovoltaic (PV) energy with electrical grid feed-in as an example, a significant amount of energy should be exported to the grid in the summer time to balance the energy imported in the winter time, as shown in a brief example of Figure. 1.

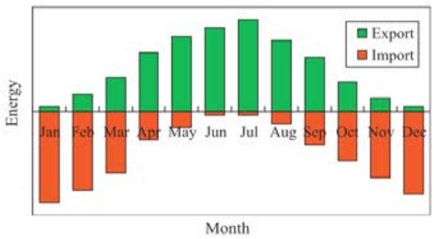

Figure 1. Mismatch profile that will occur with on-site PV generation in a NZEC configuration [2]

A new district in the city of Helmond will be realised in the near future, which shall incorporate a new approach of energy management. In the preliminary development report, a vision is given on the subject of energy management:
"The vision for smart district in Brandevoort is to become a zero energy city (ZEC) by incorporating concepts like energy sharing, energy storage and community based energy grid" [3]. In this case, a zero-energy city means a net zero-energy district, and implies that electricity and heat are fully provided by on-site renewable energy sources.

In turn, this will lead to an inevitable mismatch between the supply and demand of energy, thus creating the need for energy flexibility and energy sharing.

RESEARCH OBJECTIVES

In order to come up with a district energy system can deliver the most satisfying results for energy matching and self-consumption, the main research objective is as following:

• A comparison of a collective and an individual NZEC solution on the potential of on-site energy matching of renewable energy sources (RES) applied to the case study "Brainport smart district".

These two solutions have been selected for a comparison because of their fundamental difference in behaviour. For example, we assume that an individual system is not capable of seasonal storage, while a collective system is. This makes it an interesting case to see how seasonal storage will perform against the more conventional NZEB solution of an air-source heat pump.

To reach the main research objective, a few partial objectives are formulated to outline the research methodology. The sub-objectives are as following:

• Analysis of district energy demand and on-site RES generation: research on occupant behaviour, building performance, appliances and renewable energy sources.

• Study on technological solutions for the district energy systems, and create systems designs.

• Creating computational models to simulate and assess performance of two energy system solutions on on-site energy matching indices.

Figure 2. Location case district "Brandevoort" in the city of Helmond

CASE STUDY

The future district Brandevoort II, also known as Brainport Smart District, is located to the west of Helmond. The project shall be the pinnacle of innovation for Helmond on various topics such as health, transport, energy and environment. The district shall contain 1800 dwellings, a commercial area with offices and a secondary school. These respective building types have been incorporated into the case study, by modeling their energy behaviour in combination with a typical Dutch user-behaviour to create a representative energetic footprint that will be used in the district energy system models to compare energy matching performance.

DISTRICT ENERGY OBJECTIVES

The district has the objective to serve as an example project for future districts on the topic of energy. Therefore a high standard needs to be set, or in the words of the research group: a Zero Energy City, better defined: net zero energy community (NZEC). The energy performance of a net-zero community can be accounted for in several ways [4].

The most common definition used is net-zero site energy which is defined as the amount of renewable energy that is produced locally in the community by buildings and infrastructure, as is needed by buildings and infrastructure on annual basis. For transportation, the site energy needs would be based on a calculated or measured mileage of vehicles traveled by community occupants, regardless of whether they filled up their gas tank inside or outside the community.

As stated earlier, the definition allows for fuel switching so that excess renewable electricity generation can offset various fossil fuel use. The district will also be independent of natural gas, and therefore be all-electric in heating and cooling. There is also the possibility to share energy between residents. The district will also support the national grid, in terms of minimizing peaks in generation and loads. The performance of this objective is explained later on in the results.

ENERGY SYSTEM DESIGN

For the design of the district energy system, two concepts are applied: an individual variant where heat is generated by a stand-alone air-source heat pump allocated to every building, and a collective variant where heating and cooling is generated by a central system.

INDIVIDUAL VARIANT

For the individual variant, the air-source heat pump was the most appropriate. Ground-source and solar-assisted HP-variants were studied, but did not meet the requirements for this case study.

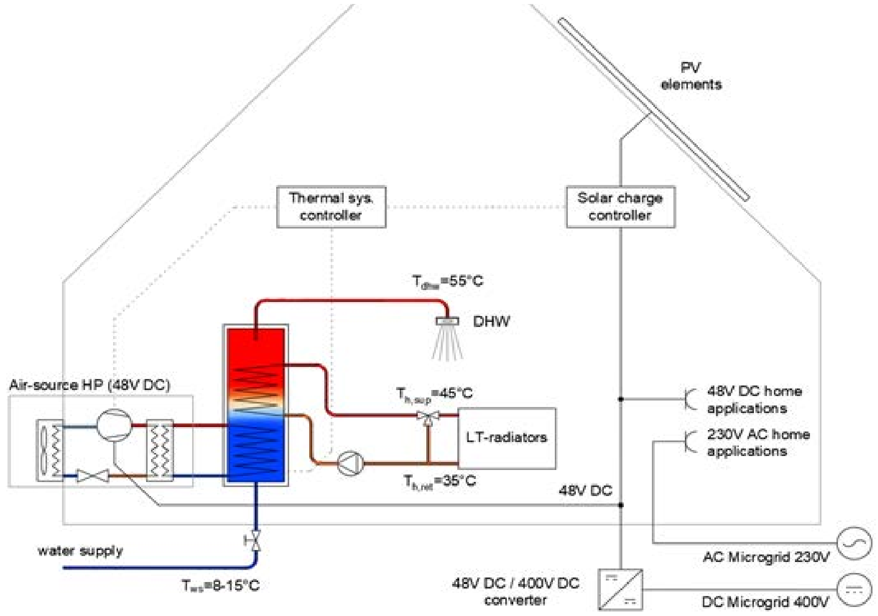

Figure 3. Overview of the individual variant of the residential energy system

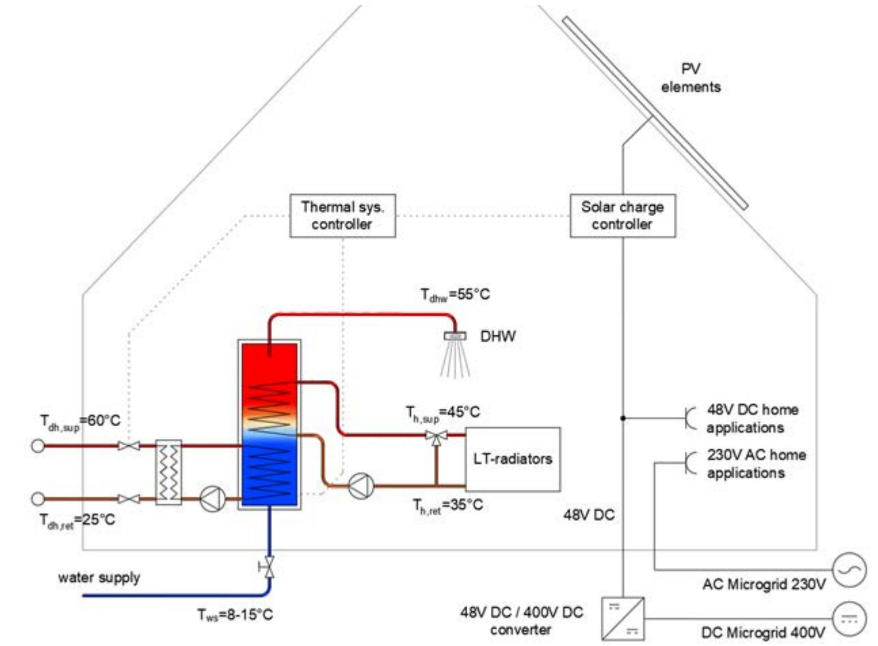

Figure 4. Overview of the collective variant of the residential energy system

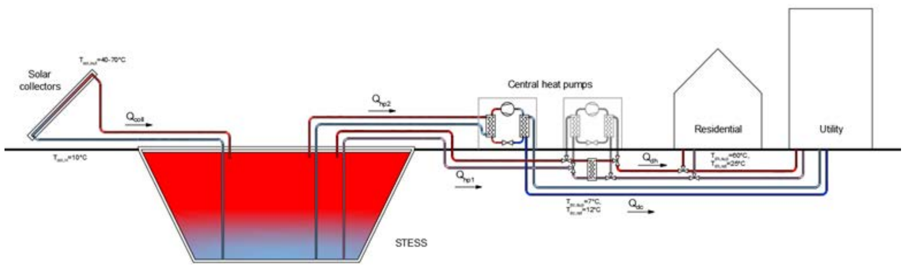

Figure 5. Schematic overview of the solar DHC plant during summertime

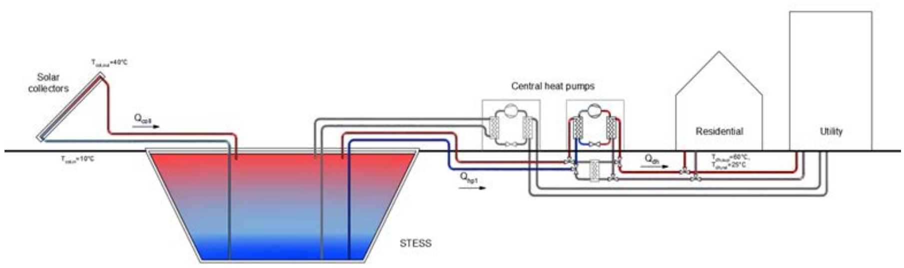

Figure 6. Schematic overview of the solar DHC plant during wintertime

For the electric part of the energy, system photovoltaics are used. They are connected to a 48V Direct Current grid in the buildings, Their energy can be efficiently converted to the district's central battery storage system via a 400V DC microgrid.

COLLECTIVE SYSTEM VARIANT

The collective variant was determined to be a solar plant equipped with seasonal pit storage. This energy concept has great potential and benefit over other collective energy solutions such as aquifer storage. Pit storage can attain higher temperatures compared to underground storage, which in turn leads to higher heat pump efficiencies, or even a heat pump by-pass during summer. The system works as follows: An array of solar collectors (18,000m²) generates heat, and during summer stores the surplus of heat in the STESS (seasonal thermal energy storage system). Temperatures in the top of the storage can exceed 70°C. This can then be directly used to feed the district heating (DH) system with a heat exchanger. During winters, the storage gets depleted of heat, and a heat pump is required to increase the temperature to the DH supply threshold of 60°C.

COMPUTATIONAL MODELLING

The district energy systems are simulated by modelling the behaviour of energy system components with a numerical computer model created and run in the MATLAB-Simulink environment. The model is verified based on data from manufacturers theory, and scientific papers describing system components such as the pit storage and the DHC network. The results of the simulations are expressed with the on-site energy matching and fraction performance indicators. These represent the cover ratio of generation and loading respectively. Also, the annual cummulative energy in the form of electricity import and export are compared with each other. The maximum and minimum values of power were noted.The results are divided into cases which represent different battery configurations. The base-case is also used to test the possibility of power-to-heat flexibility of both systems.

SYSTEM VERIFICATION

The validation of the energy systems was a very critical part of the research. The lack of data of a complete working system required the components to be validated individually. The pit-storage and solar collectors were derived from a research paper modeling and validating the Danish Dronninglund DHC project. Applying this data to our own model allowed for validation of thermal energy storage as well.

PERFORMANCE INDICATORS

The energy flexibility performance of both systems will be compared on three on-site energy matching indices. The

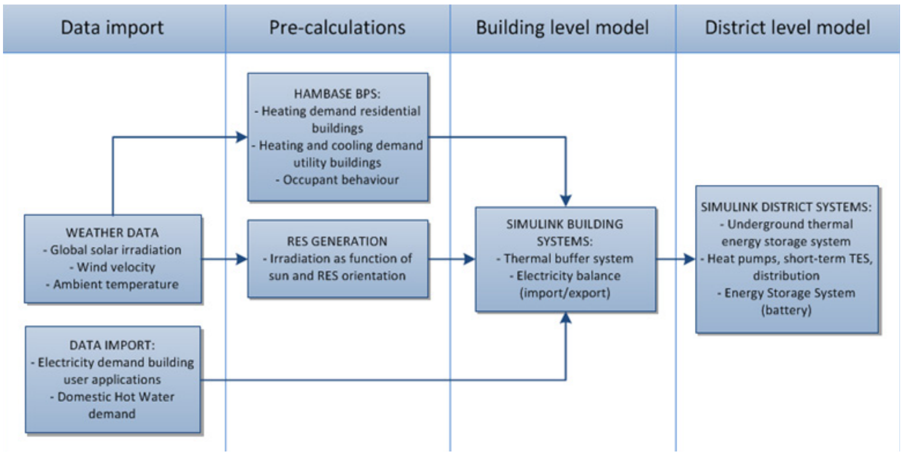

Figure 7. Modeling phases: Chronological order of simulating

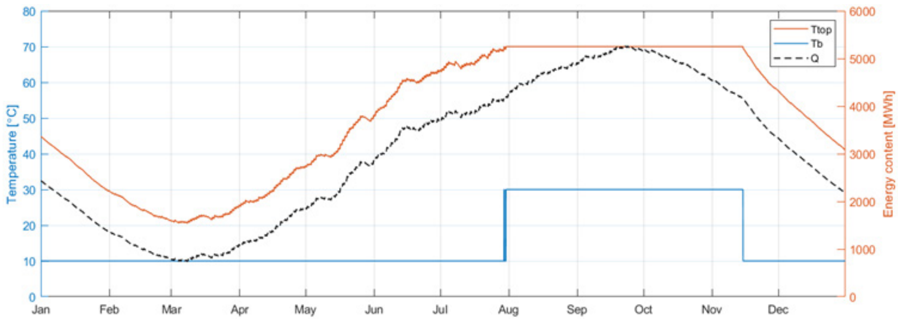

Figure 8. Temperature of the storage tank throughout the year

first indicator is the maximum power import and export from the local district microgrid to the national grid. The second index is the cumulative district energy import and export over the period of a year, and the third is the on-site energy matching and fraction.

The on-site energy matching and fraction are performance indices that quantify the system performance on self-consumption of on-site power generation. The on-site energy matching (OEM) index provides an indication of how much of the generated energy is comsumed instead of exporting it to the utility grid. The on-site energy fraction (OEF) determines what fraction of the electric load is covered by the on-site energy generation, as shown in Figure 9. The on-site energy matching indices are calculated with the following equations:

$$OEF = \frac{\int_{t1}^{t2} Min[G(t); L(t)]dt}{\int_{t1}^{t2} L(t)dt} ; 0 \leq OEF \leq 1$$

$$OEM = \frac{\int_{t1}^{t2} Min[G(t); L(t)]dt}{\int_{t1}^{t2} G(t)dt} ; 0 \leq OEM \leq 1$$

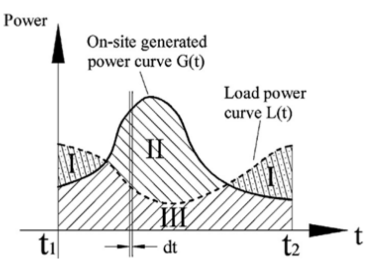

Figure 9. The generation and load curves representing the district [2]

RESULTS AND DISCUSSION

RESEARCH CASES

In order to get a better understanding of the possibilities that both variants of district energy systems can provide, the systems are configured and compared in four research cases:

- Case 1: No power-to-heat algorithm, no battery storage
- Case 2: A power-to-heat algorithm, no battery storage
- Case 3: Same as case 2, but uses a small battery storage (C = 6.6 MWh)
- Case 4: Same as case 2, but uses a large battery storage (C = 13.2 MWh)

First part of the results explain the behaviour of the energy flows within system, in order to explain the final results. The first research case serves as a base case for comparison. Neither the power-to-heat optimization nor battery storage is used, disabling the ability to shift power loads. The second research case incorporates a power-to-heat algorithm that will program the thermal systems to operate when it detects a surplus of generation by the PV panels. The third and fourth research cases use the same power-to-heat algorithm as in Case 2. However, energy storage in the form of a smaller and larger battery respectively are added.

Figure 10 and 11 display how the daily profiles of generation and loads differ between systems without and with battery storage. The results of different configurations are shown in order to provide an insight into the behaviour of the different research cases.

Table 1. System performance on RES self-consumption, numbers are on annual basis

SUMMARY (YEAR	CASE 1		CASE 2		CASE 3		CASE 4	
	COLLECTIVE	INDIVIDUAL	COLLECTIVE	INDIVIDUAL	COLLECTIVE	INDIVIDUAL	COLLECTIVE	INDIVIDUAL
IMPORTED ENERGY (MWH)	4331	5291	4228	4958	2801	3501	2515	3048
EXPORTED ENERGY (MWH)	4563	5037	4451	4862	3024	3406	2738	2989
OEMe	0.387	0.398	0.406	0.419	0.600	0.593	0.638	0.643
OEFe	0.392	0.387	0.414	0.415	0.612	0.580	0.651	0.636
MAX IMPORT (KW)	2644	3038	1778	2817	1778	2817	1778	2817
MAX EXPORT (KW)	6710	7637	6710	7652	6584	7388	6590	7414

Figure 11 adds a purple line which represents the behaviour of the battery. A value above zero means the battery is charging, below zero means it is discharging. The graphs on the left in Figure 10 and 11 represent the winter scenario, in which the little power generation is not enough to create a large offset for the battery to store energy. During the summer periods, displayed in the graphs on the right in Figure 10 and 11, the generation is too large for the battery to store. There is not enough load to discharge the battery on self-consumption, therefore the charging capability is also reduced. This indicates that there is a limit to applicable battery sizes.

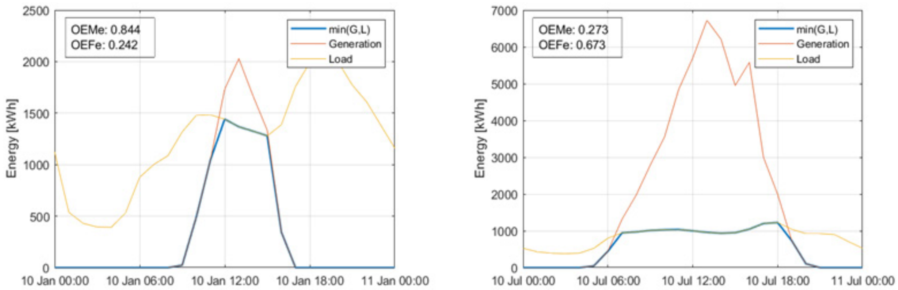

Figure 10. Daily results of the OEM and OEF indices, for the district systems without battery storage

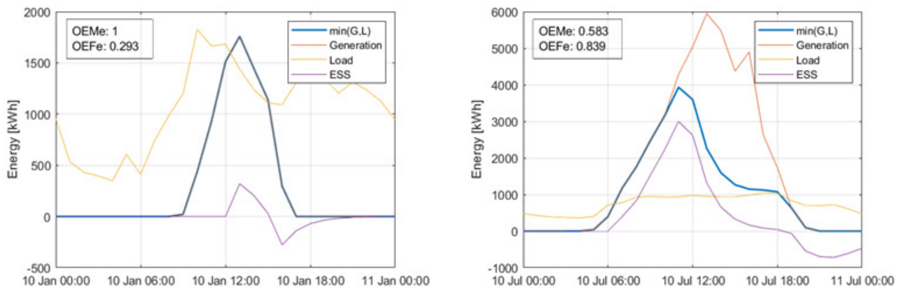

Figure 11. Daily results of the OEM and OEF indices, for the district systems equipped with battery storage. Left represents the winter and right the summer.

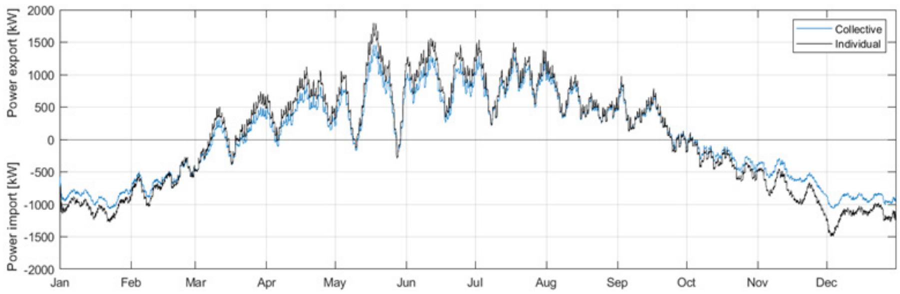

Figure 12. Comparison on the energy generation and demand between the collective and individual system variants

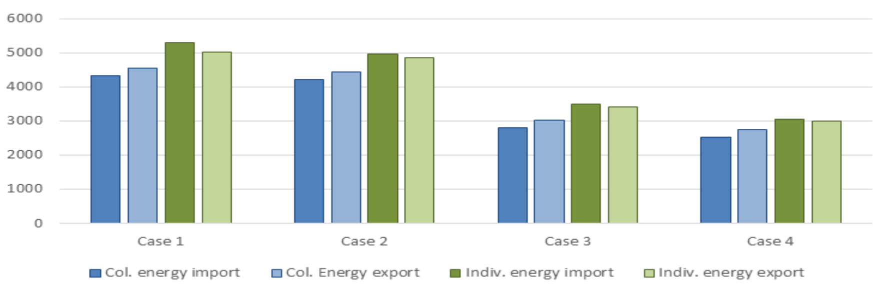

Figure 13. Comparison of the district annual energy import and export

CONCLUSION

In this study, two district energy system concepts were investigated on their energy matching behaviour. By applying them to a district in the Netherlands, the results could generate a useful indication for what system could be a feasible solution for the Dutch built environment. This was achieved by using representative local Dutch climate files and implementing representative Dutch residential occupant behaviour.

Individual and collective energy variants were designed and modeled by simulating component behaviours. The results indicate that the collective system requires less import and export of power from and to the national grid than the individual variant. This is mainly due to the fact that the thermal energy of the collective system can be stored seasonally and it greatly improves the efficiency of the thermal energy supply system. Therefore, the need for PV panels is reduced and energy peaks and dips become less pronounced. The results also show that an appropriately sized battery substantially improves the on-site energy matching and fraction within the district. This is mainly the case in-between seasons. During the winter and summer, the balance between energy generation and consumption is too far apart for the batteries to meaningfully decrease peak loads. ■

[1] Europese Unie, "Richtlijn 2010/31/Eu Van Het Europees Parlement En De Raad," vol. 2010, no. juni, pp. 13–35, 2010.

[2] S. Cao, A. Hasan, and K. Sirén, "On-site energy matching indices for buildings with energy conversion, storage and hybrid grid connections," Energy Build., vol. 64, pp. 423–438, 2013.

[3] L. van Buuren, K. Grooten, M. de Klijn, and S. Puranik, "Brainport smart district: A step towards future cities," Eindhoven, 2017.

[4] P. Torcellini, S. Pless, and M. Deru, "Zero Energy Buildings : A Critical Look at the Definition Preprint," ACEE Summer studay, vol. 2, p. 15, 2006.

[5] PlanEnergi, "Long term storage and solar district heating," 2016.

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Alumni At Work: Jeroen Houben

My name is Jeroen Houben, I'm a former member of Study association Mollier. I remember the day when I joined Mollier in 2004- we were a pretty small group, and in the end, the very last ones that fully graduated from the entire Bachelor-Master Building Services. I often think back with great pleasure about the coffee times in the morning and the beers in the afternoon. Of course, not to forget the great study trips, with our unforgettable bus driver 'Wout' in the early years of my Bachelor, and the trips far abroad in later years!

I graduated at Volantis, where I already had a one-day-a-week job during my student time. Afterwards, I could start directly as junior sustainability/building services consultant. During my time at Volantis, I learned a lot and was involved in feasibility studies, simulation studies, and consulting for a variety of projects, including office buildings, educational buildings, dwellings and multifunctional real estate.

In 2012, I left Volantis in order to explore more of the building industry and I went to the Christiaens Group. Christaens Group is active in the field of turn-key mushroom growing facilities, waste management factories and food digesters.

Their unique combination of worldwide projects and total-installer approach made me decide to make this career move. The work I did there was a combination of developing business standards, research and development projects, and regular project work. For example, we developed new techniques to make growing facilities more energy efficient by including heat pump technology. We built mock-up test rigs to investigate new substrate bed heating and cooling technologies, and we investigated new automated irrigation systems.

In the end, I realized that I missed the diversity in clients, technology and projects that I encountered in Building Services consulting, as I was used to from my past at Volantis.

Therefore in 2014, I started to send some open job applications to a number of companies and I chose to work as an integral design consultant at Nelissen ingenieursbureau in Eindhoven. I'm still working with great pleasure at Nelissen in a nice ambience on a variety of projects, ranging from office buildings, museums, university buildings to concert halls and everything in between.

The role I fulfil is very diverse, comprising of doing tender projects. Where I develop and present design visions, R&D projects, coaching interns and trainees, but also regular project work such as developing energy concepts, feasibility studies, total-cost-of-ownership studies, writing preliminary design and detail design documents, etc.

Moreover, in the majority of the projects, I fulfil the role of integral design leader, forming the main link between the design team and our internal Nelissen project team. In addition, I am also concerned with research and development activities in order to keep exploring new innovative technologies in our projects.

To give an example, we realised the first river-water heated and cooled secondary school in the village of Cuijk – Merlet College – one of the projects I am very proud of.

Figure 1. Merlet College Cuijk, one of my integral projects, where we designed an innovative heating/cooling system using water from the Maas river.

In my leisure time, I like to play piano, have drinks with friends and go road cycling now and then,. and not to forget, at least once a year, I go skiing in the Alps. I can't skip that one for sure! ■

Figure 2. On winter holidays, skiing in the Italian Dolomites (Val Gardena)

Indoor Climate is not the only Factor for a Healthy Building

Author
Deerns

Healthy buildings are the centre of interest in the global construction and real estate market. Where is all this interest coming from? What does Deerns mean by a healthy building? And what does this mean for the design and construction process?

On average, people spend ninety per cent of their time in buildings. That is why the Netherlands applies rules for the construction and renovation of buildings for, among other things, the indoor climate. The Buildings Decree imposes architectural and technical installation requirements that, for example, guarantee sufficient daylight and clean air and protect users against too much external noise or noise from installation systems in the building. In other words, the Buildings Decree prevents people from becoming ill through buildings, such as in the 1980s. But can buildings that do not make people sick really be classed as healthy? In Deerns' vision, buildings are not healthy unless they promote the health of its users. Users feel so comfortable in healthy buildings that they clearly learn, work or heal better. Our ambition is to achieve buildings that give users energy. 'Energy producing' buildings leave you with more energy after a day's work or learning than when you entered it in the morning.

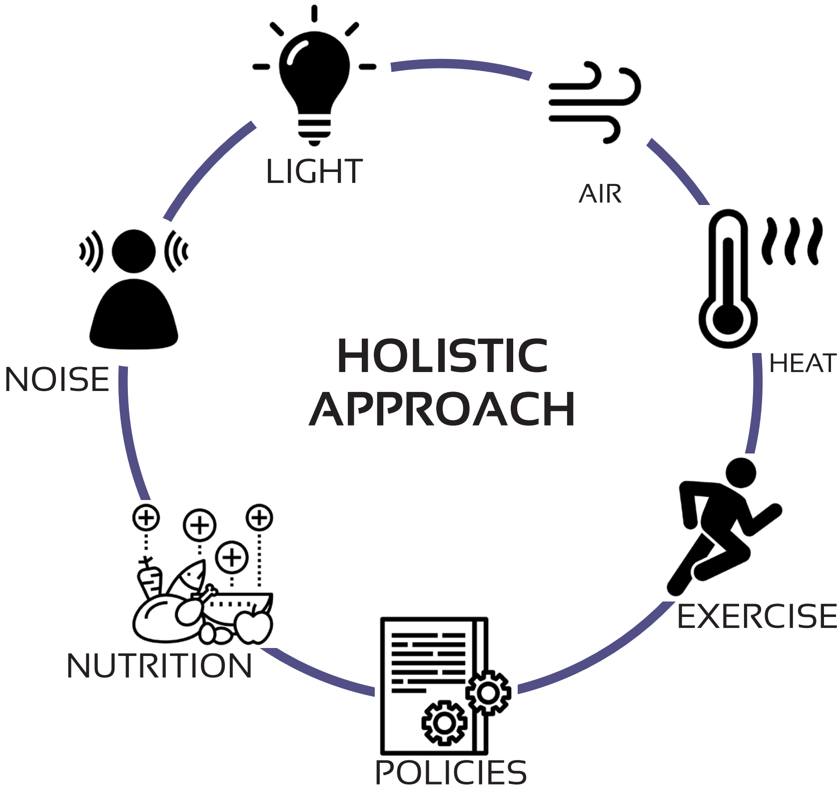

Figure 1. Holistic Approach

HOLISTIC APPROACH

In our view, a comfortable indoor climate – a total sum of optimum quality of light, air, noise and warmth – forms the basis of every healthy building. There are also other factors that have a great impact on the health of building users such as exercise, nutrition and personnel policies. That is why Deerns designs healthy buildings from a holistic approach. We create the best possible indoor climate: By not applying building materials or other materials that contain volatile organic substances, or by applying a particulate filter. By, together with the architect, creating an acoustic design whereby we look at the global layout of the building, at busy and quiet zones. And by creating lighting through a combination of natural daylight with optimum artificial lighting that follows our natural sleep-wake rhythm. In our design we also include other health aspects, such as exercise, nutrition and personnel policies. We encourage exercise with fitness rooms, desk bikes and sit-stand desks or by making it attractive to walk up and down the stairs. We offer building users healthy food in the company restaurant. Fruit and vegetables are preferably from a company's own garden, because people demonstrably eat more healthily when they grow their own. We also take HR measures that improve physical health, varying from ergonomic workplaces, flexible working hours and locations (working from home) to a healthy workload.

SMART AS AN ENABLER

In our view, healthy buildings are also smart. Building systems and installations communicate through the Internet of Things (IoT) with the user. Climate and lighting installations recognise the user's preferences through their smartphone, for instance. They automatically adapt the colour and intensity of the lighting and the temperature in a workplace. That same IoT technology helps users to exercise more. A desk chair with sensors advises a user to go for a short walk by monitoring sitting hours. A building navigation app proposes a route that avoids lifts and thus encourages using the stairs. And a company restaurant application can recommend your meal based on your BMI or a diet. Smart, healthy buildings function as a user's personal assistant and generate a large amount of big data. Data on preferred settings of climate systems can be used to further optimise climate control.

Big data also gives insight into the energy consumption of a building. Using this information, we strive to achieve an optimum balance between healthy building functions and energy efficiency.

EVERYONE FITTER

Deerns believes in healthy buildings because everyone becomes fitter, financially or physically: the employee, the employer and the building owner who lets out the building, but also the health insurer. Employees benefit health-wise particularly; they feel physically and mentally fitter. This translates into higher labour productivity and lower absenteeism. And that benefits the employer. The labour costs (for an office, on average about 70% of the total operating costs for an employer) will consequently decrease, according to research conducted by Deerns into the impact of healthy buildings on productivity and absenteeism in office buildings. A healthy building is also good for an organisation's employer branding; working in a healthy building is attractive to employees. The building owner also benefits from a healthy building. He can have the building independently assessed to establish how healthy it is using the WELL Building Standard. A good rating will make the building distinctive in the market, resulting in a higher market value. Finally, society as a whole will benefit. Healthy people need less health care, which will save on health care costs.

HEALTH DIRECTOR

The many factors that affect the health of a building user (indoor environment, exercise, nutrition HR) lead to many parties gathering around the table during the design and construction process. In addition to the traditional chain parties, other specialists, such as an occupational health and safety physician, ergonomist, landscape architect, facility manager and HR manager, also participate. That requires integrated cooperation under the leadership of a 'health director', a consultant who takes all the interests into consideration based on ambitions and budget. Deerns fulfils this role. From our experience with sustainable projects we know how to realise as healthy a building as possible with minimal investment; a building that changes with the circumstances, if necessary, and thus retains its value. In addition, we combine expertise in the field of building physics and MEP design with know-how on smart buildings and WELL. This is how we lay the foundations for a healthy building and, together with other parties, arrive at extra, smart and healthy solutions. These are necessary to make the transition to a healthy building. By combining scientific research with market research we are capable of developing healthy building concepts. Deerns carries out research into the concrete health effects of buildings and identifies market needs. In the coming years, office buildings and multi-tenant commercial buildings will take the step towards healthy. At a later stage, buildings with public and semi-public functions, such as government buildings, schools and hospitals, will become 'healthy'. How fast or how slow healthy construction will gain a foothold remains to be seen. Healthy buildings do not materialise as a result of purely economic reasons (higher productivity, distinctiveness), but also as a result of worldwide social trends such as healthy ageing and social corporate responsibility. But, as far as we are concerned, healthy construction is here to stay. ■

The International WELL Being Institute (IWBI) has developed an assessment method based on medical-scientific research for healthy buildings: the WELL Building Standard. The aim is to make buildings even healthier and thereby provide a better living environment for their users, resulting in higher productivity and lower absenteeism. WELL has building health scores in the categories Air, Water, Nourishment, Light, Fitness, Comfort and Mind. A final assessment results in one of the three WELL certificates: Silver, Gold or Platinum. For the moment, WELL only offers assessments for office buildings, but other building types, such as hospitals, residential buildings and hotels are expected to follow.

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Cooling of a Smoke Layer by a Sprinkler Spray

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INTRODUCTION

Computational Fluid Dynamics (CFD) models are increasingly used in building design. In the context of fire safety engineering, CFD models have proven to be useful for the prediction of smoke transport in buildings in case of a fire. In a fire scenario where sprinklers are activated, the temperature and movement of the smoke layer is subject to the sprinkler spray. Fire suppression by a sprinkler spray can be distinguished in three regions, namely the interference of water droplets with the fire plume (flame), the smoke plume, and the smoke layer. This graduation project focused on the interference with the smoke layer.

By spraying water directly into a smoke layer, it may cause diffusion and descension of the smoke. This phenomenon is called smoke-logging and was introduced by Bullen in 1974. According to Bullen, the stability of the smoke layer depends on the ratio between the drag force (D) and buoyancy force (B) on the smoke layer. Smoke logging will occur when D>B, otherwise the smoke layer will remain stable [1]. Smoke logging can potentially result in a decrease in the efficiency of a smoke extraction system [2] and compromised egress routes.

In the past, the effects of water droplets on a smoke layer have been studied with numerical models and experiments. The volumetric flow rate of smoke going upwards decreases due to a sprinkler spray due to the cooling effect of the water droplets [3]. So far, numerical simulations are performed with an evenly distributed water mass and velocity within the spray envelope. However, separate studies by Sheppard and van Venrooij indicate irregular water droplet distributions within the spray envelope for both elevation angle and azimuth angle, which is strongly dependent on the geometry of the nozzle [4], [5]. Further development of CFD-models and more experimental data is required to validate the CFD-models.

The Fire Dynamics Simulator (FDS, v6.6.0) is developed to model low-speed, thermally-driven flows with an emphasis on smoke and heat transport caused by fires, unlike other CFD software packages such as ANSYS Fluent and Phoenics [6]. However, the results obtained from these simulations need to be treated carefully since the reliability of the outcome can be uncertain. A careful validation is necessary before applying the results to (non-)academic engineering problems.

The main research objective of this study is to gain insight into the cooling effects of a sprinkler spray on a smoke layer. Subordinate to the main objective, numerical simulations in FDS are attempted to be validated by acquiring experimental data. In addition, the study aims to gain insight into the influence of different sprinkler spray patterns by varying the water flow rate.

METHODOLOGY

EXPERIMENTS

The experimental set-up (Figure 1) is based on earlier conducted studies with similar research objectives [3, 7, 8]. The set-up consists of two connected cabinets. In the combustion cabinet , smoke is generated by a fire. The smoke flows into the smoke cabinet where a smoke layer is formed. This smoke is then extracted by a mechanical fan. In the exhaust duct, the smoke is analysed to determine the heat release rate (HRR) of the fire. When a stable smoke layer is formed, the sprinkler spray is activated to cool the smoke layer.

Smoke and heat is generated by pool fires. In total, nine experiments were performed with heptane as a fuel for two different pool sizes ($0.25m^2$ and $0.35m^2$).

In the middle of smoke cabinet, a pendant sprinkler nozzle is placed at a height of 2.9m. The sprinkler with an orifice diameter of 11.1 mm has a K-factor of 80.6 L/min√bar and a 25mm deflector plate diameter. The sprinkler spray is activated manually and the operating pressure at the sprinkler nozzle is controlled by pre-set pressures of the pump's frequency controller.

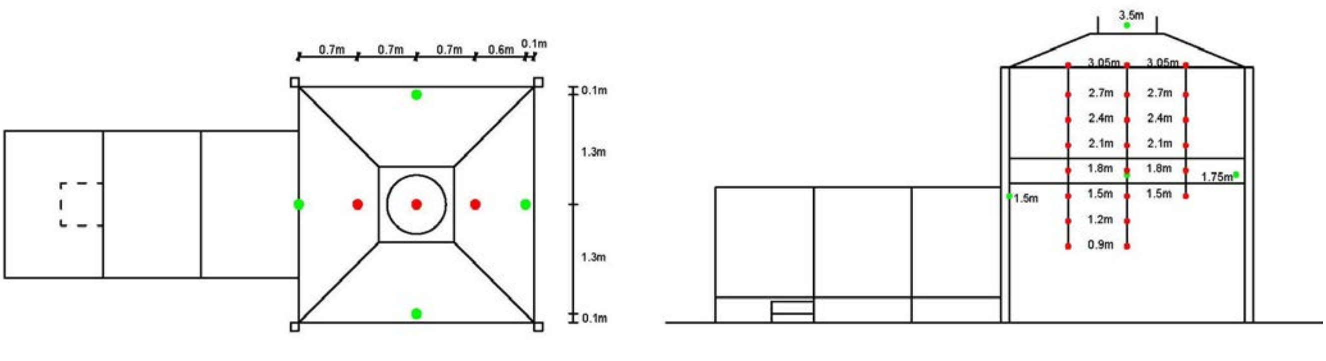

Figure 1. Positions of thermocouples; top view (left) and side view (right)

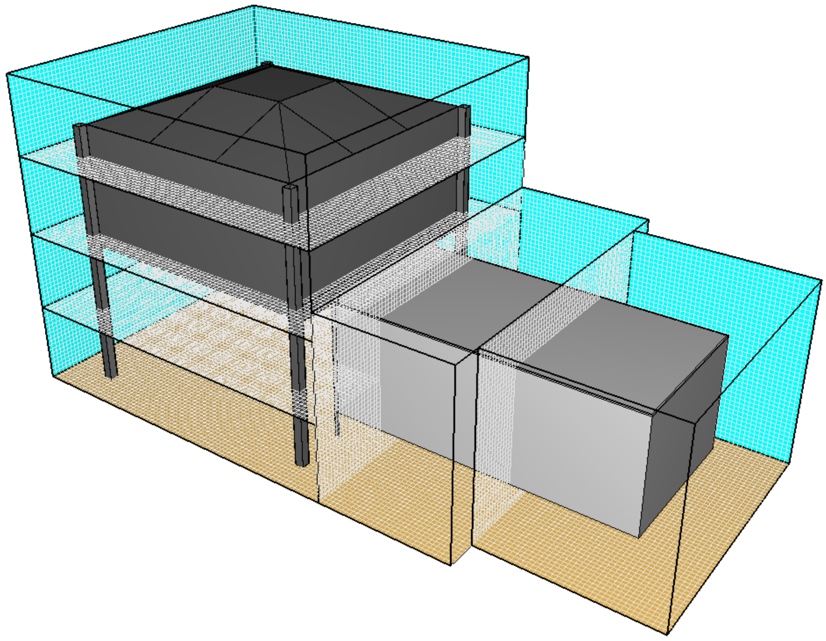

Figure 2. Computational domain divided in sub-grids for MPI processing

The smoke cabinet is equipped with a thermocouple array. To prevent the thermocouples from wetting, aluminium conical shields were placed above the thermocouples.

The combustion products are analysed in the exhaust duct to determine the HRR with the Oxygen Consumption Calorimetry (OCC) method. This method is similar to the described method in NEN-EN 13823+A1:2014 (Reaction to fire tests for building products) [9]. The following quantities are measured in the exhaust duct: temperature, differential pressure, O_2-concentration and CO_2-concentration. Humidity and atmospheric pressure are measured at the start of the experiment. With these quantities, the volumetric flow rate, the oxygen depletion factor, the ambient mole fraction of oxygen in dry air, and the HRR have been calculated.

NUMERICAL MODEL

The flow of a fluid can be described by the Navier-Stokes equations, a system of partial differential equations. For the modelling of turbulence, FDS uses the Large Eddy Simulation model (LES-model). In this approach, transport equations are solved for the large eddies and an eddy viscosity model (turbulence model) is used to model small eddies.

The mesh is restricted to rectangular Cartesian grids in FDS. The modelled physical space is divided into a uniform grid with approx. 600,000 cubic cells of 50mm to solve the low Mach number equations. It is assumed that within each cell, quantities as the gas velocity, temperature, pressure etc. are uniform and only change in time.

The HRR is calculated from the exhaust flow measurements and used as non-stationary input for the CFD model. The default 'simple chemistry' combustion model was used to determine the reaction products. This single-step mixing controlled chemical reaction contains three lumped species, namely air, fuel and products. A lumped species is a group of primitive species, e.g. air consists of oxygen, nitrogen and insignificant amounts of water vapour and carbon dioxide. The model requires the number of carbon, hydrogen, oxygen, and nitrogen atoms, along with the soot yield and carbon monoxide yield to determine the reaction products [6].

The spray pattern of a sprinkler can be defined by characteristic diameters and statistical size distributions [8]. In numerical simulations, the water droplets are assumed to be spherical. However, in practice, water droplets are not fully spherical. Therefore, the volume diameter can be described as the diameter of a sphere having the same volume as a droplet. The volume median diameter separates the higher half of the volume diameters from the lower half. The volume median diameter differs for different types of sprinklers and water pressures [4].

When a sprinkler nozzle is activated and the water flow hits the deflector, the water volume is scattered into small droplets, called sprinkler atomization. To avoid the simulation of the complex atomization phenomena, sprinkler droplets are introduced in the model in a spherical surface at a fixed distance from the sprinkler nozzle. The trajectory of a water droplet after injection at the spherical surface is calculated with the Lagrangian approach.

The centre of the sphere represents the sprinkler nozzle. The injection surface is divided into smaller surfaces by defining multiple elevation angles and azimuth angles. For every injection surface, the velocity and mass fraction are added to model a realistic spray pattern. In numerical simulations, it is impractical to follow the motion of every single droplet in the sprinkler spray, therefore a particle injection rate (N_p) is prescribed. A large group of real droplets are then represented by a computational Lagrangian particle [10].

Bucket tests in an open space are performed to model the sprinkler pattern. A mathematical model is used to translate the water collection at the floor into the abovementioned injection properties for the spherical injection surface. The 'spray table' is implemented in the FDS-model to model the sprinkler spray. The results of the bucket tests are compared with the FDS predictions and subsequently the spray pattern table is improved by 'trial-and-error'. The spray table of the best-fitted results is used in the final simulations.

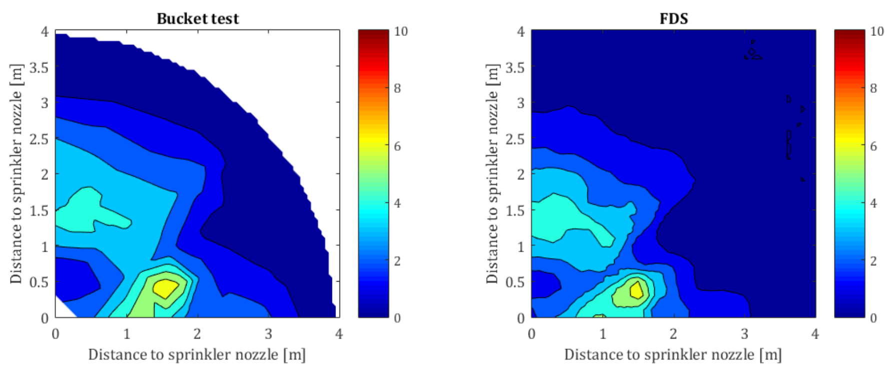

Figure 3. Water collection at floor (lpm/m2), Bucket test (left), FDS (right)

RESULTS

EXPERIMENTS

A smoke layer with an average temperature of approximately 150 - 160°C is reduced by 50°C, 70°C and 90°C for water flow rates of 56 l/min, 71 l/min and 93 l/min. In Figure 4, the average smoke layer temperature is shown of experiment SH2 (56 l/min). The sprinkler is manually activated, this is indicated by the dashed lines. The expected temperature curve without sprinkler activation is shown by the blue, dashed line. During all experiments, the HRR of the fire keeps slowly increasing during sprinkler activation, resulting in a small temperature increase of the smoke layer during sprinkler activation. It takes around 50 seconds for the smoke layer to reach its 'minimum' temperature and at this point the smoke layer is cooled down by 45 – 50 °C compared to the expected temperature without sprinkler activation. Once the sprinkler is deactivated, the temperature starts to increase again till the fire is terminated.

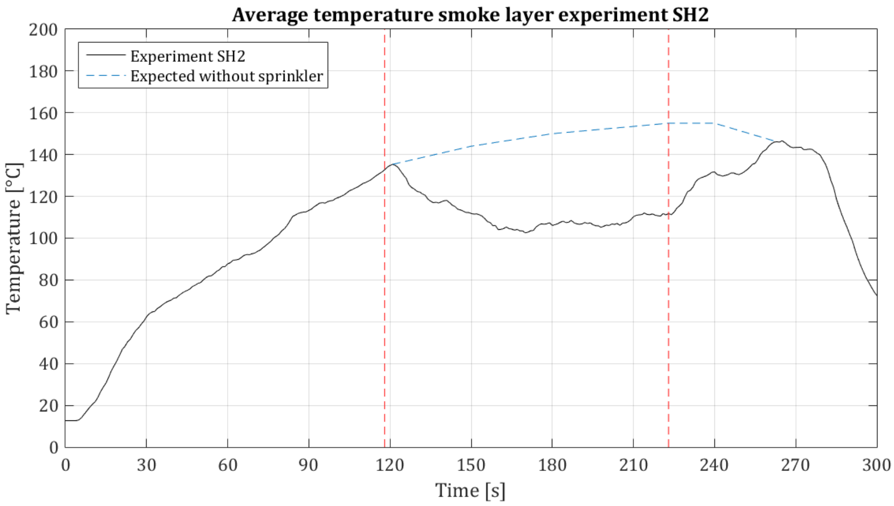

Figure 4. Average smoke layer temperature sprinkler test heptane 2 (SH2)

SIMULATIONS

To examine the cooling of the smoke layer in FDS, the CFD-models were simulated twice. The first run includes the sprinkler spray. In the second run, the same simulation is performed but without the sprinkler spray. In Figures 5 and 6, the simulation results corresponding to experiment SH2 and SH3 are shown.

In the development phase of the fire, FDS predictions and the experimental results of SH2 show good agreement. Thereafter, the average temperature in the simulations increase faster and at sprinkler activation, the temperature is approximately 20°C higher. The blue surface in Figure 5 shows the cooling of the smoke layer by the sprinkler spray in FDS. After 15 seconds of cooling, the temperature starts rising again with the sprinkler still active. This effect is caused by the increasing HRR. During sprinkler cooling in FDS, similar trends for temperature decrease and increase can be seen between the sprinkler model and model without a sprinkler. The temperature difference between those curves remain constant, with an average cooling of 26°C. Where the temperature remains rather constant after its minimum is reached in the experiment, the predicted temperature in the model is higher at sprinkler deactivation than it was at activation.

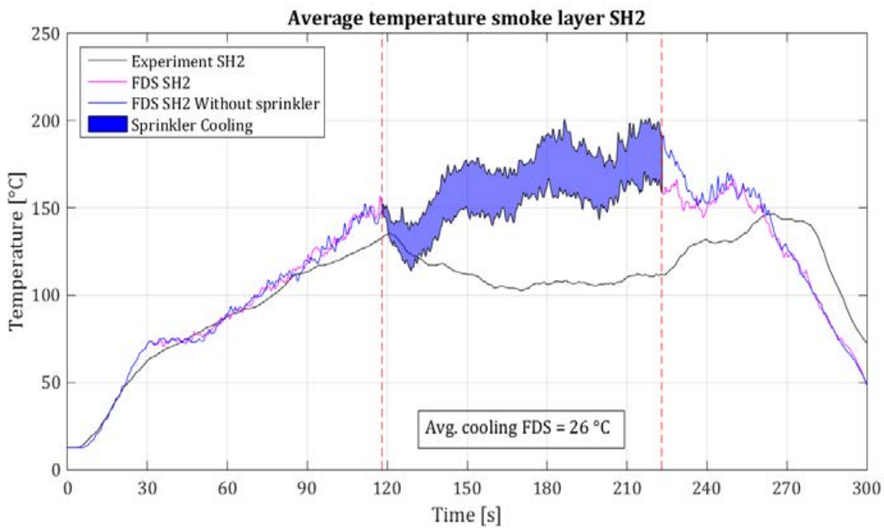

Figure 5. FDS predictions of average smoke layer temperature SH2

To study the influence of cell size, for SH3, a coarse grid is created in the sprinkler region with cells of 10x10x10cm. The cell size in the burner region is maintained equal to the previous models with a fine grid size of 5cm. The results show that the underprediction of the average smoke layer cooling is larger than for the model with a fine mesh with cell sizes of 5cm, however this is no significant difference.

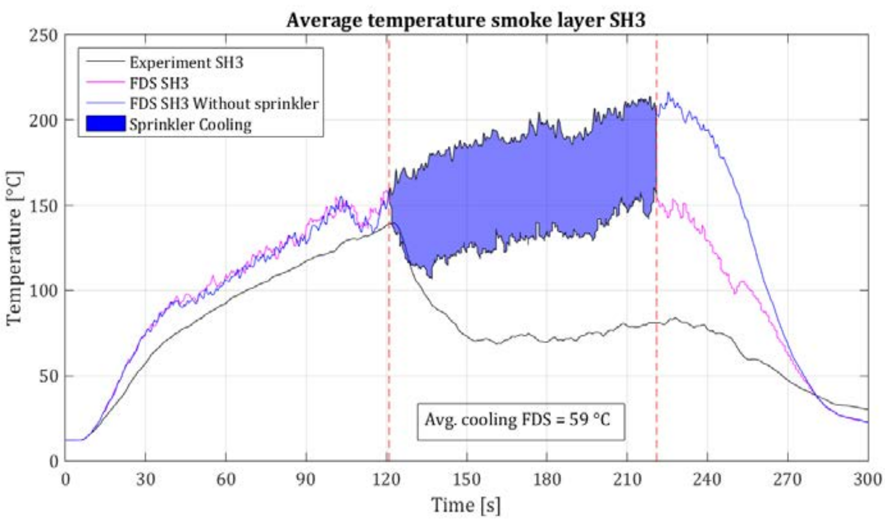

Figure 6. FDS predictions of average smoke layer temperature SH3

Figure 7. Smoke logging, water flowrate 56, 71 and 93 l/min

Also, a simple sprinkler spray pattern is used to see if the complex sprinkler spray model results in better predictions. In the simple spray model, the spray envelope is not divided into small surfaces and a Gaussian distribution is applied between an elevation angle of 0° and the maximum elevation angle.

The difference of 2°C in smoke layer cooling with the sophisticated sprinkler model is negligible. However, the simple sprinkler spray drags more smoke down, meaning the average temperature of the smoke layer is more difficult to compare to the measurements. The results of the different models are given in Table 1.

The results for the models with coarse grids are contradictory. More energy is transferred to the water particles, but the temperature decrease is smaller than for models with a finer grid and lower. This implies that with a coarse grid, other forms of energy transport are underpredicted. Additional research is required to gain more insight into these effects.

It can be seen in Figure 7 that the smoke logging effect increases when the water flowrate is increased. For a flow rate pressure of 56 l/min bar, almost no smoke logging was observed, whereas for 93 l/min, a diffuse smoke layer reduces the visibility significantly.

CONCLUSION

This study has shown the limitations of FDS when used for predicting the effects of smoke layer cooling caused by an activated sprinkler nozzle. Multiple experiments with and without sprinkler activation are performed and thereafter simulated with FDS. The injection of water droplets into the sprinkler spray reduces the smoke layer temperature. The experiments show that increasing the water flow rate of the sprinkler nozzle results in a larger temperature drops. The thickness of the smoke layer increases within the sprinkler spray envelope. A water flow rate, with relatively large droplets causes a very small amount of smoke logging, whereas a flow with smaller droplets, results in an unstable smoke layer and significantly reduced visibility. It can be concluded that smaller droplets amplify the downward smoke displacement.

All simulations that have been carried out with FDS underpredicted cooling by the sprinkler spray. The spray pattern that was modelled corresponded with a measured water distribution at the floor surface. Simulations with a low-detailed, simple spray pattern did not result in significant differences for the smoke layer cooling. Regardless of the level of detail from the sprinkler spray, the models embedded in the FDS code to solve the numerical equations are not capable of predicting the smoke layer cooling by water droplets.

The non-dimensional expression between the characteristic fire diameter and cell-size is often used to express a coarse, medium or fine grid. However,, even for 'fine' meshes, this ratio is dependent on fire size and results in a relatively large cell size for large fires. The numerical simulations showed that in the sprinkler region, coarsening of the mesh results in less accurate results. Therefore, the non-dimensional expression is not always applicable in the sprinkler region, meaning that the modeller needs to make a well-considered choice in this region.

Cooling of the smoke layer by a sprinkler spray is underpredicted in the FDS simulations, which results in a conservative outcome when studying the smoke layer temperature. In practice, the combination of conservative outcomes, high computational times, limited information about water droplet distributions and the required level of understanding, makes modelling sprinkler cooling with FDS less feasible. ■

Table 1. Energy transferred to water particles and temperature decrease

Case: SH3	$Q_{particles}$	Avg. cooling (ΔT)
Fine grid + Complex pattern (reference)	102 kW (-)	59 K (-)
Coarse grid + Complex pattern	107 kW (+5)	53 K (-6)
Fine grid+ Simple pattern	95 kW (-7)	57 K (-2)
Coarse Grid + Simple pattern	108 kW (+6)	48 K (-9)

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De Stichting PIT zet zich in voor promotie en innovatie binnen de installatiebranche. Wij financieren projecten die in technisch, economisch of wetenschappelijk opzicht vernieuwend zijn. Dat doen we voor organisaties die zich zonder winstdoelstelling bezighouden met onderwijs en kennisontwikkeling in de branche. Denk bijvoorbeeld aan universiteiten en onderzoeksinstituten.

Zo draagt Stichting PIT bij aan het genereren van nieuwe kennis en innovatieve ontwikkelingen waarvan de gehele installatiebranche kan profiteren. Daarbij moet altijd sprake zijn van substantiële cofinanciering. Zo waarborgen we dat er binnen de branche draagvlak bestaat voor onderzoeken en projecten die door de Stichting financieel worden ondersteund.

Ice Breaker: Sietse de Vries

In September of this year, I started the master track of Building Physics and Services, and by doing so, I became the only one from my bachelor year (2015-2016) that chose this specialization, as far as I know.

I grew up in a small village in the beautiful province of Fryslân, in the north of the Netherlands. Three years ago, when I was eighteen years old, I moved to Eindhoven to study the bachelor Architecture, Urbanism and Building Sciences at the TU/e. While the transition from the quiet countryside to the lively Eindhoven seemed harsh, I felt a good bond with the city, its people and the university. Like many other bachelor students, I chose this bachelor due to a fascination with the built environment. During the study, I spent a lot of time contemplating which specialization I wanted to focus on. As was already somewhat clear before I started the program, my main interest lay within the technical aspects of the built environment. However, after following a lot of Structural Design courses in my second year, the specialization did not seem like the perfect fit. In my third year of my bachelor, I decided to switch completely to the underdog within the study program, Building Physics and Services.

Within Building Physics and Services, my biggest interest is in Building Lighting, which is also what I would like to focus on during my masters. In line with this specialization, I also have an interest in lighting technology in a broader context.

During my bachelor, and currently still am, I have been a fairly active member of CHEOPS, the study association of the built environment. Apart from organizing the ski trip and being a member of some small committees, I also designed and made the LED wall elements of the Skybar! Underground Lounge. In December 2017, I got the opportunity to lead team IGNITE, a student team formed as a collaboration between CHEOPS and Lucid, the study association of Industrial Design. As a team, we want to design one of the main light installations for Eindhoven's annual GLOW festival. We want to create a unique visitor experience which combines interesting architecture and interaction with a sculpture. For GLOW 2018, we are creating a relatively small installation for research purposes. For the next edition of GLOW 2019, we hope to execute our main installation, which we have been designing for the past year.

Figure 1. First construction test of Team IGNITE's GLOW 2018 installation

Apart from academics, I enjoy spending time outdoors, having a beer with friends, working part time as a student assistant, and cooking. For someone coming from the flattest country on earth, it may sound a bit unnatural, but I really enjoy being in the mountains, hiking with amazing views during the summer and skiing in the winters. If there ever is a dedicated Mollier ski trip, I would totally be in for it.

Figure 2. Hiking near Wapta Falls, Canada

Furthermore, I play tennis, squash and recently ran two half marathons, with Eindhoven's being the latest, would like to run the marathon of Rotterdam next year.

In the past year, managing Team IGNITE took up a considerable amount of my time. However, I personally think that experiences gained by expanding are much more valuable than just theoretical studying. Hence, I am not particularly keen on completing my master track in a hurry. In the upcoming years, I would like to broaden my knowledge and experiences by doing more than just academic courses. Moreover, I would like to do an internship abroad in two years and possibly be in the next board of Mollier!

I would like to thank Mollier and its members for giving me a very warm welcome and I do really look forward to meeting more of its members! ■

Figure 3. Completed GLOW 2018 Installation

Abroad: Field work in Delhi

Author
ir. Jill Vervoort

To be honest, India didn't sound like my cup of tea. Since the land, culture, and climate do not really stroke with my personality. I love structure, I like an efficient full program, I dream about making a better world; and whilst striving towards my goals, I need my personal space. These things do not yet fit in with India's culture. However, when I came across this graduation project I just couldn't turn it down.

My graduation project was on healthy nearly zero energy building designs for governmental schools in Delhi. The project was supervised by BBA Binnenmilieu bv, and we worked together with Santrupti engineers pvt ltd. Santrupti, who were hosting my stay, gave me the opportunity to explore the 'real' India. Believe me when I say that everybody is most helpful and humble to work with me (I am still not sure if it is because of the foreign looks though).

Figure 1. Measurements in a classroom together with my collegue Priyanshu (Left) in Delhi

As expected, personal space and structure was nowhere to be found. Additionally, it was hard to get things set for my fieldwork. There was a lot of paperwork involved in order to get into the government schools, and still they managed to keep me out.

Luckily there was enough to do around there. I either hung out at tourist attractions or I tried to blend in with some locals going to yoga classes and cafés. A good thing was that the festival season had recently started (October). I noticed there were all kinds of different religions or different ways of celebrating one religion. Religion and family still play a big role within India's culture. By the way, did you know each region has its own language and culture. In my last two weeks I got the chance to explore few of those regions outside Delhi. Every place was a different experience each time.

The art of getting to know a bit of the 'real' India: stay normal. Don't act like a selfie-queen, stop staring, forget about the culture shock. Yes, there is a lot of chaos, honking, inequality, poverty, and illiteracy, but there are so many good things happening. They might even be happening in a faster pace than in the western world. In order to see those accelerations you need to go with the flow. That's how I got to see glimpses of the rising generation of India. The ones who create their own fortune instead of letting it be decided by family and belief only. The new generation which is going to handle things slightly different than the religious way. ■

Figure 2. Typical Indian classroom without window glazing and equipped with ceiling fans

Figure 3. At every tourist attraction we could start a new photoshoot all over again full of selfies

Figure 4. Chaotic market at the old city center of Bikaner during Diwali festival

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