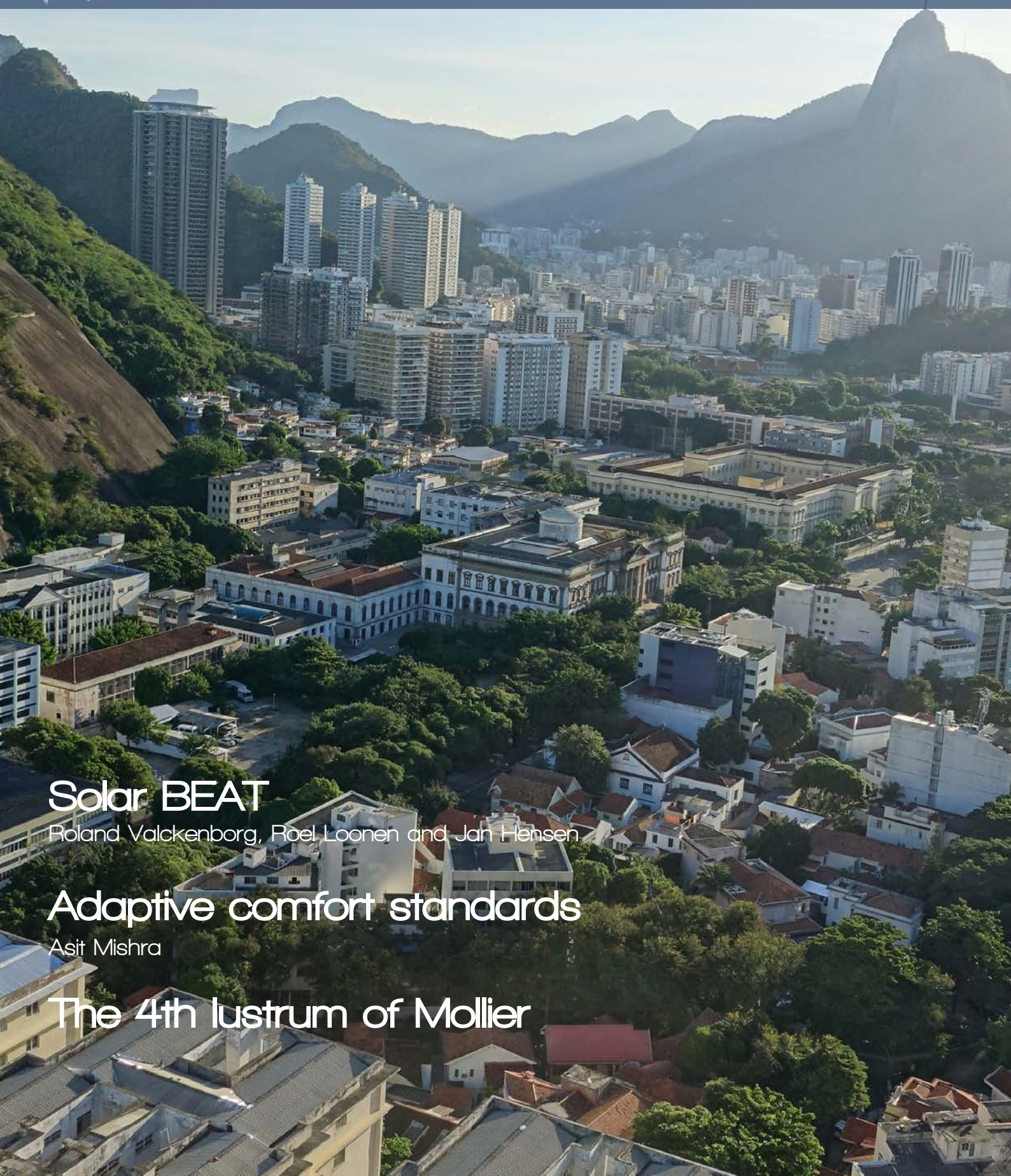
Academic year 2015 - 2016 #2 | June

MOLLIER

Study Association
Building Physics and Services

INSIDE INFORMATION

MOLLIER | UNIT BPS | STUDENTS | ACTIVITIES | MEMBERS



Solar BEAT

Roland Valckenborg, Roel Loonen and Jan Hensen

Adaptive comfort standards

Asit Mishra

The 4th lustrum of Mollier

MODERN INNOVATION HAS LED TO THE DEVELOPMENT OF AN APP FOR MEASURING AND CALCULATING RELATIVE AIR-HUMIDITY...

Foreword

Charlotte Rosenkötter

Dear reader,

I would like to present the second and last INSide Information of this acedemic year. This year was dominated by the 4th lustrum of s.v.b.p.s. Mollier, with several activities including an exhibition highlights of previous years. Moreover, members, alumini, BPS university staff and partner were invited to cellabrate the lustrum with a gala including dinner, drinks and music. It started as a formal gala and ended with a lot of danse moves until late night! The pictures of the gala are released during a drink at the Gaslab. The last activity of Mollier' 4th lustrum was the BBQ at Stratumseind.

For this INSide magazine, we received multiple articles of the unit including an article about lighting in open-plan offices and a column about the individual in the indoor environment. Furthermore, the project behind the dummy houses, located at the roof of the Vertigo building is decribed. SolarBEAT is involved in different projects with the aim to get more experience with the building integration aspects of solar energy into the built environment, if you are interested in this topic please read the article on page 21.

Beside all the informative articles from our (graduation) students, you can also read a detailed travel report about our study trip to Brazil with some amazing pictures.

Finally, several editors have stopped after the last INSide magazine, I would like to thank these editors for their new ideas, time and enthusiasm! The INSide magazine has become more professional, which is a good baseline for next years. So, we are looking for some new editors, if you want to participate in the INSide commitee, don't hesitate and please let us know!

Charlotte Rosenkötter

EDITOR IN CHIEF Charlotte Rosenkötter

EDITORS Lotte Kooi
Jelle Reinders
Hester Thoen
Koop-Pieter Ziel

COLOPHON

INSide Information
Volume 20 Number 2,
June, 2016

The INSide Information is
published by s.v.b.p.s. Mollier

Front cover: Lennert Evers
Cartoon: Koert Stavenuiter
Back cover: Hester Thoen

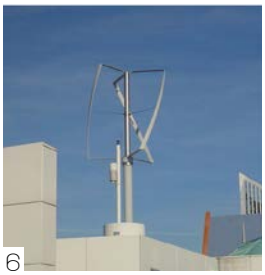
Printing office:
Drukkerij Van Druenen BV

Visiting address
TU Eindhoven
Vertigo 2nd floor

Post address
Postbus 513
p/a Secretariaat BPS
5600 MB Eindhoven
Tel: (040) 247 4406

Email: info@mollier.nl
Website : www.mollier.nl

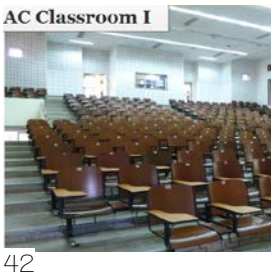
This INSide


6

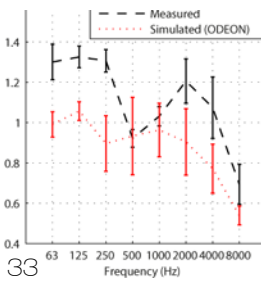

16


21


34



42



33

Aerodynamic optimization of vertical axis wind turbines for the urban environment

Author
ir. A. (Rahim) Rezaeiha

Supervisors
prof.dr.ir. (Bert) Blocken
dr. (Ivo) Kalkman

SUMMARY

Vertical axis wind turbines (VAWTs) are promising candidates for wind energy harvesting in urban environments, where rapid variations in wind direction are common. This is mainly due to their omni-directional capability, low noise level and low manufacturing, installation and maintenance costs. However, currently their aerodynamic performance is lower than that of their horizontal axis counterparts. This can be attributed to their complex aerodynamics, leading to early designs with poor performance due to insufficient understanding of the flow complexities. This hindered their further development at that stage and resulted in a comparatively small amount of research in this direction during the last 2-3 decades. The author intends to utilize numerical and experimental methods in order to provide a better understanding of aerodynamics of VAWTs and use this knowledge to optimize their performance for urban environments. The outcomes of this project are intended to encourage further utilization of optimized VAWTs in urban environments.

INTRODUCTION

VAWTs (see Figure 1) have recently received growing interest for energy harvesting purposes offshore [1] as well as in the urban environment [2]. They offer several advantages over horizontal axis wind turbines (HAWTs): omni-directional operation, hence no need for a yaw control mechanism; lower manufacturing costs due to simple blade profiles and shapes (no twist or taper); lower installation and maintenance costs due to having the generator installed on ground level (or sea level in case of offshore application), scalability, robustness and lower noise level due to lower operational tip speed ratios [3].

The early development of VAWTs in the 1970s-1980s did not lead to competitive designs in terms of performance and lifetime compared to HAWTs [3]; this hindered their further development. These poor early designs were a result of an insufficient understanding of the complex aerodynamics of VAWTs. These complexities have been found to include phenomena such as the unsteady 3-dimensional wake of the turbine, interactions of the blades with the wakes of other blades (blade-wake interaction) and large cyclic variations of angle of attack and loads on blades which depend on the operational speed of the turbine (dynamic stall). Better understanding of these effects is essential in the optimization of VAWT performance.

Several activities have focused on providing a better understanding of these complexities as well as finding ways to enhance the performance of VAWTs using low- to moderate-fidelity models, high-fidelity viscous CFD simulations and wind tunnel experiments [4]. Several parameters can potentially be used to optimize VAWT performance include airfoil shape, blade solidity and shape, tip speed ratio, blade pitch angle and the utilization of flow control on blades.

The current research project intends to investigate how these parameters can be used to increase the performance of VAWTs in urban environments. The project will be using a combination of CFD simulation and wind tunnel experiments in order to provide accurate validated results.

AIMS AND OBJECTIVE

By using CFD calculations together with wind tunnel experiments we aim to investigate various ways to enhance the performance of VAWTs in urban environments. Performance optimization is essential for VAWTs in order to make wind energy harvesting in the urban environment an economically attractive proposition. In order to meet the general aims of the project the following objectives were defined for the project.

Figure 1. A small VAWT installed on the roof of a building in the Netherlands [5]

Development of guidelines for accurate CFD simulation of VAWTs

Due to the fact that there are no specific guidelines to ensure the accurate CFD simulation of VAWTs the project will first investigate the effect of different simulation parameters on the results in order to provide recommendations for various aspects of a CFD calculation. These parameters include the computational domain size, grid layout and density, time step size, turbulence modeling and convergence criteria based on number of revolutions of the turbine. [6].

Characterization of aerodynamics of VAWTs

Using the guidelines derived above high-fidelity CFD calculations will be performed on several VAWT designs in order to provide a further understanding of the complex aerodynamics of VAWTs. Wind tunnel experiments will be conducted in order to validate and complement the CFD results.

Optimization of performance of a single VAWT

Once a qualitative understanding of VAWTs has been obtained the effects of different design modifications on the performance of a single VAWT will be assessed using high-fidelity CFD calculations and used to optimize the turbine design. The optimization studies will include (but not be limited to) the effect of tip speed ratio and solidity, pitch angle [7, 8], airfoil shape, central shaft detailing [9] and the utilization of flow control methods. Wind tunnel experiments will be conducted in order to validate and complement the CFD results.

Investigation of VAWTs in optimized arrangements

In many cases not a single VAWT but multiple turbines will be installed in a specified arrangement. The arrangement of this wind farm can significantly affect turbine performance. This study will therefore also investigate optimum arrangements for VAWTs using CFD calculations in order to provide further understanding of the flow field of VAWTs operating in the wake of another turbine.

METHODOLOGY

Within this project computational fluid dynamics (CFD) will be used in order to simulate the flow around VAWTs. This will include both Unsteady Reynold-Averaged Navier-Stokes (URANS) calculations as well as more advanced hybrid RANS-LES methods (where LES stands for Large Eddy Simulation). The hybrid methods are computationally more expensive. Unlike URANS however, in these models the energetically most important turbulent length scales are explicitly resolved instead of modeled as a result of which they can provide a significantly higher accuracy. Figure 2 shows the computational domain created for the CFD simulation of a 3-bladed VAWT and Figure 3 shows the contour of vorticity magnitude in which the unsteady vortex shedding from the blades and the blade-wake interactions are clearly visible. Due to the fact that a limited amount of experimental data is available for the validation of CFD results the project will include wind tunnel measurements as well.

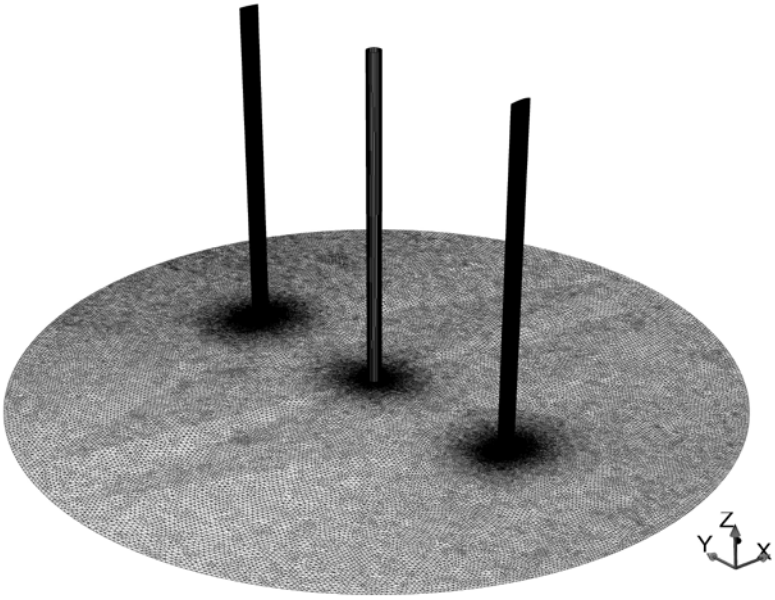


Figure 2. Illustration of geometry and surface mesh for a 2-bladed vertical axis wind turbine including shaft in the center

MASTER PROJECTS

Currently the following four topics are proposed as master projects that students from different departments who are interested in challenging themselves with CFD, aerodynamics and wind energy can apply for.

1. Investigation of passive flow control for VAWT performance optimization
2. Investigation of trailing-edge flaps for VAWT performance optimization
3. Investigation of leading-edge slats for VAWT performance optimization
4. Investigation of boundary layer suction/blowing for VAWT performance optimization.

Please contact the author at a.rezaeiha@tue.nl for further information.

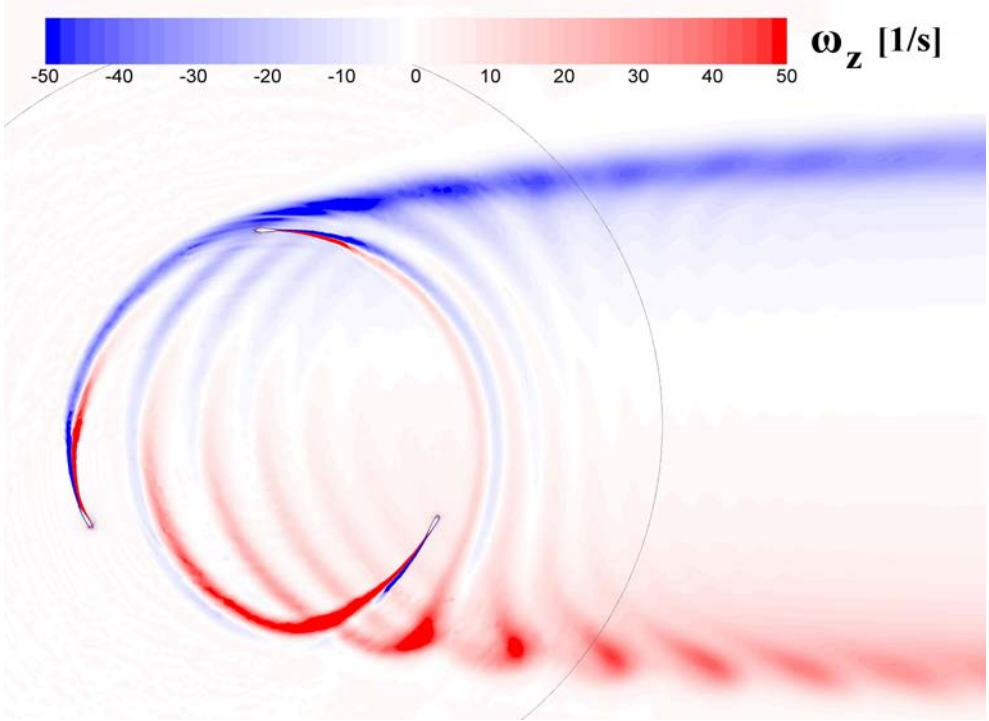


Figure 3. Contour of Z-Vorticity in the 2D cross-section of a 3-bladed vertical axis wind turbine

INVESTIGATION OF PASSIVE FLOW CONTROL FOR VAWT PERFORMANCE OPTIMIZATION

Passive flow control methods (e.g. vortex generators, Gurney flaps, leading edge slots, etc.) have been used for aerodynamic optimization and load alleviation on aircrafts, helicopters, horizontal axis wind turbine (HAWT) and cars. Figure 4 shows some of the applications of passive flow control methods. They help the flow over the wings or blades with either flow separation or circulation control. As the VAWTs experience cyclic variations of angle of attack with a wide range of variations the flow stalls on parts of the revolution. These types of flow control mechanisms can potentially increase VAWT performance by improving the stall behaviour. Therefore, the objective of this study is to understand how these methods can help to optimize the aerodynamic performance of VAWTs. High-fidelity CFD calculations will be employed to address this objective.

INVESTIGATION OF BOUNDARY LAYER SUCTION/BLOWING FOR VAWT PERFORMANCE OPTIMIZATION

Active flow control methods have also been investigated for aircrafts, helicopters, HAWT and cars and their investigation for VAWTs can be very promising. Figure 4 shows some of the applications of active flow control methods. The second, third and fourth project are in line with the first project. However, the main difference is that they utilize an active method to control the flow. This can be a big advantage over passive flow control methods; in spite of the complexity they add to the system they can potentially offer large performance benefits based on either some preliminary simulations/ measurements (feed-forward) or real-time measurements (feed-back).

For the second project the trailing edge flap will change its relative angle (to the airfoil chord line) during the revolution of the turbine and this change is designed to ensure maximum performance. Similarly a leading edge slat will open and retract at regions of high angle of attack to delay the flow separation, and suction/blowing will be turned on/off during each revolution of the turbine to improve stall behaviour. The objectives is to investigate how these proposed active flow control methods can improve the aerodynamic performance of VAWTs. High-fidelity CFD calculations will be employed to address this objective. ■

Figure 4. Leading-edge slot (top left) and vortex generator (top middle) on the aircraft wing; Gurney flap on Porsche 962 rear wing (bottom left); vortex generators on HAWT (right) [10]

Figure 5. Leading edge slat on Airbus A319 (top) [11] and trailing edge flap for a HAWT (bottom) [11]

[1] U. S. Paulsen, H. A. Madsen, K. A. Kragh, P. H. Nielsen, I. Baran, J. Hattel, et al., "DeepWind-from idea to 5 MW concept," Energy Procedia, vol. 53, pp. 23-33, 2014.

[2] S. Mertens, Wind energy in built environment. Brentwood, UK: Multi-Science, 2006.

[3] I. Paraschivoiu, Wind turbine design: with emphasis on darrieus concept. Montréal, Québec: Polytechnic International Press, 2009.

[4] A. Rezaeiha, I. M. Kalkman, and B. Blocken, "A short review of recent research activities for aerodynamic optimization of vertical axis wind turbines," in 1st International TU1304 WINERCOST Conference, Ankara, Turkey, 2016.

[5] G. J. W. Van Bussel, S. Mertens, H. Polinder, and H. F. A. Sidler, "TURBY: concept and realisation of a small VAWT for the built environment," in EAWE/EWEA Special Topic conference "The Science of making Torque from Wind", Delft, The Netherlands, 2004.

[6] A. Rezaeiha, I. M. Kalkman, and B. Blocken, "The effect of computational domain size and azimuthal increment on the performance prediction of a VAWT using CFD simulation," in The Science of Making Torque from Wind (TORQUE 2016), Munich, Germany, 2016.

[7] A. Rezaeiha, I. M. Kalkman, and B. Blocken, "The effect of pitch angle on the performance of a vertical axis wind turbine," in International Sustainable Built Environment Conference, Malta, 2016.

[8] A. Rezaeiha, I. M. Kalkman, and B. Blocken, "Investigation of decoupling of power and instantaneous loads for a vertical-axis wind turbine: CFD simulation," in 1st International TU1304 WINERCOST Conference, Ankara, Turkey, 2016.

[9] A. Rezaeiha, I. M. Kalkman, and B. Blocken, "A numerical study on the effect of the central shaft on the performance of a VAWT," in XIV Conference of the Italian Association for Wind Engineering (IN-VENTO 2016), Terni, Italy, 2016.

[10] www.wikipedia.com

[11] C. B. Berg, M. Barone, and N. C. Yoder, "SMART wind turbine rotor: Data analysis and conclusions," Sandia National Laboratories, USA2014

ARCADIS Design & Consultancy for natural and built assets

IMPROVING QUALITY OF LIFE

Het is onze passie om de kwaliteit van leven te verbeteren. En het mooie is, dat we dagelijks bewijzen dat we daarmee bezig zijn. Met onze deskundigheid creëren we bijzondere en duurzame oplossingen voor de natuurlijke en bebouwde omgeving. Zo dragen we bij aan de antwoorden op grote uitdagingen als verstedelijking, schaarsheid van water en hulpbronnen, en klimaatverandering. Maar Arcadis wil ook een eersteklas werkgever zijn die van deze expeditie een plezierreis maakt!

Voor studenten en pas afgestudeerden organiseren wij meerdere malen per jaar Inhousedagen.

Kijk op www.werkenbijarcadis.nl voor o.a. alle actuele (afstudeer)stage vacatures en informatie over onze Inhousedag

Volg ons op:

Kuijpers

Kuijpers & Mollier
Resultaat door **betrokkenheid**

Kuijpers is een professionele technisch dienstverlener met ruim 800 medewerkers. We verzorgen het ontwerp, de bouw en het onderhoud van technische installaties in gebouwen en industrie. De wensen en mogelijkheden van onze klanten zijn het uitgangspunt voor onze technische oplossingen. We richten ons daarbij met name op functionaliteit en prestaties. Met een compleet concept en verschillende specialismen in huis, kunnen we onze klanten goed bedienen. Vanaf het begin van het proces tot het einde. En ook daarna nog. Kuijpers is een familiebedrijf, waar echte mensen werken aan echte oplossingen.

Een persoonlijke band met onze medewerkers en relaties staat daarbij voorop. Samen ontwikkelen we ons. Om zo het beste in elkaar naar boven te halen. In een betrokkenheid die leidt tot resultaat.

Kuijpers biedt mogelijkheden voor traineeships, afstudeeropdrachten en stageplaatsen. We hebben bovendien vele uitdagende functies beschikbaar. Nieuwsgierig? Kijk op:

www.kuijpers.nl

www.facebook.com/KuijpersNL
www.twitter.com/KuijpersNL

CIE clear sky and Utah spectral sky models compared

Author
M.T.H. (Manon) Derks BSc

Supervisors
dr. ir. M.B.C. (Mariëlle) Aries
P. (Parisa) Khademagha, MSc, PDEng

INTRODUCTION

Light has an important role in the work performance of humans [1]. Therefore daylight calculations, often through simulation software, are performed during the design stage of a building. In the current daylight simulations (e.g., with Radiance) the spectral distribution of daylight is not taken into account. This research focused on the accuracy of daylight simulations where the Utah spectral sky model is implemented. This project studied and validated the developed spectral sky in Radiance. Moreover, the usability of the spectral sky model in the field of building lighting was investigated.

SIMULATIONS

Prior validating the spectral sky, first an exploring research was performed to investigate the effect of different color scenarios for a little room (3.7 x 1.8 x 2.7 m) and its surroundings. Hourly data (between 5:00 and 20:00) were collected for the 15th of March, June and December, representing respectively a middle, high, and low solar elevation.

REAL-TIME MEASUREMENTS

The simulation data were compared with real-time data, collected in a room (3.7 x 1.8 x 2.7 m) in the BPS laboratory, from November 23rd till December 7th 2015. Spectral irradiance values were measured using two illuminance spectrophotometers. The given X, Y, Z tristimulus output was converted to R, G, B tristimulus values. The collected data was filtered for clear sky moments determined based on KNMI cloud cover data.

RESULTS AND DISCUSSION

The simulation results are shown in Figure 1 with the mean R, G and B irradiance difference of the color scenes per month between both sky models. At 12:00h solar time all results were within the acceptable 20% range [2]. For March and December the mean difference increases when further away from midday. June shows slightly constant results. Radiance shows the highest mean difference, because of the spectral composition of daylight. The spectral composition for the morning and evening hours consist of a higher irradiance value for the higher wavelengths (red) in relation to the lower wavelengths compared to the spectral composition of the solar maximum (12:00h). These variations were also observed by several previous studies [3], [4].

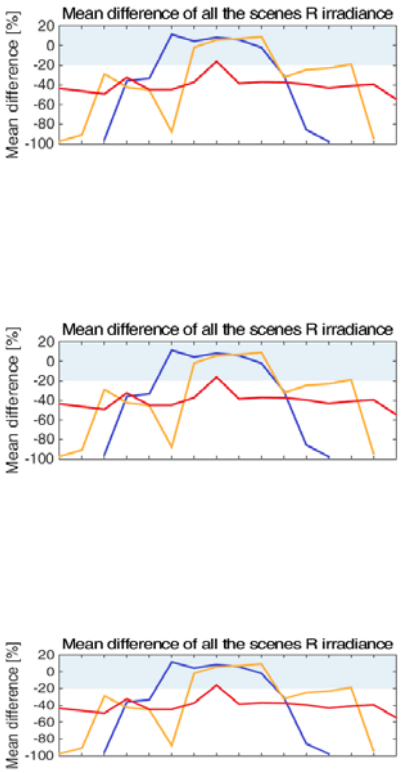


Figure 1. Simulation results: Mean difference of R, G and B irradiance for June, March and December while comparing the Utah spectral sky model with the CIE clear sky model

The differences in R, G and B irradiance results between the sky model and measured data were determined for all clear sky moments. The mean value of these differences was calculated, resulting in the mean difference for each sky model per sensor point. These differences are shown in Table 1. Although the 20% range [2] is exceeded, the spectral sky shows a better agreement with the measurement data for both sensor points. However, to conduct a decent validation, more measurement data is necessary, which includes a unobstructed sensor point, wider period of measurement, various locations and more detailed cloud cover data.

Table 1. Mean difference of R, G and B irradiance when comparing the sky models to real-time measurements

		Sensor point 1		Sensor point 2	
		Mean difference [%]		Mean difference [%]	
		CIE	UTAH	CIE	UTAH
Irradiance	R	321.6	268.6	315.1	291.1
	G	181.8	169.0	211.5	211.7
	B	116.7	99.7	169.1	145.3

CONCLUSION

The spectral sky model shows a better agreement with the measurement data compared to the regular clear sky model, and may be a more accurate sky model for building lighting simulations. ■

[1] Silvester, J., & Konstantinou, E. (2010). Lighting, Well-being and Performance at Work: A review of the literature. London: City University.

[2] Ochoa, C. E., Aries, M. B. C., & Hensen, J. L. M. (2012). State of the art in lighting simulation for building science: a literature review. Journal of Building Performance Simulation, 5(4), 209–233.

[3] Lorente, J., Redañ, A., & De Cabo, X. (1994). Influence of Urban Aerosol on Spectral Solar Irradiance. Journal of Applied Meteorology.

[4] Cornaro, C., & Andreotti, A. (2011). Solar spectral irradiance measurements relevant to photovoltaic applications. Proceedings 3rd International Conference on Applied Energy, (February), 1–10.

Stichting Promotie Installatietechniek (PIT)

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.

Mollier Calendar

Past events

FEBRUARY

COCKTAIL PARTY 3.0

After the great success of the past two editions, the cocktail party has become a real Mollier tradition. To make the party bigger and better, the committee introduced a new theme 'Childhood Heroes!'. The matching cocktails and the karaoke made the party complete. We look forward to next year!

LUNCHLECTURE #3 - KARIN KOMPATSCHER (PHD)

At the end of your study, you will face the choice between staying in academics or go working within the industry. The lecture gave a welcoming idea of the possibilities after your master, if you choose to be an academic. A lecture based on Karin her own experiences, which provided new perspective that may have broaden the horizon of our members.

MEET & GREET

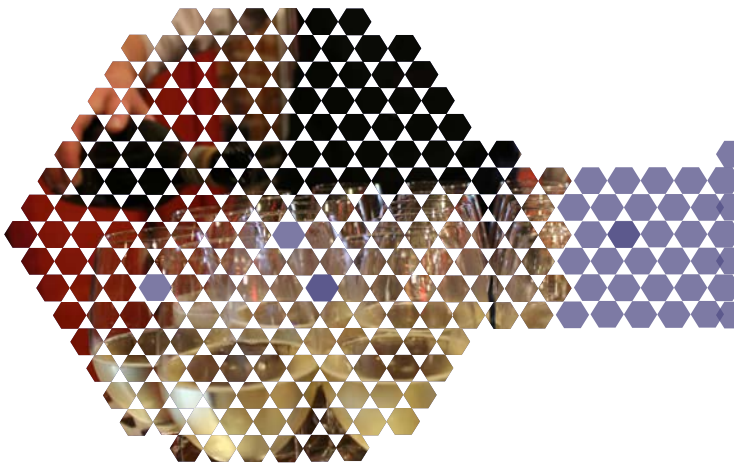
Mollier' yearly Meet & Greet took place with 13 sponsors and approximately 45 members present. The afternoon started with an elevator pitch. Immediately one could notice that the atmosphere was informal and that the sense of humour from our sponsors was well appreciated. Especially since the main goal during this drink was to expand your personal network. Get to know the opportunities that BPS can provide you during and after your study. Perhaps you will be the sponsors next intern, graduate student or colleague. Once again a very successful event for which we want to thank all that participated.

HEIJMANS MASTERCLASS - TRANSFORMING THE FUTURE, TODAY

Every year Heijmans organizes an unique event for which 12 top students get the chance to meet Heijmans during several activities and case studies. Central topic for this year: robotics in the built environment. The world is changing and therefore it is important to think about the future of the built environment. The masterclass offered participating students the opportunity to engage the discussions with each other and with Heijmans in relation to this topic.

LUSTRUM GALA

The 4th lustum of Mollier is upon us! The study association Mollier was founded in 1996, turnin 20 this year. To celebrate the gala was organized at the 20th of February with dinner, drinks and good music. It was an unforgettable evening with members, alumini, BPS university staff and partners, who joined for this celebration.



The purple tie dress code inspired many in a creative and original way. As the party begun as a formal gala with the official photoshoot, it evolved into an unforgettable and awesome party untill late at night. Besides this, food, drinks and dance moves were good and plentyfull.

Photo's were released later on during a drink at the Gaslab. A big screen showed the pictures and babble box movies to the amusement of many. Gala attendees could also collect a copy of both pictures and movies provided on a gadget: Mollier USB sticks! A great closure for the celebration of Mollier' 4th lustrum. Hopefully we will meet again at the 5th.

MARCH

LUNCH LECTURE #4 - JOHNSON COTROLS & STRUKTON WORKSPHERE

After a small introduction Johnson Controls highlighted their role within the construction of the Jeroen Bosch hospital in 's Hertogenbosch. Main focus was on the implementation of an energy efficient sun blind control system that should match the high energy efficient goals set for the building. Strukton Worksphere provided a lecture about their new energy motoring service called PULSE. This project is about optimizing energy performance of building services based on monitoring and analyzing big data. Once more a well visited lecture for which we want to thank our attending members and sponsors.

APRIL

BEER TASTING

Mollier always have held the reputation high when it comes to the knowledge of beers. A valid reason to expand this knowledge during an activity. With Belgium just around the corner, some beer fanatics of our association went for a drive. They created the The Trappist tour or the Summer tour which could be chosen in advance. Besides the beer tasting, the organization also created a beer and Mollier quiz. Is our stated knowledge about beer valid? And what do we know about Mollier' history? The winner (Niels Hoekstra) received, what could it be otherwise, a beer package! Special thanks for the organization goes to Jelle Reinders, Mollier's beer professional.

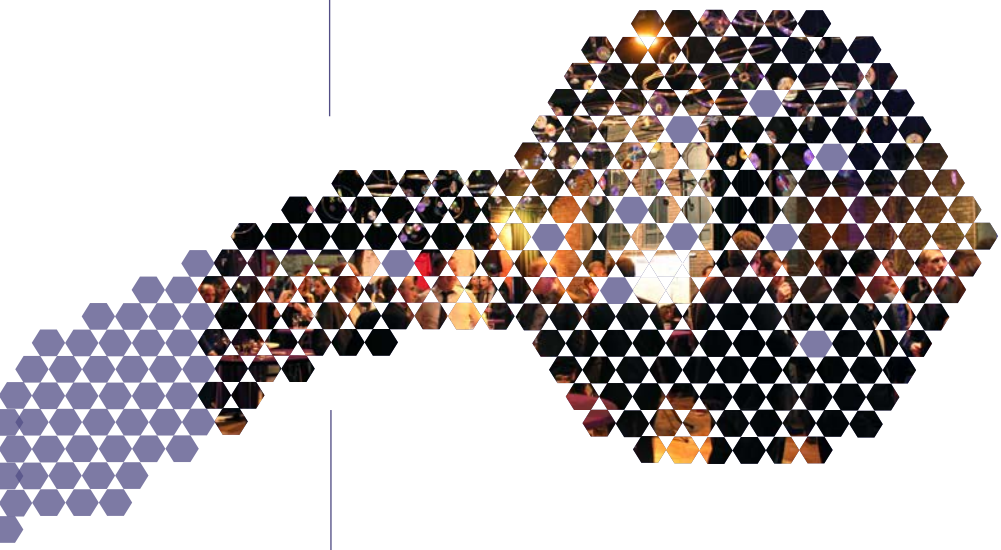
JOB APPLICATION AND LINKEDIN TRAINING - KP&T

On April 20w Mollier and KP&T organized a job application and LinkedIN training. With the welcoming presence of a beverage and well prepared guests we enjoyed an informal and informative meeting on the subjects of presenting yourselves, application talks, preparation, curriculum vitea and profiling on social media. We thank all attendees for their presence, and especially Deborah and Evy of KP&T.

LUNCH LECTURE #5 - KUIJPERS & NELISSEN

Nelissen guided around 25 interested members through the challenges they face regarding fire safety engineering. The case discussed was the extension of a school, where among other the new built addition blocks the escape route of the present building. An interesting case for the more building physics minded members among us. On the other hand Kuijpers highlighted a building services related project. They discussed the challenges that lay within the replacement and maintenance of the mechanical installations for the Catharina hospital in Eindhoven. Challenging was the replacement of the installation in such way that the hospital could operate under its normal conditions.

MAY



STUDYTRIP 2016 - BRAZIL

This year's study trip went to Brazil. The cities Rio de Janeiro, Paraty and Sao Paulo got visited by 20 members of Mollier. Many can be told about this study trip, which is too much to fit in Mollier' timeline. The article about the study trip can be found within this INSide edition. In short among other highlights Christ the Redeemer, the Copacabana, research center CRESESB and many more was visited by the group. Perhaps a new Mollier drink called Caipirinha's is born during this study trip. Altogether a very successful journey for which we want to thank the committee for their more than welcoming organization. Thank you Tom, Michiel, Wouter K, Joshua, Riccardo, Stefan and Hanneke.

LUSTRUM BARBEQUE

Final closure of Mollier' 4th lustrum was the BBQ at Stratumseind. Café Jantjes provided us a great location in the city center of Eindhoven. A well organized barbeque by the committee with good food and low priced beers were well enjoyed by all present. Over 60 people present exceeded the expectations. Mostly Mollier members and some alumni made it a great evening, which for many continued unitll late at other bars of Stratumseind. What a succes for Mollier's 4th lustrum!

SCHOONE LEIJ SPRING ACTIVITY

At Saturday the 28th of May alumni association Schoone Leij had its annual spring activity. This year an escape room with BBQ afterwards. About 20 people were present of which 4 new members were welcomed in the alumni association. Together with our alumni, Mollier members joined this activity which continued with drinks and small talk afterwards in the city center of Eindhoven. ■

Stage of afstuderen bij Nelissen ingenieursbureau?

Als integraal adviesbureau op het gebied van bouwfysica en installatietechniek, loopt duurzaamheid als een rode draad door al onze werkzaamheden heen. Veel van onze collega's hebben aan de TU/e gestudeerd dus heel wat expertise in huis!

Wil jij bij ons stage lopen, heb je een interessante afstudeeropdracht of ben je in de gelegenheid om naast je studie één dag per week bij ons te komen werken?

Stuur dan je curriculum vitae met motivatie naar Marie-José van Eck, adviseur P&O, m.vaneck@nelissenbv.nl.

www.nelissenbv.nl

vanhout
adviseurs en installateurs

Honderdéénenveertig-kommazevenmiljoeneuro

Zoveel geld hebben we aantoonbaar bespaard voor eigenaren van gebouwen. Klanten die ons uitdagen koploper te blijven in installatietechnische oplossingen, verduurzaming en slim fiscaal advies.

Wil jij weten hoe wij 80 jaar kennis en knowhow benutten om bedrijfspanden energiezuinig te maken. Op een plek waar je alle ruimte krijgt om je technisch talent te ontplooien. En waar jouw ideeën uitgangspunt zijn voor je verdere ontwikkeling?

Kijk dan op van-hout.com en realiseer met ons de ambitie van vijfhonderd miljoen euro.

*) totale besparing door Van Hout gerealiseerd voor haar klanten

Van Hout. Voor rendement.

Ice breaker

Author
J.J. (Arjan) Kraakman

My name is Arjan Kraakman, 24 years old. I grew up in a village called Hoogkarspel, about 60 kilometres above Amsterdam between Hoorn and Enkhuizen. This region is called 'West-Friesland' and it has its own dialect. My older brother and sister live somewhere else and are busy with raising a happy family.

My building construction carrier started when I was a little boy. Most of the time I was busy with building cabins or vehicles together with my older brother. When I was thirteen years old, I followed courses on my secondary school in making building components like, masonry walls, window frames etc. In my free time I made my own projects, like furniture and a cooling box to cool beer during parties. In this period I had my first internship on the construction site. After graduation, I started a Intermediate Vocational Education (in Dutch: MBO) level 4 in Building construction. During this education I have learned to work in all stages of the building construction process. I have got many practical experiences, because of internships at different kinds of building construction companies, like contractors and housing association.

I decided to start a Higher Vocational Education (in Dutch: HBO) in building construction in Amsterdam. Because of my previous education it was possible to skip the first year. After half a year it was necessary to choose a specialization course. I chose 'Building Technology'. During this course I learned much about making (technical) drawings, use of building physics and designing with climate installations. However, my thesis was about something completely different, namely 'Using the knowledge of human anatomy and psychology to make an energy efficient home'. Because of this research I got interested in the psychology of people during their stay in buildings. With this interest and the fact that one of my assessor's was a professor of the TU/e, I started a pre-master 'Human Technology Interaction' at the TU/e. I learned much about psychology and how to use it in combination with technology. Unfortunately I did not finish the pre-master by the failure of Calculus. In addition, the study is to theoretically and not practical for me. I decided to go back to my roots and started this year the pre-master BPS. After several weeks I felt that I was here more on my spot. I hope to finish my premaster this year, so I can start the Master BPS.

My hobbies are swimming tracks or just for fun, riding on my motorcycle, building and maintaining of computers. Also I like to organise weekends, events and trips. I do this regularly in my Christian student association Ichthus, here in Eindhoven. Moreover, I also like traveling to new destinations. Last summer I went to Brazil for a study trip of three weeks and one week traveling by myself. During the study trip we went to Rio de Janeiro, Brasilia and São Paulo for visiting companies, universities and sightseeing. We went to Paraty and Ilha Grande for relaxing. In the last week I traveled to Salvador for exploring the city and Manaus for a three-day trip to the Amazon. This summer I am going to the city Izhevsk in Russia for 2,5 weeks for a summer project. Together with Dutch and Russian students, I'm going to help with the establishment of a Christian student movement. If you want to know more about me you can always say hi and have a talk. ■

Practical relevance of lighting control strategies in open-plan offices

Author: ir. C. (Christel) de Bakker

Supervisors
dr. ir. M.B.C. (Myriam) Aries, prof. dr. H.S.M. (Helianthe) Kort
prof. dr.-Ing. A.L.P (Alexander) Rosemann

INTRODUCTION

During both the design of new office buildings as well as the renovation of existing ones, lighting tends to receive (too) little attention. In most cases, the lighting design starts when the most crucial decisions have already been made. Often, luminaires are positioned in a functional grid. However, if the lighting control strategy was tailored to the office space, much more could be accomplished than the mere functionality of providing a specific illuminance at desk level. Especially open-plan offices can profit from this attention as they are used by occupants with different tasks, behaviours, and activities. Therefore, standard solutions are less likely to suffice here. This article discusses what may be achieved if the lighting control strategy is tailored to the usage of the open-plan office spaces. Focus is given on the practical relevance in order to convince employers and/or building owners to give lighting more attention.

SAVING ENERGY

Research has shown that 20-45% of offices' energy is consumed by lighting [1]. Through proper operation, i.e. the right placement of luminaires in combination with an appropriate control strategy, the energy consumption for lighting in a building can be reduced. An example of a strategy that reduces this consumption is the use of occupancy sensors to control the lighting. These sensors switch off the lighting when no employees are detected over a set time frame (the time delay setting). Several studies have shown that implementation of occupancy sensors reduces energy consumption for lighting, varying from 20% to 60%, depending on the time delay setting and the type of space [2-4].

In open-plan offices, which are shared by multiple occupants, the implementation of these sensors is less straightforward than in private, single room offices. These are just used by one occupant. This means that the sensors only need to detect this one occupant. In addition, the lighting solely needs to be switched on and off depending on this occupants' presence. In open-plan offices not only multiple occupants need to be detected, the lighting also needs to consider the presence of multiple occupants, which can differ in job type and accompanying activities. Consequently, lighting is typically controlled centrally, as this is the easiest way. This means that lighting throughout the whole space is switched when the occupancy of one/ a single occupant is detected. Similarly, lighting is only switched off if all occupants are absent, which is likely to occur only a few times per day. Research has namely shown that employees show differences in their occupancy patterns. Chang en Hong (2013) identified five typical patterns, which can be found in Figure 1 [5].

Figure 1 shows that the first occupant type spends the whole day behind his or her desk, while the second type also takes a lunchbreak. In addition to these differences in patterns, occupants also tend to differ in the times they arrive and leave the office, which were found to vary up to 2,5 hours [6]. If lighting is controlled centrally, this means that the time that the first occupant arrives in the open-plan space determines when lighting is switched on. The time that all the lighting is switched off again is determined by the moment the last occupant leaves the

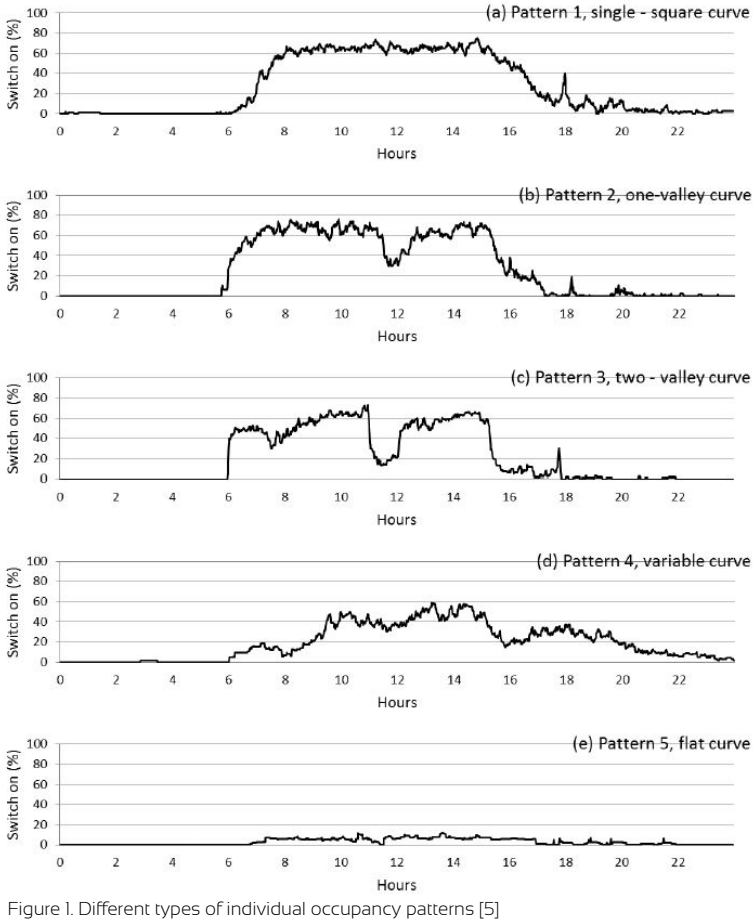


Figure 1. Different types of individual occupancy patterns [5]

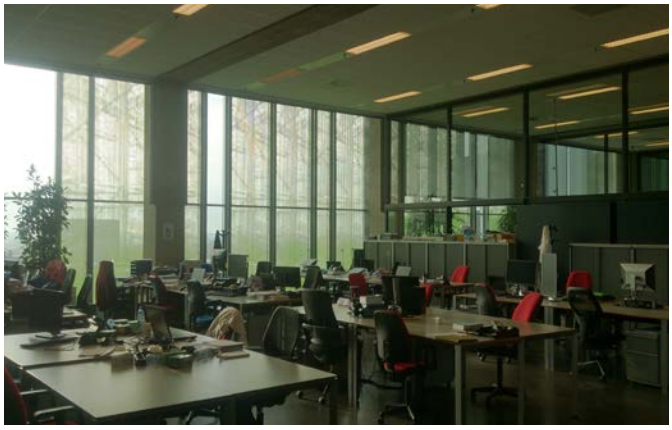


Figure 2. Example of an open-plan office with centrally controlled lighting

Figure 3. Typical workplace in an open-plan office in the USA

space. If one of the occupants inhabiting the space has an occupancy pattern of type 1, this means that lighting will remain switched on between these times, or in other words, the whole day. Lighting is thus used far from optimally, as becomes clear in Figure 2.

These differences between individual occupants are likely to increase even more due to the introduction of flexible working styles. These allow employees more flexibility in when they work and provide them with the freedom to work at a location different than the office. Within the office, workplaces are no longer occupied by one employee, but can be used flexibly by all employees. It enables occupants to sit behind another desk every day. Because of this trend it will suit the open-plan office better to control the lighting locally instead of centrally, or, in other words, per individual workspace instead of per open-office space. By controlling lighting based on the presence of an employee at his or her desk energy can be saved on lighting use. Rubinstein en Enscoe (2010) already tested this strategy in office buildings in the United States of America [7]. They installed luminaires above each workspace which provided in direct as well as indirect lighting (respectively downwards and upwards). They found this localized lighting control strategy to result in 40% energy savings compared to the original centrally controlled lighting. It indicates that controlling lighting locally has a high potential to reduce energy consumption for lighting use in open-plan offices.

GUARANTEEING USER'S COMFORT

Saving energy should not be the only aim when implementing a lighting control strategy. It should not scarify the (visual) comfort and functioning of the employees. This is important to address especially with a local lighting control strategy. When lighting is controlled centrally, the illuminance level throughout the space is constant. With a localized lighting control strategy, however, this level will vary throughout the open-office space. Every time an employee leaves his or her workplace, there will be a luminous change at this particular workspace.

Rubinstein en Enscoe (2010) evaluated the strategy with employees, and their research showed that the local lighting control strategy was preferred over the central control. However, USA open-plan offices look very differently compared to offices in Europe. In the USA partitions separate all workplaces from each other, as can be seen in Figure 3.

These partitions highly restrict occupants' field of vision. They are only able to notice luminous changes in relation with a change in occupancy of their direct neighbouring colleagues. In Europe, however, every occupant is able to oversee the whole space and consequently also all (local) luminous changes. Therefore, their visual comfort might be affected by occupancy changes from employees other than their direct neighbours. In addition, the luminous changes might pose a higher distraction to their work as they are able to notice much more luminous changes. Thus, implementing this strategy in European open-plan offices, therefore, requires additional attention for the visual comfort of the worker as well as the co-workers.

CONCLUSION AND FURTHER RESEARCH

Lighting design deserves more attention in open-plan office spaces. This will result in better use of lighting, or, in other words, energy savings. In order to achieve this, lighting and the control strategy needs to be defined at individual workspace level. While energy savings provide a reason to convince building owners to implement this strategy, its practical relevance will be further increased if the visual comfort of the employees also increases. Companies would not want their employees' work performance to be negatively affected as salary costs are still the largest expense of an employer. This issue, however, still needs to be investigated for European open-plan offices and forms the research focus of Christel de Bakker. The most optimal lighting is a result of a balanced mix between energy-efficiency and providing a good and stimulating visual environment for occupants. The research questions to be addressed will lead to lighting control strategies relevant for the practise. The results will not only be published in scientific journals but also with stakeholders in the professional lighting field via organizations such as the NSVV (Nederlandse Stichting Voor Verlichtingskunde) as well as professional magazines. ■

[1] M.-C. Dubois and Å. Blomsterberg, "Energy saving potential and strategies for electric lighting in future North European, low energy office buildings: A literature review," Energy Build., vol. 43, no. 10, pp. 2572–2582, Oct. 2011.

[2] T. M. Chung and J. Burnett, "On the Prediction of Lighting Energy Savings Achieved by Occupancy Sensors," Energy Eng., Jul. 2009.

[3] A. D. Galasiu, G. R. Newsham, C. Suvagau, and D. M. Sander, "Energy Saving Lighting Control Systems for Open-Plan Offices: A Field Study," LEUKOS, Sep. 2013.

[4] B. Von Neida, D. Manicria, and A. Tweed, "An Analysis of the Energy and Cost Savings Potential of Occupancy Sensors for Commercial Lighting Systems," J. Illum. Eng. Soc., vol. 30, no. 2, pp. 111–125, Jul. 2001.

[5] W. Chang and T. Hong, "Statistical analysis and modeling of occupancy patterns in open-plan offices using measured lighting-switch data," Build. Simul., 2013.

[6] P. Maleetipwan-Mattsson, T. Laike, S. Lavy, and J. Lai, "Optimal office lighting use: a Swedish case study," Facilities, 2015.

[7] F. Rubinstein and A. Enscoe, "Saving energy with highly-controlled lighting in an open-plan office," LEUKOS, 2010.

Vox Populi

'The voice of people'

Author
dr. ir. MGLC (Marcel) Loomans

Vox populi (the voice of the people) is not one-on-one to be compared to a referendum such as the one we 'experienced' earlier this year in April. However, many opinions from many different persons did pass the headlines, leaving context and interpretation to the reader. We could note that it was difficult to arrive at a consensus as the referendum question posed (on the EU - Ukraine Association Agreement) was not an easy one to answer. The general impression seemed to be that it was an unsatisfactory experience...

If we look to the indoor environment, obtaining useful values for the intended outcome with respect to comfort and health (e.g., thermal conditions and air quality) is not an easy task as well. But the individual opinion about it on health and comfort is generally very clear! Also in this case the experience is not always satisfactory...

Health and comfort finally have found a firm position as the 'new' design goals for the built environment. The energy issue is being 'solved' in due course... There is however a scaling issue. At societal level the average values are of importance, reflected in epidemiological studies. These averages can be translated into Euros and that supports political decision making. At the urban level we see attention on average values as well to detect local areas of concern (e.g. Particulate matter concentration near roads). However, at the building level health and comfort find a reference to the individual and the individual requirements (man/woman, young/old, healthy/ill, vivid/frail, thick/thin, ...). As you experience yourself, most of the time we are exposed to indoor conditions...

Where we (relatively speaking!) know a lot about the averages, now is the time to try to explore the individual requirements better. With developments in sensor technology and simulation techniques we are able to understand the indoor environment and its physical performance better. But as yet we have not been very successful in understanding the impact of it on each individual. As a design solution (effective...) personal control is a means to optimize the indoor environment individually. But if you look to health that may not be the total solution; we can cope with a lot. Luckily we already can see many types of sensors that monitor the 'health' of a person more objectively that may allow us to learn and optimize the indoor environment from. We are just at the start of that... But we should not forget that our complex human brain builds a perception based on many other things than just the physical conditions. The Happy Building Index and Well Building appear interesting initiatives in that direction, but can we really learn from that for the individual?

In any case, it is time to 'listen' more closely to the vox populi, meaning not the average, but the individual indoor environment requirements and contemplations and with that open up the world for the subtleties that can be found in real life and generally also in real (individual) persons... When we will be able to connect building performance better to these requirements and design to it accordingly, it will not only result in a better indoor environment, but it will also open up a new world of innovations and options. But who to talk to first? ... ■

Shouldn't buildings be able to communicate on multiple devices, too?

Metasys is designed to work the way you work. You use multiple devices. So *Metasys* gives you easy access and fast control of your building's automation systems from multiple devices. And to make you even more productive and efficient, *Metasys* has introduced the industry's best mobile optimized user interface. And a building automation system is just one of the innovative ways *Metasys* can help you get the job done. To find out more, visit johnsoncontrols.com/metasys.

METASYS®
MASTER YOUR ENVIRONMENT.

Johnson Controls

SolarBEAT

'Building & Infrastructure Integrated PV Outdoor Performance Research'

Authors
dr. ir. R. (Roland) Valckenborg
ir. R.G.C.M. (Roel) Loonen
prof. dr. ir. J.L.M. (Jan) Hensen

Solar Building Elements Application Testing, abbreviated as SolarBEAT, is the name for the outdoor research facility in the area of BIPV(T), located at the roof of the Vertigo building. See Figure 1 for a picture taken with a drone in the summer of 2015, when all with the exception of one dummy house were built. SolarBEAT is a cooperation between SEAC and the TU/e. SEAC is an independent research organization that was founded in 2012 on the initiative of ECN, TNO and Holland Solar. From the TU/e side, an active role is played by the BPS Building Performance Chair, as they are experienced with the building integration aspects of solar energy into the built environment. Other TU/e departments are also involved through the Eindhoven Energy Institute.

Within SolarBEAT [1, 2], new innovative BIPV products are analysed on their physical and electrical integration in the building envelope. Various BIPV concepts for roofs and facades, as well as hybrid-PVT (PV and Thermal) systems are analysed on a pilot scale (typical 6m x 5m). Measurements involve the PV performance, which is the kWh yield of every minute, as a function of the solar irradiance in that specific minute. Moreover, all relevant building aspects are monitored by using a variety of sensors like hot-wire anemometers, thermocouples, etcetera.

SolarBEAT started early 2014. At the moment, five dummy buildings with a pitched roof and one dummy building with a façade are realized. Each project in these dummy buildings performs its own research program. Nearly all of these projects involve a consortium of multiple parties from the construction and solar industries, research institutes, and universities and hogescholen. A centrally installed Solar Measurement Station (abbreviated with SMS) has been installed already in April 2014 and is since then continuously up-and-running, measuring the solar irradiance at the Vertigo roof in the horizontal plane. Not only the total Global Horizontal Irradiance (GHI) is measured with a highest class pyranometer, but also the part which is coming from diffuse light (DHI) is measured with a shading ball positioned on a tracker; and the part of the light coming from direct sunlight

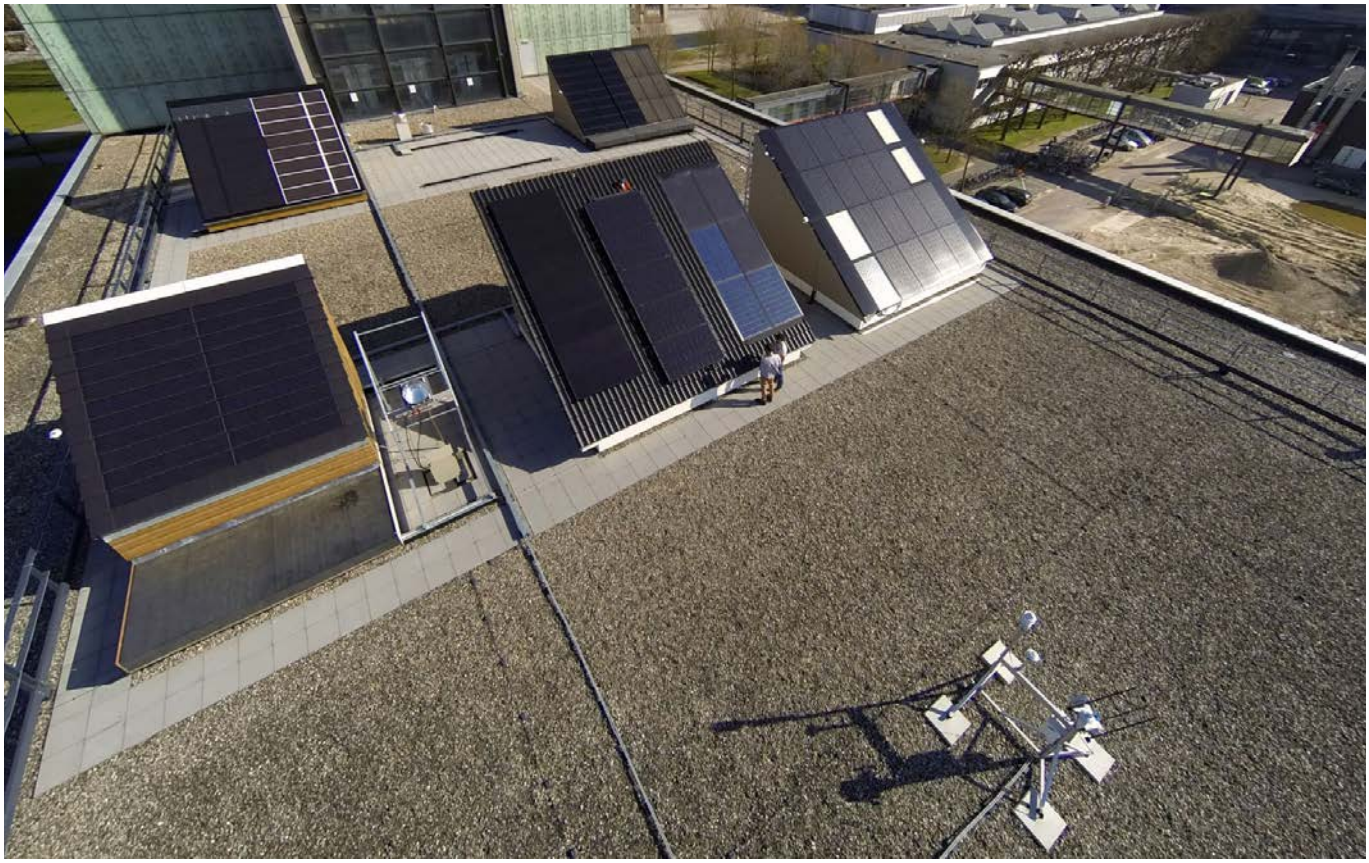


Figure 1. Overview picture of SolarBEAT research facility on roof of Vertigo 'Laagbouw', as taken with drone in summer 2015

(DNI) is measured with a pyrheliometer positioned on the same tracker. The tracker itself knows always where the sun is positioned, even in overcast days, because it has a built-in GPS receiver that provides exact location and atomic time, and hence the position of the sun is calculated with enough accuracy. An internal motor positions the tracker every day from sunrise until sunset into this calculated direction of the sun. The SMS system has also a weather station, that is measuring every minute ambient temperature, relative humidity, wind speed, wind direction, ambient pressure, and precipitation type and intensity. All this data is available for TU/e students and employees throughout a freely available GUI. To make it even easier, one can visit the BPS lab at Vertigo (new room number VRT 2.123, old number VRT 2.57) to find a PC close-by the coffee table that has this GUI already installed. Just log in with the credentials written on the screen, and one can monitor, analyse, or export the data from the SMS for free, and use them for your own project.

One could think that the various projects at SolarBEAT would be competitors of each other. That is not the case. Each product has its own proposition in the ever growing solar energy market. The diversity of prototypes that are developed is large. One could think of the following unique properties of some projects:

a) A combination of thermal insulation panels and PV panels prefab assembled into standard building elements.
b) A light-weight construction with quick (re)assembly on the roof and superior aesthetics.
c) A full roof combination of solar-electricity and solar-thermal panels.
d) PV and solar heater at the same square meter stacked on each other.
e) A combination of PV electricity and a heat pump. And many more ideas and project proposals in the pipeline.

Discussing all these projects in full details goes beyond the scope of this article. Somehow randomly we pick the latest installation at SolarBEAT for a more detailed description, as this project has not been reported yet in other articles. This is the façade dummy house installation, which was finalized in May 2016. The full consortium of the TKI ZonneGevel project consists of the companies Heliox, Heijmans, Polyplastics, SGS Intron, SCX Solar, WallVision, W/E adviseurs and knowledge institutes SEAC, TU/e and Zuyd Hogeschool. Two new prototypes are demonstrated at the new façade in SolarBEAT.

The lower part of the test façade (Figure 2) is used by SCX Solar. Two rows of five landscape positioned solar PV panels with thin-film technology

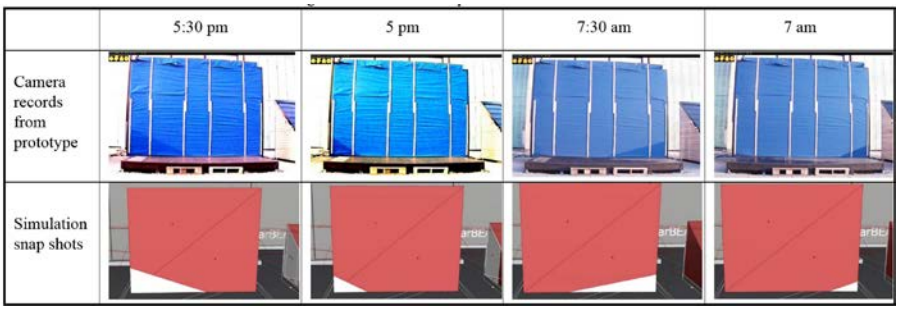


Figure 3. Comparison of real shadows measured by the webcam, with shadow modelling software applied to the SketchUp-model of Vertigo and SolarBEAT for an arbitrary day in winter 2016

are installed. Their product is called SoloWall. The general perception is that these thin-film PV panels have a better aesthetics than the more common crystalline PV panels. We are going to test that assumption. The outdoor performance will be measured in terms of kWh output as a function of all the ambient conditions that are measured in the SMS. The contribution of ground reflection (so-called albedo) is also incorporated in the performance research, because the lower row of panels is quite close to the ground. Soiling is investigated, and researched in relation to the amount of rain and snow fall. Also the possible negative impact of shadow from the neighbouring cabins is investigated. SolarBEAT has been drawn in SketchUp already. With the help of software packages GrassHopper and Rhino, the exact times of shadow on each specific PV panel have been calculated to a time interval of 5 minutes for the full year. A first comparison of these shadow calculations with real live data from the webcam pointing on the façade permanently, looks promising (Figure 3). This enables us to predict the electrical DC output based on its IV-curve (a kind of fingerprint of the PV panel) that was produced during a flash-test before installation. Total AC (kWh) performance will be measured and stored in the central SEAC SQL-server. Because the amount of data is quite large, data extraction is not done with the above mentioned GUI, but with open-source Python coding (including usage of the impressively improving packages like Pandas, Matplotlib, Datetime, etc...).

Figure 2. Picture of the façade cabin at which two companies of the ZonneGevel project are testing their new products. Lower part: SoloWall from SCX Solar. Upper part: ZigZag Solar from WallVision

The total PV system will be simulated with the software package PV-SYST. The detailed comparison between that simulation with the real measurements should reveal the acclaimed electrical performance benefits of the CIGS thin-film technology over crystalline technology. By the end of this year (2016), we will have gathered enough data and knowledge to draw some conclusions that will be interesting not only for the company SCX Solar, but also for the international BIPV community. Additionally, the mechanical and building aspects of this newly developed façade construction are researched. The easy 'clicking in-and-out' of an arbitrarily chosen panel in the complete façade (without demounting the complete façade) has been performed already a couple of weeks ago when we needed to change something to the cabling of specific panels. This could become a real Unique Selling Point (USP) of the SoloWall product. Last but not least, the thermal behaviour will have influence on the specific design of cabling and power electronics for feeding the electricity into the grid. For that purpose, measurements will be done with thermocouples, RH-probes and hot-wire anemometers.

The upper part of the same test façade (Figure 2) is used by WallVision. This company is bringing a very innovative façade product to the market, called ZigZag Solar; the name ZigZag refers to the Z-shaped look of the façade. People on the ground cannot see the PV panels because they are installed under a relatively low angle with the horizon. Visible from the ground are only the decorative panels that have a much steeper angle and can be adjusted to the specific wishes of each customer. Already a large part of commercially available cladding material (e.g. Trespa) can be put in as decorative panel. As a bonus, most cladding material is reflecting light onto the PV panel below. This gives a boost to the electrical output of the system. But how large is this boosting factor? At first, one could think that this question can be answered with a few fast back-of-the-envelope calculations. On the contrary! The complexity of this system emerges when one starts to investigate: the effect of the location of installation on Earth,

with a largely varying trajectory of the sun in the hemisphere; the effect of the compass direction of the building (a lot of interested potential customers like to renovate their existing buildings with hence façade directions that cannot be changed anymore); and the effect of the reflection of light from the decorative panel (that is chosen by the potential customer) which is partly diffuse and partly direct light.

Three rows of three ZigZag cassettes (a cassette is defined as a combination of a PV panel and a decorative panel) are installed. The most upper row has a whitish reflector; the bottom row has a grey reflector, and the middle row has a neutral reflector with measurements focussing on the electrical performance. AC and DC electrical performance are measured with a one minute resolution creating a huge amount of viable data. Also the irradiance is measured with the same one minute resolution and synchronized clocks: in the vertical plane, in the plane of the PV panels, and inside the reflector, with pyranometers and photodiodes. Simulating the ZigZag system is difficult and most probably impossible with standard commercial software packages, although in parallel we are still trying to do so. Because of this geometrical complexity, last year we decided to start modelling the light behaviour in the ZigZag cassette completely from scratch, i.e. drawing the full system and applying the relevant physics on it, see Figure 4.

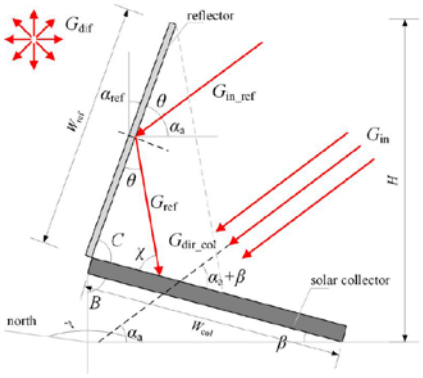


Figure 4. Sketch of geometrical model of ZigZagSolar system

After about half a year of hard work, at the BPS group, an advanced optical model has been developed successfully (initiated by Mollier board member Xin Xu) and coded in Matlab. The model is still being improved continuously. The validation of this model with the results of the SolarBEAT measurements is in hands of BPS PDEng trainee Mohammad Ghasempourabadi, who is also in charge of the research on the SoloWall system. The better the model can handle the varying light and weather conditions, the more applicable the model is going to be. The ambition is, that the model will predict the kWh yield of the ZigZag product for any orientation, any location on Earth, with any decorative material. It will be the input for optimization decisions regarding the electrical lay-out of the cassettes on the façade, and it makes sure that most optimal geometry is tuned to the specific location of installation. A preliminary result of predicted irradiation in kWh/m²/year

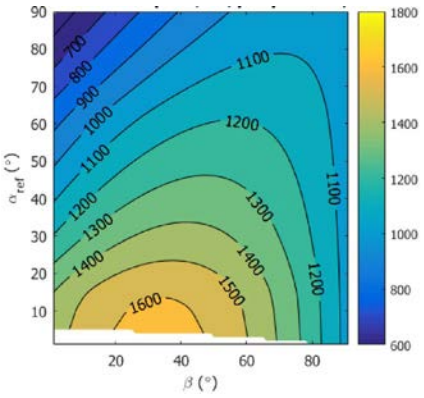


Figure 5. Preliminary modelled irradiation in kWh/m²/year on the PV-panel as a function of PV module tilt angle and reflector panel angle is shown in for a location in the south of Europe, and specific decorative material

on the PV-panel as a function of PV module tilt angle and reflector panel angle is shown in Figure 5, for a location in the south of Europe, and specific decorative material.

Most results for the ZonneGevel project as described above for both the SoloWall product and the ZigZag Solar product will become available mid 2017. Hopefully, after reading all these details, the reader now understands a bit more of the discipline of 'Building & Infrastructure Integrated PV Outdoor Performance Research'. And the reader understands that it goes beyond the scope (and length) of this article to describe all 6 projects in SolarBEAT with the same level of detail as we have done for the ZonneGevel project.

Finally, we like to mention the measurement location outside the roof of Vertigo that will soon be operational. In 2015 the project proposal for a Mobility Center was granted by RVO. In this project we will research how volunteers experience a luxury e-bike sharing concept. Volunteers consist of the group of employees that live just too far (about 8 to 20 km's) from TU/e and are tempted to take their car for daily commuting instead of their bike. This so-called Mobility Center is not an ordinary bicycle shed, but a high-quality charging station for 10 e-bikes. Users control the door and the e-bike unlocks from an app on their smartphone. The employer pays the bill according to usage or statistics that are stored on a central server; the user is care free. Electrical power for the e-bikes is captured by a solar PV roof that is designed to be large enough to run the Mobility Center in an autonomous way. However, that needs a large enough battery bank which makes the product more expensive. The precise size of the battery bank and the best charging strategy ('which e-bike gets charged at which moment depending on time of the day, day in the year, weather forecast, and driving history of each specific user...') is one of the major research topics. The social side of the research is to find out at which boundary conditions, potential users leave their car in the garage, and pick a high quality e-bike instead. In the end, this is unquestionably better for their own health, better for the employer (providing an e-bike is cheaper than providing a lease-car), and better for the Dutch economy, because this product can be a real hit for the Dutch companies in the project and also their suppliers.

Wrapping up, at the moment SolarBEAT is having nearly 100% occupation. However, all running projects have an end date. Therefore measurement positions will become available in the near future. Moreover, plans are made to extend the measurement positions on the Vertigo roof, as the number of project proposals and leads is still growing and goes beyond the existing capacity.

Are you a student and would you like to work on BIPV(T) research for your next master project, please consult us for an overview of available traineeships. Are you working on new innovative BIPV(T)-solutions no matter if it is building integrated or infrastructure integrated, please let us know. Are you an architect or project developer in the building industry and interested in more details, just let us know. Or are you interested in some other way, do not hesitate to contact us. ■

[1] http://www.seac.cc/fileadmin/seac/user/doc/PVSEC_2014_6AV425_SolarBEAT_by_SEAC_Valckenborg_et_al.pdf
[2] http://www.seac.cc/fileadmin/seac/user/doc/6AV_5_26_Valckenborg_et_al.pdf

The 4th lustrum of Mollier
Back in time along the INSide

Authors
K.P. (Koop Pieter) Ziel
L. (Lotte) Kooi

THE START [1997-1998]

The very first students Installation Technology at the TU/e had to each select their own course schedule based on a pile of stapled papers. Since the program Installation Technology was based on subjects in the curricula of Mechanical engineering, the Built Environment, and Electrical Engineering, it was quite a puzzle to attend appropriate courses each trimester and exams were to be taken regularly at the same time.

1998 2000 2002 2004 2006

1997 1999 2001 2003 2005

So there was a great need for exchange of information and experiences of fellow students. Hence the idea to create a study association. An association to form a home base for the Installation Technology students, to gather practice exams, professional literature and make them available to members. And, of course, the social aspect was very important in order to bring students together, who were often individually wandering between different faculties.

FIRST CONSTITUTION DRINK

Of course the founding included a constitution drink. The Skybar, at that time actually a rooftop bar at the universities main building, was rented. The deposit for this drink was paid from a personal donation of prof. Pierre Leijendeckers of fl. 100 guilder. It was guessed that the 'tip box' at the entrance of the Skybar would eventually provide enough revenue to be able to meet the beverage account afterwards.

[2006]
New yearly tradition "Sister day". Mollier students were supposed to bring their sisters for a nice evening dinner and late night out..

[2003]
Mollier darts championship at highest level.

[2003]
The start of a series of successive "Schoone Leij Alumni Activities"

1996

[2012]
The 17th board is fully from Limburg.

[2010]
All the lectures in English! For the first time many 'foreign' students.

[2012]
New investment: the first own coffee machine for Mollier.

[2014]
Launching a fabulous new website.

[2010]
Merging of the master Building Services and the master Building Physics to one new master "Building Physics and Services".

2008 2010 2012 2014 2016

2007 2009 2011 2013 2015

[2013]
Milestone! Mollier is guided into the 21st century: The study association can be found on Facebook.

[2009]
Lack of active female members! A promotion to attract more ladies to Mollier was made.

[2011]
Board has become part-time and a lot of new committees.

[2015]
The 19th board has a female chairman since our foundation

[2007]
First time in Mollier: "The study trip abroad" to United Arab Emirates.

[2013]
The 18th board is the first mainly female board of mollier.

- 2016

CONNECTING TECHNICAL PROFESSIONALS

KP&T

Techniek is jouw toekomst.
Voor een baan of traineeship kom jij dus graag in contact met die ene interessante organisatie. KP&T verbindt je doelgericht aan de opdrachtgever die echt bij je past. Met veel aandacht voor jouw kwaliteiten en ambities creëren we de samenwerking waarin jij op je plek bent. Samen brengen we je kansen in kaart. We helpen je op weg naar je sollicitatiegesprek en begeleiden je terwijl je werkervaring opdoet. Al zin om te starten? Bel of mail een van onze adviseurs in jouw regio voor een afspraak.

KP&T verbindt professionals.
In bouwkunde, civiele techniek, elektrotechniek, energietechniek, High Tech, installatietechniek, Oil & Gas en werktuigbouwkunde.

Bouw
Ruimte
Milieu

Ontwikkelen, realiseren en beheren

Akoestiek
Bouwfysica
Brandveiligheid
Duurzaamheid
Energie
Gebiedsontwikkeling
Lawaaibeheersing
Milieu
Rentmeesterij
Ruimtelijke ordening
Trillingen

LBP|SIGHT is een onafhankelijk advies- en ingenieursbureau met 45 jaar ervaring. Passie voor het vak is wat de honderd professionals bindt.

Zelfs het eenvoudigste project heeft tegenwoordig grote implicaties, zowel ruimtelijk, juridisch, maatschappelijk, economisch als milieutechnisch.

Geïntegreerde, specialistische kennis is cruciaal. Op ieder vakgebied hebben we de beste mensen in huis – experts die hun vak tot in de haarvaten beheersen.

Out of the box-denken en gezond verstand zorgen voor andersoortige, effectieve maar vooral praktische oplossingen.

Stage lopen of afstuderen?
Neem voor meer informatie contact op met Erika Knoop (030) 231 13 77

LBP|SIGHT

Kelvinbaan 40
3439 MT Nieuwegein
(030) 231 13 77
www.lbpsight.nl

Case-study for a fit-for-purpose model complexity selection

Author
ir. E. (Eva) van Enk

Supervisors
I.I. (Isabella) Gaetani
dr. ir. P. (Pieter-Jan) Hoes
prof. dr. ir. J.L.M. (Jan) Hensen

INTRODUCTION

The stringent regulations on buildings' energy efficiency have resulted in the development of a wide range of modelling approaches for building energy analysis. Such approaches can be classified according to their complexity, and in particular they range from quasi steady-state spreadsheet tools to detailed, dynamic building energy simulation tools. While there is an overall tendency to deem more complex models as more accurate, in reality the predictive ability of models is very case specific [1]. In fact, the overall error in a model's prediction consists of the sum of abstraction error and input uncertainty. Every model is a simplified representation of the reality, and thus suffers from abstraction errors. Typically, simple models have a higher abstraction error, while more complex models provide a more accurate simplification of reality. On the other hand, complex models might require a higher number of inputs to be specified by the user, and such inputs might not always be defined or certain [2].

In this context, it is extremely difficult for the BPS user to choose which model to apply when. In practice, however, simulation users commonly rely on experience or familiarity with specific tools to select a BPS approach. My study aims at gaining insights on the differences among outcomes of tools commonly used in a Dutch company and characterized by different complexity levels. In particular, the effect of the model complexity on the decision-making process is highlighted.

METHODOLOGY

FIT-FOR-PURPOSE FRAMEWORK

There exists a trade-off between input data uncertainty and abstraction error in a prediction model used within a certain design phase of a building. Indicating the balance between these two aspects could help to select the fit-for-purpose model complexity. Figure 1 illustrates that the lowest overall prediction error occurs at the intersection of the curves representing abstraction error and input data uncertainty. The overall error is assumed not to decrease for a more complex model after this intersection point. Therefore, there is no sense adding any additional modeling complexity beyond this point.

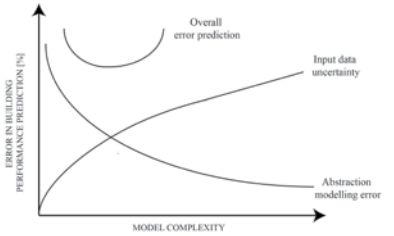


Figure 1. Trade-off between model complexity and error in building performance prediction (Zeigler et al., 2000)

Figure 2 presents a flow-chart to identify the fit-for-purpose model complexity. The first step is the specification of the simulation objective(s). Depending on the objective and the case specific criteria (e.g. performance indicator(s), building type, and project phase) there will usually be a range of suitable BPS tools available that vary according to model complexity. To select the fit-for-purpose model complexity, the AME referred to the lowest suitable level of model complexity have to be determined. Then, the input uncertainty referred to the higher level of model complexity will be quantified by Monte Carlo simulation. Once AME and input uncertainty are quantified, the trade-off point between the two is identified and the most appropriate level of model complexity can be determined. If the input uncertainty of a more complex model is higher than the AME of a model with a lower complexity, the model with the lower complexity is more appropriate, as the overall error in the model prediction will not decrease by adding complexity. In case the calculated level of overall prediction error is inconclusive, further treatment is needed to reduce the overall prediction error. By means of

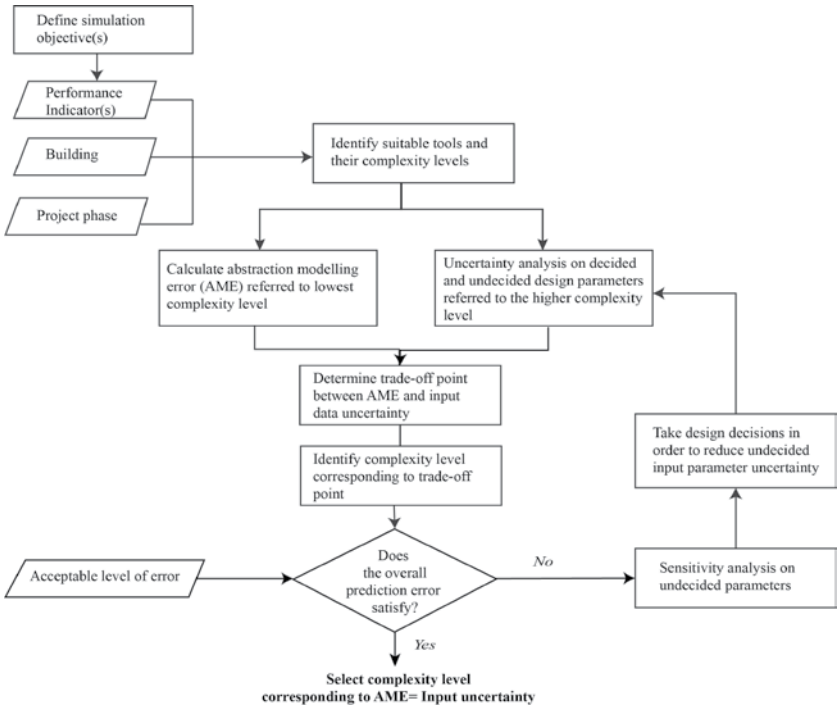


Figure 2. Flow-chart to define the fit-for-purpose model complexity level

$$AME_{\text{P1:Evaluated level}} = \left[\frac{Output_{\text{P1:Evaluated level}} - Output_{\text{P1:Highest level}}}{Output_{\text{P1:Highest level}}} \cdot 100\% \right] + AME_{\text{min}}$$

Equation 1. Abstraction modelling error $AME_{\text{P1:Evaluated level}}$ [%]

a sensitivity analysis, insight is given into the contribution of parameters to the output. Once the most influential parameters are known, the simulation user can focus on reducing the undecided parameters' uncertainty by making design decisions upon those parameters.

ABSTRACTION MODELLING ERROR

In this research, the AME for the evaluated level is calculated using equation (1), where $AME_{\text{P1:Evaluatued level}}$ [%] is the abstraction modelling error for the evaluated level for a given performance indicator (PI). $Output_{\text{PI,Evaluated level}}$ [%] is the output of the evaluated complexity level for the given PI. AME_{min} represents a minimum level of abstraction modelling error. All models will suffer from a certain level of abstraction error, as a model is by definition a simplified representation of the reality. It is found in literature, that it is not possible to predict the energy consumption more accurately than 10-15%, even if all input parameters are known [3]. Therefore, the minimum level of abstraction error for the energy performance indicators is set on 10% for the most complex model that is presumably the most physically correct.

CASE STUDY

The building case study (Figure 3) is an eight-zone office building (19 ·4· 3,5 m) located in De Bilt, Netherlands. The building has typical construction materials that comply with the benchmark.

SELECTED TOOLS

In this study, the tool selection criteria are: the tools should: (i) represent different levels of model complexity, (ii) allow batch processing, (iii) include the outputs of annual energy needs and peak loads, and (iv) be used at the company. Table 1 shows the three levels of complexity and the corresponding tools that are selected for this project.

SIMULATION OBJECTIVES

Typical design questions occur at different phases in the building design process. These phases correspond to a different set of design parameter uncertainty (undecided and decided design parameters). In this study, three typical design questions were considered corresponding to the phase in the building life cycle and, thus, to the uncertainty in the design parameters.

Table 1. The three considered model complexity levels and their associated software tool for the calculation of the building load and system energy.

		Selected tool	
	Description of the level	**Building load**	**System energy**
Level I	Quasi steady-state method	Excel	Excel
Level II	Dynamic BES using decoupled approach	TRNSYS	Excel
Level III	Dynamic BES using coupled approach	TRNSYS	TRNSYS

A. BUILDING DESIGN COMPARISON

For comparison of (architectural) design alternatives in early design stages, the absolute values obtained from the model are less crucial, as the common belief is that the relative differences between the design is of interest and that the alternatives are based on almost exactly the same assumptions. Therefore, the focus is on the relative differences between the alternatives are of interest. Two design alternatives (Design A and B) are considered that differ from glazing type, and window-to-wall ratio (WWR).

B. SYSTEM SIZING

Once the optimal building design is selected, the next iterative step in the design process involves the selection of equipment and the design of the HVAC system to meet the predicted heating and cooling loads of the building. For sizing the systems, the simulation outputs of interest are the peak loads and the profiles of heating and cooling loads. These load profiles are represented by a load duration curve, in which the relationship between the capacity requirements and capacity utilization in hours of a year is given. We compare the load duration curves for the two levels of complexity.

C. SELECTION OF HVAC SYSTEM

The last simulation objective is the selection of the HVAC system. For simplicity, we only consider three HVAC configurations that have been coupled with the office building. All the configurations consist of a radiator and an all air conditioning system with Constant Air Volume (CAV). The main difference between the configuration is the type of heat recovery method. Conf. 1 consists of a twin-coil heat recovery with an efficiency of 45%. The second configuration uses a cross flow heat exchanger with an efficiency of 75%. The last configuration adds Indirect Adiabatic Cooling (IAC) to the second configuration configuration.

RESULTS AND DISCUSSION

FIT-FOR-PURPOSE MODEL COMPLEXITY SELECTION

The results of the uncertainty analysis for Level II and the AME of Level I are shown in Table 3. This table demonstrates the trade-off point between AME and input uncertainty. The first row of this table represents the uncertainty due to only the decided parameters' uncertainty. This uncertainty is of particular interest in the final design stage, wherein it is assumed that all the design decisions have been made.

These case-specific results confirm the intuition of using simplified tools in early design stages and more detailed simulation software in later design phases. Due to the strong correlation with the input parameters, it will be hard if not impossible to generalize an AME for a certain tool, let alone a total complexity level.

A. BUILDING DESIGN COMPARISON

Figure 4 compares the simulation results in terms of heating and cooling energy demand for two building designs, respectively design A and design B.

Figure 3. Impression of the building case-study

Table 3. Results of uncertainty analyses on respectively heating and cooling energy demand for Level II. The set of design parameters are shown on the two right-most columns of this table. The dotted line represent the abstraction modelling error (AME) of Level I

μ Average value in variation | Represents 75% of the scenarios | Represents the upper 25% of the scenarios

		Uncertainty on Annual Heating Energy demand [%]									Uncertainty on Annual Cooling Energy demand [%]											
		5	10	15	20	25	30	35	40	45	10	20	30	40	50	60	70	80	90	100	150	250	350
Decided parameter uncertainty		μ = 2,0									μ = 12,4											
Glazing type [two glazing types]	WWR North [20%]	μ = 2.5									μ = 13.6											
	WWR South [20%]	μ = 5.7									μ = 11.0											
	WWR S+N [20%]	μ = 5.7									μ = 13.6											
	WWR all [20%]	μ = 6.4									μ = 24.0											
	WWR North [20%]	μ = 15.7									μ = 68.0											
	WWR South [20%]	μ = 15,8									μ = 71.6											
	WWR South [20%]	μ = 19,3									μ = 75,8											
	WWR all [20%]	μ = 19,4									μ = 82,1											

$AME_{\text{Level I}}$

Level I suggests that design B is the preferred option in terms of heating and cooling energy demand. To confirm that an higher modelling complexity would lead to the same design decision, the results from Level II are added. The reported results highlight the weakness of simplified tools for the prediction of cooling energy demand. For the investigated design alternatives, it shows that Level I can provide guidance for selecting among building design alternatives during early design phases and that, for this case, a detailed simulation tool is not required. A limitation of the presented comparison is that it is obvious that design B is the most preferable design solution given the better thermal resistance and glass performance.

B. SYSTEM SIZING

Figure 5 shows the year load duration curves for design alternative B for the both levels. The cooling peak load obtained from Level I is almost two times higher compared to the dynamic simulation. The higher peak loads that are observed are a result of the neglecting effect of the thermal capacity; this effect is especially relevant for the cooling energy requirements. Hence, the equipment size required for the system will differ according to these results.

C. SELECTION OF HVAC SYSTEM

The comparison between the three HVAC-system configurations for Level I, II, and III is shown in Figure 6. Based on the results, Level I does not support a design decision as configurations 2 and 3 are very similar in terms of energy performance.

In contrast, the results from Level II and III showed a fair agreement based on yearly and monthly values.

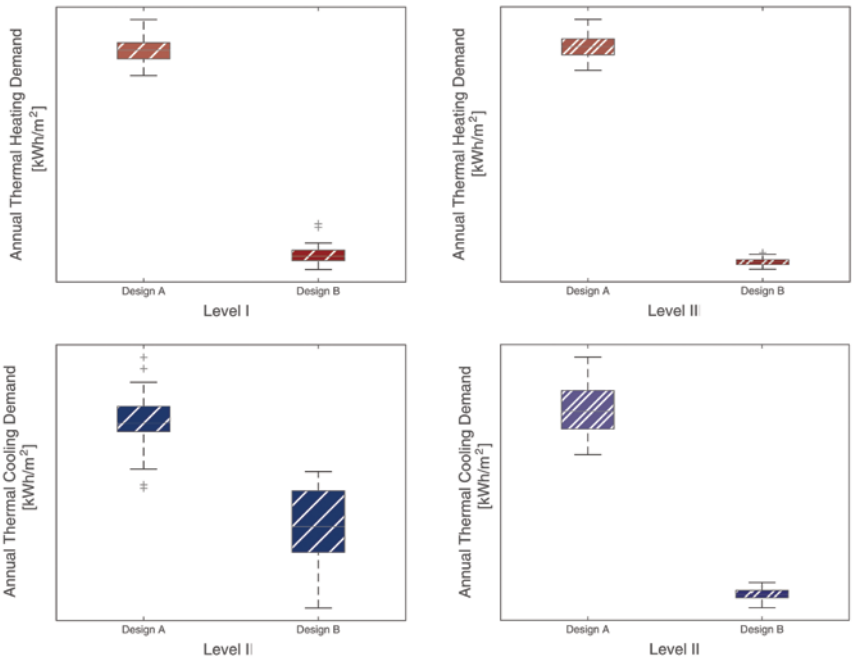


Figure 4. Annual heating and cooling energy demand for level I and II of design A and B.

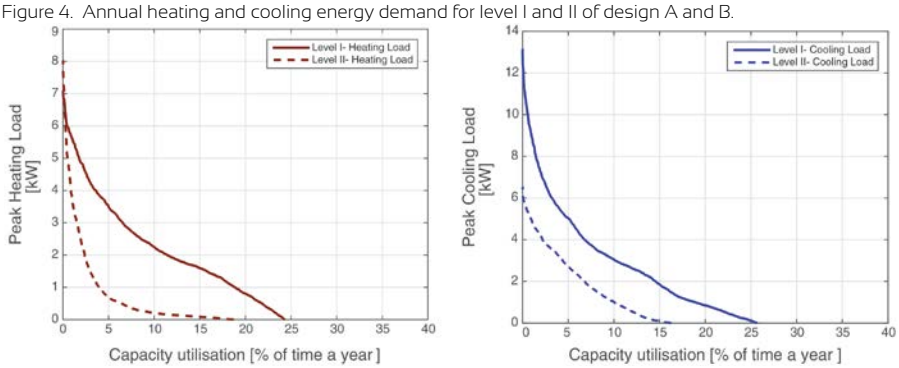


Figure 5. Year load duration curve design B according to Level I and Level II

CONCLUSION

The proposed framework provides a good starting point for finding the fit-for-purpose model complexity. The choice of the fit-for-purpose model complexity hinges on the simulation objective. The case-study results with respect to three simulation objectives showed that the quasi-steady state approach can provide guidance in the selection among design alternatives. However, the choice of system size is affected by the model complexity: in this case a dynamic BES software is required. A coupled approach does not influence the choice of HVAC system.

As every case has another set of uncertainties and every tool another set of abstraction modelling error, the methodology proposed in this paper is very case specific. Future research is needed to further develop the methodology, especially concerning the generalizability of a model's abstraction error. ■

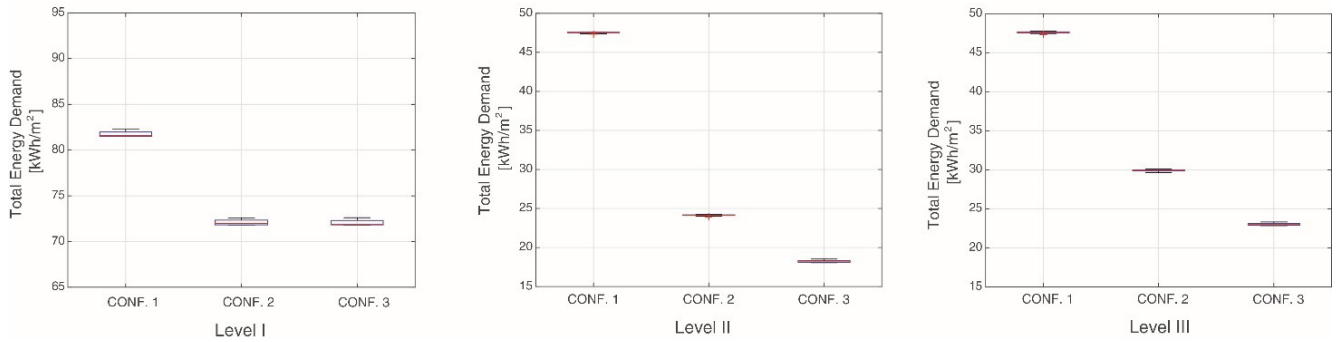


Figure 6. Comparison between three HVAC configurations for complexity levels I, II, and III for total energy demand

[1] Zeigler, B.P., Praehofer, H., & Gon Kim, T. (2000). Theory of Modelling and Simulation – Integrating Discrete Event and Continous Complex Dynamic. 2nd ed., Academic Press, New York, USA.

[2] Trčka, M., Hensen, J.L.M. (2010). Overview of HVAC system simulation. Automation in Construction 19. 93–99. doi:10.1016/j.autcon.2009.11.019.

[3] Santamouris, M. (2010). Energy Performance of Residential Buildings: A Practical Guide for Energy Rating and Efficiency. Taylor & Francis.

Study abroad
7120 Miles from Home

Author
A.P. (Arinda) Rachman

AN ADVENTURE

"Ladies and gentlemen, welcome to Schipol Airport. Local time is 09.30 am and the temperature is 10 degree Celsius. For your safety and comfort, please remain seated with your seatbelt fastened until the Captain turns off the Fasten Seat Belt sign". The announcement from flight attendant woke me up from my daydreaming. I still remember how thrilled I was when I sit on the plane 4 months ago and saw windmills spinning from above. My heart beating so fast, one of my childhood dream will come true, "Netherlands, here I come".

Traveling and live in Europe is one of my big dream since childhood. My father's bedtime stories about his experience in Germany inspired me to see the diversity that exists around the world. However, as people often said, childhood dream will be just a dream, I put this dream in the deepest corner of my heart. I live my life just like most of ordinary people, going to college and trying to finish it well, find a job, and eventually forget about 'my childhood dream'. I start to live my life as a young professional who seek to remain in my comfort zone. Then some small popular quotes from Mark Twain grasp my heart, "Twenty years from now you will be more disappointed by the things that you didn't do than by the ones you did do. So throw off the bowlines. Sail away from the safe harbor. Catch the trade winds in your sails. Explore. Dream. Discover". It come hit my mind and made me realized that 10 years from now I will remain the same if I never try to perceive anything new. Thus, I planned to live one of the biggest dream of mine, live and study abroad in Europe.

I sent some applications to several universities for my master program and was admitted in Building Physics and Service program at TU/e. It is really interesting to see and learn new experience in here. Due to different weather condition, environment and culture, I started doing habits that I've never done before. Checking the weather condition every morning, ride a bike everywhere, and have a breakfast or lunch with cheese and bread are the new habit of mine since I started studying here. There was also a time when I faced some difficulties with the education and lecture system in the Netherlands. Since the structure of education in the Netherlands is in quartiles which is really different with the structure of education in my country, I have to manage my study phase so that I can keep in tune with the lecturer at the class. Just like the other international students, there was a time when I feel lonely and homesick, especially in the first few weeks when I arrived here.

However, no matter how big the challenges I face here, the scenery of the Netherlands (apart from its weather conditions which often very unpleasant) and my parent's support become an elixir to console my heart and boost up my spirit to face of these challenges. I believe, all of the experiences and lesson to live that I got here will enrich my knowledge and develop my personality to be a better person. ■

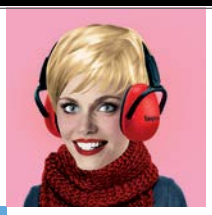
Werk jij met ons aan de volgende markthal?

techniplan adviseurs bv
RAADGEVEND INGENIEURSBUREAU

www.techniplan.nl

Ga jij de uitdaging aan om ontwerpvraagstukken over energiebesparing, duurzaamheid en een comfortabel binnenklimaat in gebouwen integraal aan te pakken? We zijn op zoek naar enthousiaste stagiairs, afstudeerders en nieuwe collega's die hierover met ons willen nadenken! Bij Techniplan Adviseurs lever je een bijdrage aan duurzame en innovatieve bouwprojecten en werk je integraal aan de advisering op het gebied van techniek in gebouwen en de gebouwde omgeving. Ook zijn er mogelijkheden voor een duaal traject, waardoor je al tijdens je studie praktijkervaring kan opdoen.

Geïnteresseerd? Neem dan contact op met Esther Gerritsen (tel: 010-4562311).



heijmans

Let's connect?!

Wil jij zien op welke wijze Heijmans aan de ruimtelijke contouren van morgen bouwt? En ben jij nieuwsgierig welke spraakmakende en innovatieve concepten Heijmans ontwikkelt en realiseert?

Blijf dan up-to-date en volg ons op Facebook & Twitter!

HeijmansNL
HeijmansNL

Mensen verbinden en grenzen verleggen.

We kennen de wereld van onze opdrachtgevers. We weten wat er nodig is voor een modern zorgcomplex, welke eisen medewerkers stellen aan een flexibele werkomgeving en hoe we de overstap op het treinstation prettiger kunnen laten verlopen.

We bouwen, samen met onze opdrachtgevers, aan een leefomgeving die mensen verbindt en grenzen verlegt. Het zijn dan ook de kwaliteiten van onze medewerkers, die het succes van onze projecten bepalen.

Ben jij op zoek naar een stageplaats of afstudeeropdracht? BAM geeft jaarlijks veel studenten de kans om bij een van de werkmaatschappijen werkervaring op te doen en onze organisatie te leren kennen.

Kijk op **werkenbijbam.nl** voor de mogelijkheden.

Onze wereld vraagt erom.

bam

Simulation and auralization of open-plan study environments

Author
M.R. (Marc) Kalee BSc

Supervisors
dr. ir. M.C.J. (Maarten) Hornikx
ir. P.E. (Ella) Braat-Eggen

INTRODUCTION

Today more open-plan work- and study environments are designed to optimize the efficiency of the use of buildings. Unfortunately, different studies show that open-plan environments can have a negative influence on the cognitive performance and the concentration of occupants [1]. According to [2], in open-plan offices, sound privacy is the most distractive factor. Therefore the acoustics of open-plan work and likely also study environments are important.

RESEARCH

This research focuses on the use of simulation for auralization in an open-plan study environment. Four room acoustical parameters; Reverberation Time (T30), Early Decay Time (EDT), Clarity (C80) and the Sound Pressure Level (Lp) are measured and compared with a simulation in ODEON. Vertigo Floor 3 is used as open-plan study environment. In the first part of the research the input variables in ODEON are derived from literature and surveying Vertigo Floor 3. In the second part a variant study is conducted in order to evaluate different input parameters, like the scattering coefficient of the objects, absorption of the ceiling and the absorption of the acoustic panels. The main goal is to establish the acoustic quality of an simulation for auralization by fitting the described room acoustical parameters, simulated in ODEON, with the measurements.

RESULTS

The measurements in Vertigo show a high reverberation time in the low frequencies (63-, 125- and 250- Hz octave band). A 'dip' is clearly visible in the 500 Hz octave band, probably due to the shape of the room and the location of absorption materials (Figure 1). The simulation in ODEON shows lower reverberation times in all octave bands. The measured 'dip' is less pronounced and shifted to a lower octave band (250 Hz). The differences between the measurements and the simulations are also visible in the Early Decay Time (lower values in the simulation) and the Clarity (higher values in the simulation). The sound pressure levels shows the best agreement.

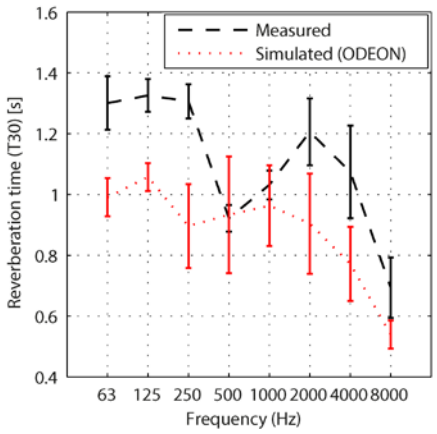


Figure 1. Reverberation time standard input variables, T30, with standard deviation

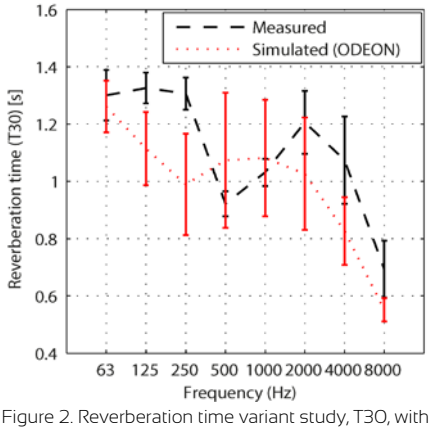


Figure 2. Reverberation time variant study, T30, with standard deviation

The most interesting parameter in the variant study is the scattering coefficient. This coefficient is always an estimation and should be chosen on the basis of the depth of the structure and details. Unfortunately, only a few studies have been conducted to this coefficient [3]. By increasing the scattering coefficient for large surface areas like the concrete walls, higher reverberation times are obtained in the middle frequency octave band in the tested study environment. This is caused by a more diffuse field and the location of the absorption materials in the room. The best agreement in the reverberation time is obtained by a combination of variables which describes a local diffuse field. An example is a filled cabinet with a high scattering coefficient near to the glass façade with lower scattering and absorption coefficient. This phenomenon could be further investigated.

CONCLUSION

Studies have shown that the Just Noticeable Difference (JND) of the reverberation time is 10 percent [4]. The established differences between the measured and simulated values of the reverberation time in this study exceed the 10 percent in five of the eight investigated octave bands. For this reason the use of an auralization should be further investigated. ■

[1] Hongisto, V. (2008). Effect of sound masking on workers in an open office. In Acoustics 08 Paris (Vol. June 29-Ju, pp. 537–542).

[2] Kim, J., & de Dear, R. (2013). Workspace satisfaction: The privacy-communication trade-off in open-plan offices. Journal of Environmental Psychology, 36, 18–26.

[3] Christensen, C. L., & Rindel, J. H. (2005). A new scattering method that combines roughness and diffraction effects Geometrical model The Reflection Based Scattering coefficient. Forum Acusticum, Budapest, Hungary, 2159–2164.

[4] Martellotta, F. (2010). The just noticeable difference of center time and clarity index in large reverberant spaces. The Journal of the Acoustical Society of America, 128(2), 654.

Studytrip goes to Brazil!

Author
Hanneke Dekkers
Michiel Willems

DAY 1: TRAVEL TO RIO DE JANEIRO

There we go, as 20 students of Mollier off to Brazil! At three in the morning we gathered at the station of Eindhoven. After arriving on the airport Zaventem, take-off and landing is all we can say about the flight to Amsterdam, which was over in 25 minutes. There was an entertainment system in the Dreamliner that allowed everyone to have fun by playing chess against each other or by watching a movie. While landing in Rio de Janeiro, everyone was surprised about the fact that it was already dark at 17:45. Arriving at the hostel we were welcomed with drinks and diner, which was very satisfying after a long and tiring journey, but one thing is certain, we were in Rio!

DAY 2: CULTURAL TOUR

In the first we woke up at 7 o'clock after a trip of 22 hours. After a brief breakfast we reached the research centre CRESESB by taxi, surfing in the wild traffic of Rio. As we stepped in CRESESB we instantly sensed the Brazilian hospitality by dr. Ricardo Dutra engineer for development of sustainable energy. During his presentation Ricardo provided a lot of information about Brazilian's energy management and future plans for increase its sustainability (40% of Brazilian consumptions are already provided by green sources!!) and stability of the energy grid. After a short and "quiet" taxi drive we arrived at Catedral San Sebastian Metropolitana in the city centre of Rio the Janeiro. An imposing building located in between the district of Santa Teresa and large office buildings. The day has proceeded with a quick lunch with Brazilian meat and continued around the city centre passing by the Theatro Municipal and Museo de Modern Art with a local market and a church in between. The whole group met at the Museum of modern art located in the bay in front of the beautiful Sugarloaf mountain, which provided a view of Christ the Redeemer. The walk continued through the coloured streets of Rio and leading to the marvellous Escalada Selaron, a staircase covered by colourful tile from all over the world. Our destination, the district of Santa Teresa, began on top of the Escalada with its typical houses hosting intellectuals and wealthy people of Rio. The streets ran up on the hill where we arrived at the Parque das Ruinas which provided a magnificent view over the city. The tour afterwards through Santa Teresa through this marvellous district ended to a cozy bar with a 'Brazilian borrel' based on tasty tapas and ice cold local beer.

Figure 2. Escadaria Selaron: these steps contain different tiles that represent different countries in the world, we spotted some 'Delfts blauw' and tiles from Amsterdam

Figure 1. View of sugar loaf mountain ath the arrival day in Rio de Janeiro (f.l.t.r. Stijn, Daan, Giel, Gerton)

DAY 3: CHRIST THE REDEEMER

An early wakeup to have a hike to Christ the Redeemer, the Jesus tatue on top of the mountain. We went to Lage Park, the starting point of the hike. After we checked our group in at the park and the monkeys were fed from our hands, we left on the hike to Christ the Redeemer. A journey of 2.5 hours through the rainforest, a lot of climbing and eventually a nice view, hopefully. The first part of the trip went well: lots

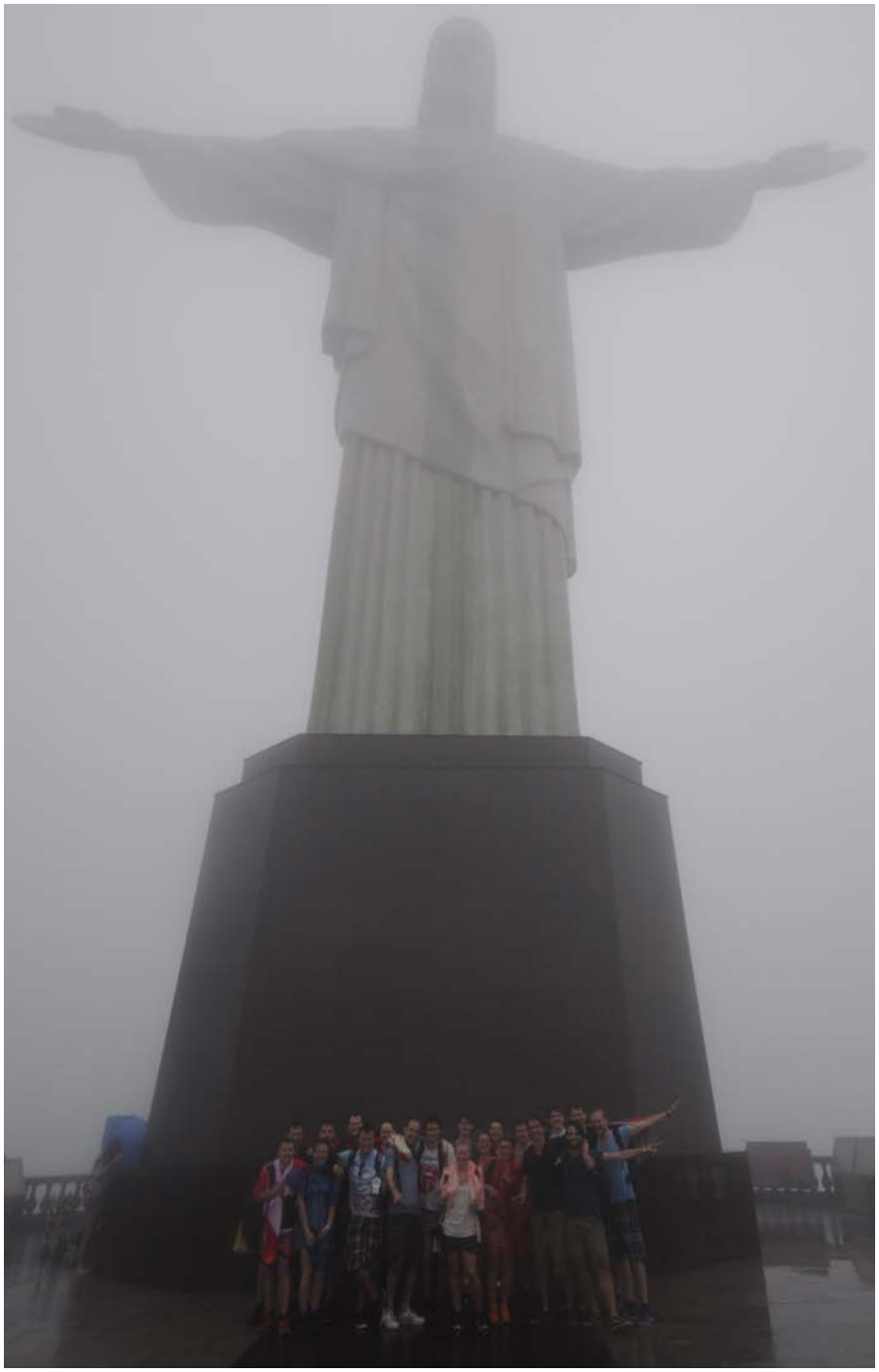


Figure 3. Group picture of the entire group that hiked to Christ the Redeemer. The bad weather resulted in a not very clear picture but the positive thing was that there were almost no other tourists

of nature, not too steep, very warm and occasionally we saw the sun through the clouds and trees. Unfortunately it started to rain after half an hour and this continued throughout the rest of the hike. Finally we climbed up in the pouring rain which was quite hard because the route was a lot tougher than we expected in some places, mainly due to a lot of slippery rocks and the climbing along chains. When we finally arrived on the mountain, everyone was soaked to their underwear and it was extra cold due to the wind. The thick fog that hung above the mountain blocked our view to the Christ the Redeemer statue. It was barely visible, so was the view. However, sometimes there was a clearing of the fog and that was the moment we took a group photo with Christ the Redeemer. Wrapped in towels, brought with us to take them to the beach, we waited for the cable car going down from Christ the Redeemer. Recovering from the journey we had a walk on the Copacabana beach and went to the night market with sculptures, paintings, magnets and all kinds of other souvenirs.

DAY 4: ILHA DE PAQUETÁ

The surprise activity of today was a boat trip to the island Ilha de Paquetá. On this island there are little to no cars allowed to drive around, instead of cars they use carriage with horses and bikes. The relative calmness of the island was a welcome change to the busy schedules of Rio's busy centre. At arrival the sun was shining bright. After a short walk we reached the beach at the other side of the island, a shocking 300 meters ahead, from where we started discovering the island. At one of the points of the island stands a beautiful ruin from which we had a beautiful view over the bay of Rio. Time to go back to the main coast, on the way back to the ferry the ladies gave a show of their driving skills, drifting wheelie on a boulevard bicycle buggy on high speed. Once arrived at the hostel we had dinner and the evening program started: a night out in Lapa.

Figure 4. Babette, Wies and Hanneke decided to explore the island Ilha de Paqueta on a 2-persons-bicycle

DAY 5: FAVELA TOUR

Today the favela tour, through the favela "Rocinha" with 75,000 inhabitants located at the west side of Rio de Janeiro. The favela is famous for its criminality, in which drug dealers and militias are no exception. We were only allowed to make pictures on "safe" places when the tour guide said so, to prevent that we would end the tour with even less persons. We spotted some individuals with a (machine)gun, varying of age starting from 12 years. The environmental status of the favela wasn't ideal. For example the open sewers with lots of pests. Riccardo and Stijn thought it was necessary to make the tour even more realistic by wearing flip-flops, which they regretted in hindsight. In their opinion this fell under the category "poor life decisions". Once the favela tour was finished, there was measurement and free time. For example the group of acoustics who measured the sound pressure levels and mapped this for different locations in the city. By using in-ear microphones (binaural) and an action camera (GoPro) the sound experience of the city is recorded. Another group has measured the air quality in the hostel, with the outdoor air as reference, for a whole set of parameters such as particulates, temperature, air speed etc. In addition to that an analysis is made of the HVAC system.

DAY 6: SUGARLOAF MOUNTAIN

It's nine o'clock in the morning, everyone is enjoying breakfast. But it's not the bread and eggs that get the attention, it's this one heroic young man on his way to immortality. Despite his recent acquirement of a driving license, the expectations are high... And so it began, the triumph of Max Verstappen. For the whole summary by Tom, please visit our online blog. As if this day

Figure 5. The tour lead us from the top of this mountain, through narrow alleys to the point where this picture is taken. Pictures from inside the Favela were not allowed

didn't bring us enough joy yet, the sky turned blue. We went to the Ipanema Hippie Fair, a relatively large square area hosting stands with all kinds of souvenirs, merchandise, food, local handcraft work, paintings and lots of soccer shirts and flip-flops. The visit gave us a first impression of Ipanema, but the most important thing had yet to come: the famous beach! After putting on loads of sunscreen, everyone chose their own strategy: get some rest, play beach soccer, walk along the shore or negotiate with the numerous amount of street(/beach) vendors. At some point, the declining position of the sun made us aware that it was time for our next stop: Sugarloaf Mountain! Two rides in a cable car brought us to the top of the gigantic rock, situated between Botafogo and Copacabana. The view of the city is enchanting and very welcome after failing to see anything of Rio back at Christ's feet. Back down, we enjoyed a genuine 'boteca' with Brazilian grill specialties.

DAY 7: TRAVEL TO PARATY

The group had an early (6 am) breakfast to get the bus to Paraty, a small historic town. The streets of Paraty are covered with cobblestones which made it very hard to walk with suitcases. The streets are built like that, due to the high water level when the tide is high. At the moment of high water, once every moon cycle, the streets of Paraty are filled with sea water. Luckily, this moment occurred during our stay. When everyone had a place to sleep, an opened suitcase, a packed backpack and a sunscreen covered body, we could start the walk to the beach for a barbecue and the evening program.

DAY 8: JEEP TOUR

The first stop of the jeep tour was at the fort of Paraty. The location of the fort was ideal to see ships coming from the ocean. This means it has a nice view over Paraty itself and the bay. The second stop which was visited contained an old hydro plant, which was put out of order a long time ago. Next to this old hydro plant a waterfall was located where many of us took a swim. Next stop was the cachaça distillery where we got a guided tour through the cachaça process and at the end of the tour we were able to taste different kind a cachaças. The jeep tour continued again after lunch and we ended up at a river where rocks created a natural waterslide. Some of us have small memorable marks on the body from the slide. Also a second distillery was visited where again some different kind of cachaças could be tasted. The evening program started off with perfectly homemade Caipirinhas.


Figure 6. The view from sugar loaf mountain before the sun went down

Figure 7. Sé cathedral in Sao Paulo

DAY 9: TRAVEL TO SAO PAOLO

We arrived in Sao Paulo, the financial heart of the Brazilian economy. Before the trip started, bags and suitcases were loaded on a jeep. Our stay in this village taught us that the streets made of cobblestones make it almost impossible to transport the luggage to the bus station by foot. After the long bus trip our visit to the Sala concert hall is unfortunately cancelled, due to traffic jams in the enormous metropole.

DAY 10: UNIVERSITY VISITS

We went to the Universidade de Sao Paulo where we started at the faculty of Civil engineering. First Professor Jay kicked off the presentations and explained us that sand in Brazil is rare and therefore very expensive, which resulted in his research on concrete and how to replace the binder with another filler. This presentation was followed by a presentation of Doctor Mia, who gave us a presentation about CFD & Energy Plus, and her research about indoor air quality. Finally, PhD candidate Rafaela ended the session of presentations with her presentation about the CICS Living Lab. After that it was our turn to give presentations that were given by Lara, Tom and Daan. When we had lunch we went to the faculty of Architecture where a very interesting presentation was held. The students of Architecture gave us a lot of tips for the rest of our stay in the city of Sao Paulo. We ended the night with a delicious Brazilian barbecue in the hostel

DAY 11: COMPANY VISITS

The alarm rang also this time early for making sure we could leave the hostel at 8 o'clock. As real Dutchies the group arrived at headquarters of Sustentech before the meeting time. We were directed to a small eight person meeting room. Some chairs were taken from the office to obtain more seats, still some had to sit in the window or on the small dresser. We realized that Brazilians aren't very punctual if it's about appointments, because after waiting fifteen minutes our host came in. We had to say goodbye at twelve, after André's interesting presentation about Sustentech's activities, clients and projects, because of the next appointment. At Arcadis we were welcomed by Jair and Eloisa who presented the company's activities in Brazil. Afterwards we discussed about different topics. Once back at the hostel everyone rested for another night exploring São Paulo..

DAY 12: EXPLORING SAO PAOLO

The first stop of the city tour that was planned was Pinacoteca do estado/parque de luz. In the museum an exhibition was held with many different art styles. Unfortunately, the raining season came looking around the corner and kept us to explore the park and possibly spot a parrot or two. After everyone had become fully awake with a cup of coffee and we robbed a street vendor of his umbrellas, we continued our tour to Mercado, where different Brazilian delicacies were tasted. Our afternoon program was begun. While part of the group took advantage of this time to do measurements, the rest went into the crowd called the centre of Sao Paulo. First stop was the Edificio Martinelli (Martinelli Building), the first "skyscraper" of Brazil. Our city tour continued to the "SÉ Cathedral". On the square in front of the cathedral we were, for the 2nd time during our trip,

Figure 8. 20 persons were put together in this small office at Sustentech fort he entire morning

Figure 9. Group picture at the Arcadis office

Figure 10. Group picture

confronted with the political problems that currently are ongoing in Brazil. Back at the hostel the search was initiated for a location for our last supper. With the help of some locals we met at the university, we ended up at a restaurant with buffet and unlimited meat on a skewer at the table.

DAY 13: HOME SWEET HOME

One group still had to do measurements, while the rest was blessed with a good night sleep. Luckily the weather was good and we decided to spend our last few hours in Sao Paulo, and Brazil, in the city. One

Figure 11. The jeep tour in Paraty allowed us often to get out of the jeep and visit the natural surroundings by foot

part of the group went to the Ibirapuera park. It is said to be one of the top ten places you need to visit when you're visiting Sao Paulo and it was well worth it. We set 15:00 as a gathering time at the hostel for one last Caipirinha, made by Hanneke, before we would take the bus to the airport. We were all waiting on the sidewalk in front of the hostel to catch the bus, but there was no sign of a bus. After many phone calls with headquarters all the way in London, the bus finally arrived an hour too late. After some rushing at the airport, we were all in the plane on our way to home.

We had a fantastic time in Brazil with all the 20 students and we are glad we did not have to leave anyone behind this time! ■

Energy efficient lighting options for table tennis

Author
E.M.N.L. (Elianne) Paulussen BSc

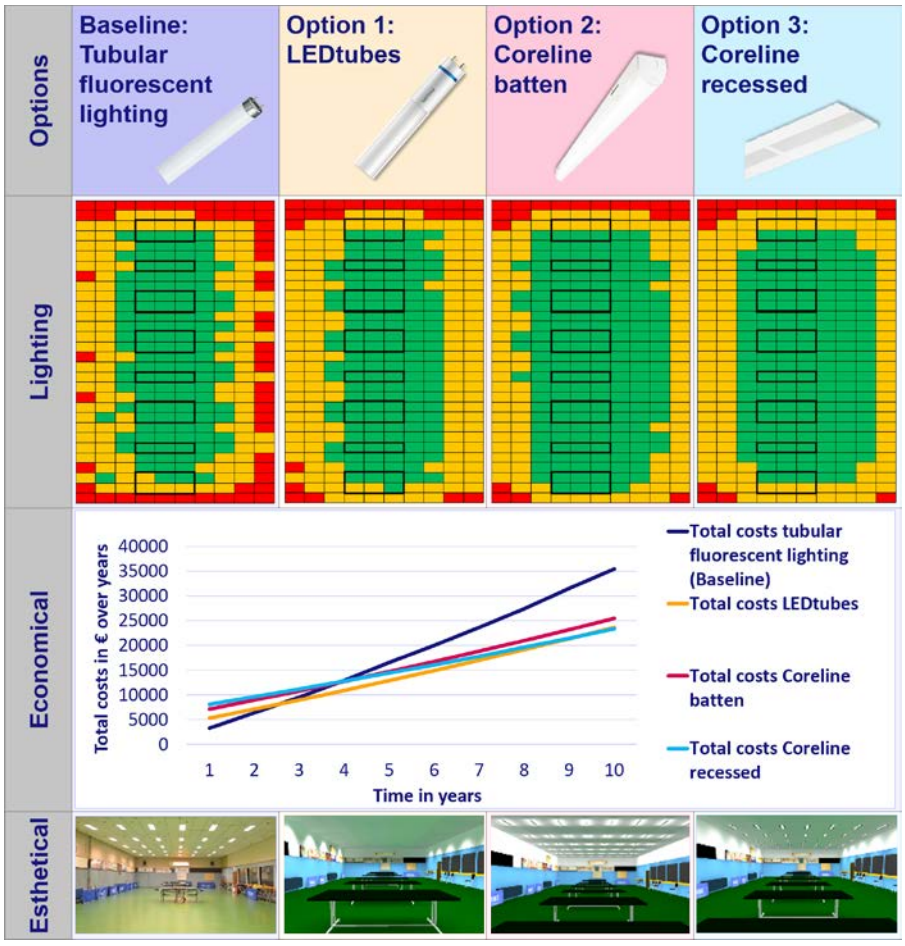
Supervisors
prof. dr. -Ing. A.L.P. (Alexander) Rosemann
ir. J. (Juliëtte) van Duijnhoven
ir. P. (Pieter) Nuiten (TTV Flash)

INTRODUCTION

Table tennis club TTV Flash Eindhoven has been wanting to gain knowledge about whether it is possible and economically feasible to change their current tubular fluorescent lighting into LED lighting. There is little budget, but because of a subsidy of 30% on material costs, LED lighting is still an interesting option to invest in. TTV Flash prefers the use of LEDtube lamps, which can be installed in the current luminaires. Unfortunately the subsidy is only for LED luminaires and not for LED lamps. In this research several LED lighting options have been selected for the club, proposed on the lighting and economical aspects.

METHODOLOGY

To investigate the lighting aspects of possible LED lighting options, measurements of the horizontal illuminance have been performed to validate a current situation simulation model. With an average illuminance difference of 10% between the measured and simulated horizontal illuminance, the model could be used for testing future LED lighting designs. For the future situation, several LED lamps and luminaires from Philips have been investigated. The luminaires have been selected based on the same dimensions and lighting color as the current lighting, and should be replaceable for the current lighting.



Figuur 1. Comparison of the lighting options for TTV Flash, proposed on different aspects. Lamp illustrations from [1]

Furthermore, a developed economical evaluation tool has been applied to calculate the simple payback time and total costs. The input exists of general properties for the use and electricity, and properties of the baseline variant and LED lighting options. The economical evaluation has been used to support TTV Flash in selecting the best LED lighting option, based on the lighting and economical aspects.

RESEARCH RESULTS

Figure 1 demonstrates the best LED lighting options for TTV Flash, based on the lighting performance and economical evaluation. The LED lighting options both have met the requirements at the table tennis tables and their surroundings. Under default input parameters, a relatively short simple payback time has been calculated for all options. The LEDtubes have had the lowest simple payback time with 2.5 years, but there have been no subsidy possible because these were LED lamps. The other options have had a simple payback time of 3.9 years. By changing the input parameters of the economical evaluation tool, different simple payback times can occur.

CONCLUSION

Several lighting retrofit options have been developed. All options have met the lighting recommendations and have been economically feasible. TTV Flash is now able to decide on how to proceed. ■

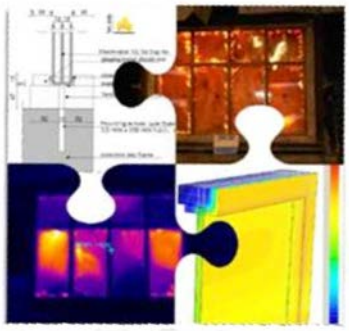
[1] Philips Lighting Holding B.V. (2016). Lamp illustrations. Retrieved from http://www.lighting.philips.nl

FELLOW/fse Stichting Fellowship FSE WO² Eindhoven University of Technology

The business network for education and research

The Engineering of Fire Safety





Examples of student research projects:

- Experimental research on fire and response of structures and separation constructions under fire conditions
- Mathematical simulation of fire and response of gasmass, building occupants and constructions
- Probabilistic approach of fire safety objectives in relation to rules and regulations

Fellow Fire Safety Engineering:
Ruud van Herpen MSc. FIFireE
R.A.P.v.Herpen@tue.nl

Postbus 1617
5602 BP Eindhoven
www.fellowfse.nl

TU/e Technische Universiteit Eindhoven University of Technology

The Indoor Climate of (Dutch) Military Fortifications

Author
J. (Jesse) Plas BSc

Supervisors
dr. ir. H.L. (Henk) Schellen
ir. M.H.L. (Marc) Stappers

INTRODUCTION

The Netherlands has many fortifications, which are important historical buildings. These buildings are exposed to different kinds of decay, e.g. direct physical forces, vandals, fire, water, (UV) light, incorrect temperature and incorrect relative humidity [1]. For the preservation of museum objects inside these historical buildings, it is important to determine the risks due to the indoor climate. This research investigated the indoor climate of (Dutch) fortifications and the corresponding risks associated to the degradation of these objects.

METHODS

In order to describe the indoor climate of (Dutch) military fortifications, Fort Kornwerderzand was used as a case study. The fortification consists of seventeen bunkers and were used in order to defend the Afsluitdijk from foreign attacks, especially during World War II. The Afsluitdijk is a dike, which connects the province of North Holland with the province of Friesland and is an important part of the flood control in the Netherlands.

Different measurements were performed in two bunkers, an abandoned bunker and a museum, during the spring and summer. Both bunkers are ventilated naturally and have no climate system. Since measurements of a whole year are required in order to perform a reliable climate risk assessment, a simulation model was created in order to predict the indoor climate for the rest of the year. To analyze the effect of the indoor climate on the degradation of objects, a specific climate risk assessment was performed, which estimates the degradation of typical museum objects [2]. The risk assessment analyzes biological, chemical and mechanical degradation (Figure 1).

RESULTS

The results show that the main risk of degradation of museum objects in the bunkers is mould growth due to high relative humidities (Figure 2). Also risks on mechanical damage to paintings and sculptures may occur on the ground floor due to high fluctuations of the relative humidity. Interestingly,

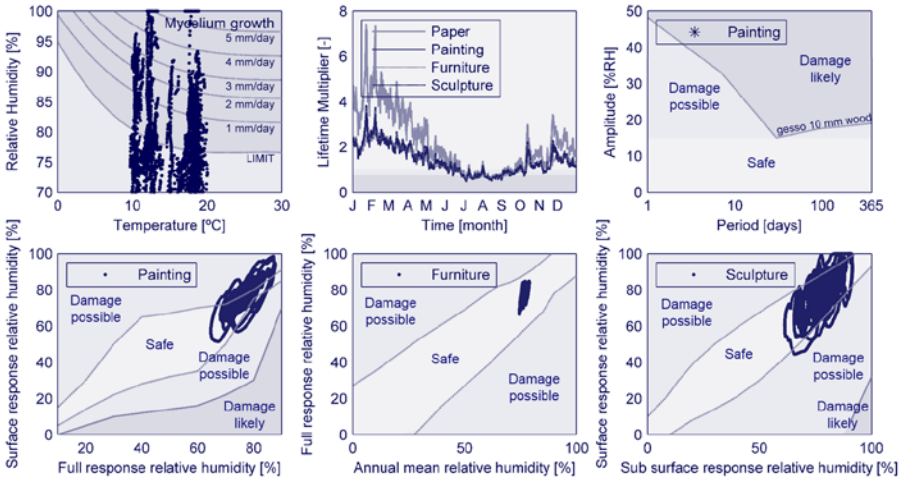


Figure 1. Impression of the climate risk assessment for bunker II, location 3

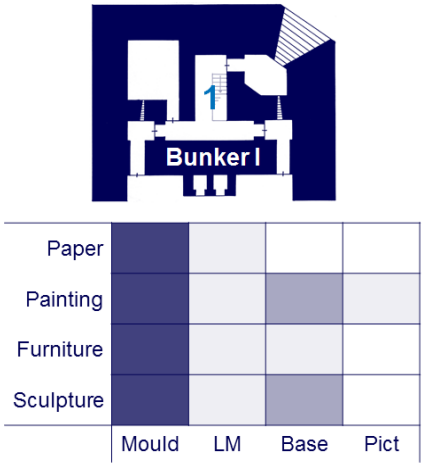


Figure 2. Floor plan of the museum bunker (II) with an overview of the specific risk assessment method, location 3. The risk is rated on a scale from low (light) to high (dark)

the basement of the museum seems ideal for the preservation of objects, because of the low temperature and a very constant relative humidity. This is inconsistent with the general thought that bunkers are very humid and thus bad for the preservation of such objects. It should be mentioned once more that no climate systems were used in the bunker during the measurements, which means that museum objects can be stored in the basement without additional energy consumption for climate controls.

CONCLUSION

A parametric study shows that the high relative humidities on the ground floor can be prevented by dehumidifiers. A heating system with hygrostatic control is also an option, but will accelerate chemical degradation due to higher indoor temperatures. ■

[1] Michalski, S. (1994). A systematic approach to preservation: description and integration with other museum activities. Preventive Conservation: Practice, Theory and Research, 8-11.

[2] Martens, M.H.J. (2012). Climate Risk Assessment in Museums. Eindhoven University of Technology. Martens, M.H.J. (2012). Climate Risk Assessment in Museums. Eindhoven University of Technology.

Adaptive comfort standards
For classrooms in hot-humid regions of India

Author
dr. A.K. (Asit) Mishra

INTRODUCTION

You may think of the human body as an engine – an extremely advanced and sentient engine. It utilises fuel to keep running and cleverly uses the waste heat produced to maintain itself at ~37 °C, ensuring peak efficiency. To maintain this temperature, the body has an intricate thermoregulatory mechanism, encompassing sweating, shivering, control of skin blood flow etc. However, even with such abilities, human beings would have been able to thrive in only limited climate types around the globe, were it not for the use of clothing and buildings. Clothing acts as a secondary protective skin and in the same vein, buildings act as a tertiary protection.

In doing their job, buildings consume about 40% of world primary energy and emit about one third of world CO^2 emissions. A noticeable fraction of total building energy consumption goes towards maintaining an "ideal" indoor thermal environment. India's proximity to equator means that this energy is primarily used for cooling. However, with already significant deficits existing [1], India's energy sector would have a bleak and unstable future ahead if an unfettered rise in building cooling energy requirements takes place.

Thermal comfort research in recent years has been driven by a need for energy efficiency in buildings sector, without compromising long term health and wellbeing of occupants. In this regard, promise has been shown by the adaptive comfort standards (ACS). At the heart of adaptive comfort standards is the idea that when a change in their thermal environment causes discomfort, occupants react in a manner so as to restore their comfort. Occupants do so chiefly by behavioural adjustments – opening windows, adjusting clothing etc. – and part of the adaptation is psychological and physiological as well. Adaptive behaviours are brought into play based on their effectiveness, ease of application and economy (the three Es). Multiple thermal comfort field studies, across different countries, show that buildings without mechanical conditioning (here on, referred to as naturally ventilated – NV – buildings) re at large perceived by occupants as comfortable [2]. Both the non-availability of adaptive means and hindrances to their exercise can make occupants feel uncomfortable and rate indoor environments poorly. We discuss here a set of thermal comfort surveys conducted in college classrooms in a hot-humid region of India. These studies targeted at establishing applicability of adaptive comfort standards in the NV classrooms and boundaries of thermal comfort for the students.

THERMAL COMFORT IN INDIAN CLASSROOMS

With ~14.6 million enrolled students, India has one of world's largest higher education systems. This continues to grow at about 6% every year, implying a significant growth in the sheer number of classrooms. Ensuring thermal comfort in the large number of classrooms of these educational institutes is in national interest and a matter of urgency. There is ample evidence showing indoor environment (in particular the thermal environment) impacts work performance. The detailed nature of this impact is not straightforward. Task nature, duration of exposure, occupant background, available means of adaptation, all have differing levels of contribution

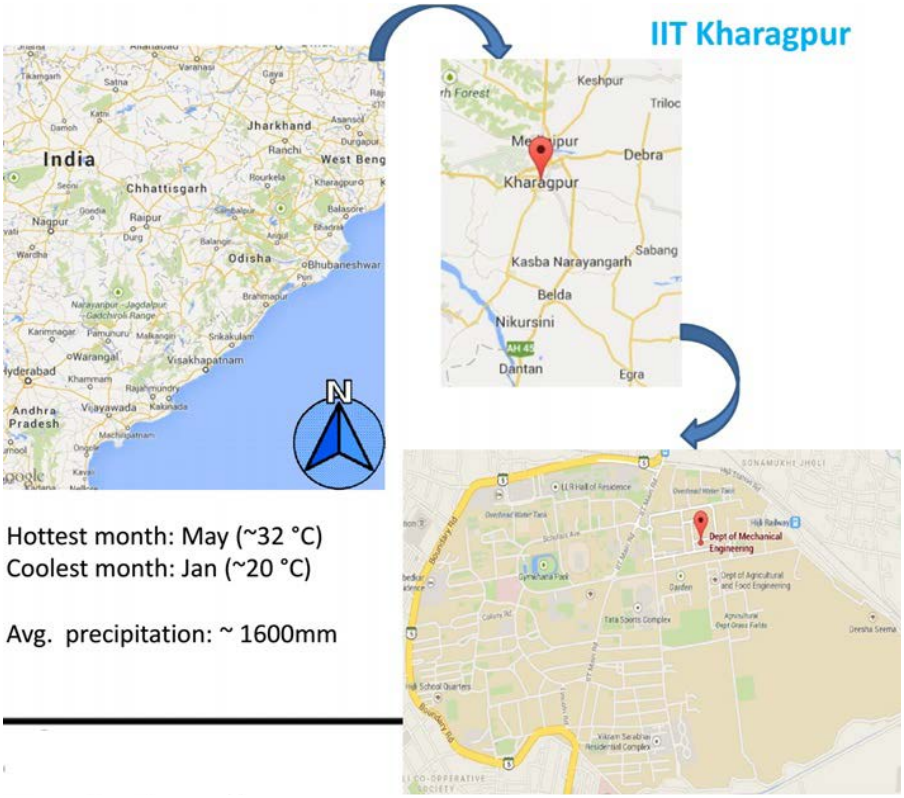


Figure 1. Study location: monthly mean temperaure of hottest and coolest month and average annual precipitation

Table 1. Comparison between studies from laboratory and classroom.

	Laboratory	Classroom
Regression neutral temperature	26.4 °C	29 °C
Preferred temperature	24 °C	26.7 °C
Comfort zone (from 2nd order polynomial fit of t_{op} and % satisfaction)	19.4 - 30.9 °C	22.1 - 31.5 °C

in determining the overall effect. Like in many other aspects of life, human ability to adapt and adjust means that there is no single ideal temperature for optimal performance [3]. Rather, over a certain extended zone, conscious effort by performers and small adaptive measures can help negate the debilitating effects of environmental stress.

While air-conditioning (AC) may be seen as an easy way out for providing thermal comfort, in terms of energy demand, the idea is hardly sustainable. For long, Indian classrooms relied on climate suitable design, natural ventilation, and ubiquitous use of fans to ensure student comfort. Supplementing current Indian building codes with suitable adaptive comfort standards would come as succour to Indian energy scenario and pave the way towards sustainable future development. Development of such standards would be immensely aided by the results of thermal comfort field studies.

THE STUDIES

Kharagpur – located in the eastern Indian state of West Bengal – has a climate classification of Tropical Savannah type (Aw) under the Köppen system. Summers are hot and humid, monsoon months are slightly cooler than summer but more humid, and the winter months are cool. Maximum outdoor temperature during summer days often crosses 40 °C. Regular semesters proceed from August through November and then from January through April.

Our first objective aimed at studying level of thermal comfort and acceptance amongst students during their regular semester classes. We also aimed to ascertain if the adaptive comfort model can be applicable at sustained metabolic rates that are slightly over ASHRAE Standard 55's current specification of 1-1.3 met. So we decided to survey the conditions during a laboratory class, in addition to regular classrooms.

The laboratory building is in an annex adjacent to the classroom buildings. During laboratory classes, students had a sustained metabolic rate higher than that during classes (1.6 met vs 1 met). At the same time, laboratories had a more flexible atmosphere as compared to classes. Students can move about the room, adopt relaxed posture, and have discussions amongst themselves. During warm survey days, almost every student was observed taking multiple breaks for drinking water. Such behaviour was not observed during lectures. The outdoor and indoor conditions during both sets of surveys were similar.

Both regression neutral temperature and preferred temperature were lower for the laboratory studies and by about an equal magnitude (Table 1). This may be ascribed to the higher metabolic rates in lab activity. More interesting are the comfort zones from the two studies. The upper limits of both comfort zones are nearly equal. This would suggest that the higher metabolic rate in laboratories was about effectively negated by availability of more adaptive opportunities. On a day-to-day basis, the survey based mean comfort temperature of occupants correlated strongly with the prevalent outdoor conditions.

Occupants in the current study had adapted to the prevalent thermal conditions and showed high levels of acceptance of their thermal environment. Students displayed adaptive behaviours like use of fans, clothing adjustment, and window operation. Over the 31 survey days, (12 from laboratory and 19 from classrooms), conditions within 21 to 30 °C were always acceptable to 80% or more students. Above 31 °C, conditions are mostly unacceptable. Less than 80% acceptability was found on 10 days, 9 of them being during March or April, mostly for afternoon classes. This identifies March and April as the problem months with the afternoon hours being of particular concern.

Studies across the world show the adaptive comfort model to be applicable for NV buildings, though the impact of this alternate comfort standard upon occupant performance has not yet been analysed in detail. The second objective of our study was designed to look at performance of undergraduate students in courses taught in AC and NV classrooms. A class of 50 undergraduate students enrolled in an engineering course were taken as the sample space. Courses taken by these students during their second and third year were identified for comparison and the corresponding classrooms were determined from records of time-table data. Figure 2 provides interior images of a couple of the NV classrooms and an AC classroom in which some of these courses took place. The ample number of ceiling fans in the NV classrooms and their glaring absence in the AC classroom are clearly. To overcome difference between courses, a scaling approach, based on cumulative deviations across different subjects, was followed. The courses were treated as two non-interacting blocks — one for those taught in NV classrooms, second for those taught in AC classrooms.

Statistical analysis showed that performance of students in NV rooms was not significantly different from that in AC rooms. This could be explained by occupant satisfaction levels, occupant acclimatization, and availability and use of adaptive opportunities. Students adapting to their thermal environments to keep up satisfaction and performance levels in NV rooms at par with their performance in AC rooms can be regarded as a corroboration of occupants being able to maintain their performance level over an extended range of thermal environments. It would be fair to conclude that in well-designed NV classrooms, where student satisfaction levels are not greatly affected, student performance should not be affected

Figure 2. Interior images from three typical classrooms of the institute.

as well. This study was a preliminary investigation and would need to be supported by further works.

SUGGESTED REMEDIAL MEASURES

Comfort surveys showed that the NV classrooms are able to provide a comfortable environment to students over most of the academic year. There are certain aspects of the surveyed building that are responsible for this. They are laid along North-South axis and have ample number of windows and ceiling fans, with windows solely on North and South facades. Students have flexibility with clothing adjustments, sitting, and opening windows or operating fans. Depending upon availability and usability of adaptive opportunities, it would seem that the adaptive comfort standard may be applicable for higher activity levels than prescribed by current standards. The problem period has been identified as from March to April. We illustrate in Figure 2 some specific additional measures here, which may be used to improve comfort in these NV classrooms, drawing upon results of several works on passive cooling.

The possible measures that could enhance comfort can be divided into two categories: building based (BB) and occupant based (OB). It is difficult to put these measures into air tight containers of occupant based or building based. For example: introduction of night cooling (BB if done by additional vents, OB if done by the opening of windows); reduced lighting and other electrical gains (BB if done by more efficient items, OB if done by better housekeeping).

Concordant to the idea of occupant based measures for extending indoor comfort in NV buildings, occupant behaviour patterns may also be regarded as an extra dimension of flexibility when synchronizing building energy demands with grids. With foreseeable greater reliance on renewable energy sources, matching electricity demand and supply has gained prominence. Such matching is traditionally aided by a building's flexibility aspects, such as scheduling appliances, pre-heating/cooling building thermal mass etc. Our contention is that occupants can provide an extra dimension of flexibility, over and above that of the buildings. Though not massive in magnitude, this flexibility may still be enough to provide some extra leeway for building designers and grid operators. For example, occupant coming in from outdoors may not have very rigid thermal expectations from the indoor for about the first half-hour. Similarly, towards day end, slow and small drifts of temperatures near borders of comfort zone may not affect office workers before they are ready to leave for the day. These and similar aspects of occupant based opportunities for flexibility in comfort conditioning are being currently examined in the iCARE project, under the purview of the Building Performance group of the Building Physics and Services unit.

A warming globe, depleting conventional energy sources, and increased pollution levels have lead us to a point where we may no longer debate 'should we?', but instead focus on 'how?' [4]. There is a growing realisation that standards advising tighter control of indoor environment are not sacrosanct and relying on mechanical conditioning's infallibility is unwise. In future buildings, building based and occupant based measures would need to be considered in tandem and not in isolation. A further important factor would be attitude of occupants. 'Greening' of occupant perspective would also be vital for success of low energy buildings. ■

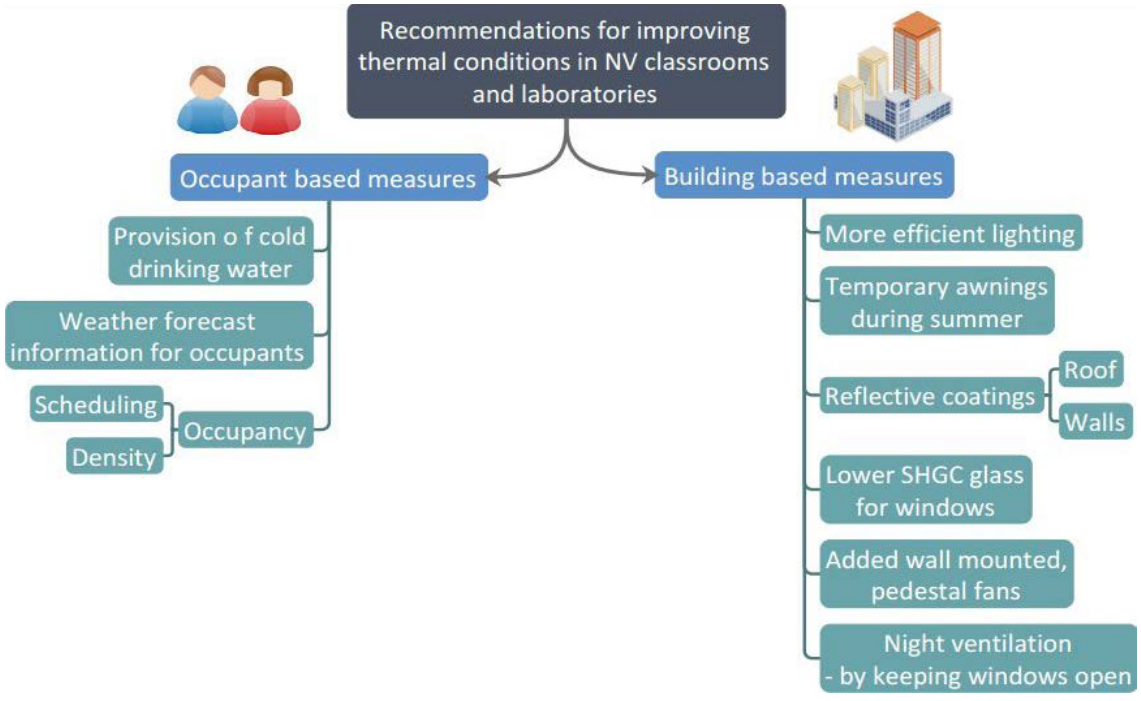


Figure 3. Remedial recommendations

[1] CSO, 2012. Energy Statistics 2012, 19th Edition. Central Statistics Office. Ministry of Statistics and Programme Implementation. Government of India. New Delhi, India.

[2] Mishra, A. K., Ramgopal, M., 2013. Field studies on human thermal comfort—An overview. Building and Environment 64, 94–106.

[3] Hancock, P. A., Ross, J. M., Szalma, J. L., 2007. A meta-analysis of performance response under thermal stressors. Human Factors: The Journal of the Human Factors and Ergonomics Society 49 (5), 851–877.

[4] de Dear, R. J., Brager, G. S., 2002. Thermal comfort in naturally ventilated buildings: Revisions to ASHRAE Standard 55. Energy and Buildings 34 (6), 549–561.

MSc and Then?

Author
ir. Tom Thomassen

After presenting myself in the INSide Information first as a nowadays so called ICE-Breaker and in later editions as treasurer (15th), and President (16th) of Mollier, now I have the honor to write to you as alumnus. It's been about two years since I obtained my Master's degree Building Services. Living the student life seems like yesterday while I'm already used to my working life. Looking back to my life as a student with a lot of good memories, I realize time flies.

After graduating and attending the graduation ceremony, suddenly there were no more obligations. During this time off, I spent my time partying and recovering from the graduation efforts. It was really a great vacation. Already during my graduation project I started looking for a job and it was not hard to get connected to a lot of companies with all interesting opportunities. Having contact with former Mollier members (nowadays Schoone Leij members) and friends within different companies really helped a lot. I noticed the network built being an active member within the association paid off. Finally this let to my job at BAM Bouw en Techniek where I started working at the department development.

First engineering and calculating relative small projects and later on as assistant tender manager on a project. As if it was meant to be we won the tender and I worked on the project as assistant design manager. This was a very nice experience first of all winning the first big tender I participated and second, being able to be part of a multi-disciplinary team responsible for the engineering. The project is in the implementation phase as I am writing this article and it is nice to see the plan is becoming reality. Nowadays I am working on a new tender project as assistant tender manager.

What I like most about my job is the variety. The work varies from engineering, participating meetings and planning to being at the construction site. These various tasks make the job quite challenging and I've learned a lot in the years I've worked so far. I think that during your MSc education you don't only learn (some of the) practical knowledge, but also develop skills in problem analysis and team work which are very helpful in many situations. Sometimes I look back at the multi-disciplinary master project and recognize quite a lot of aspects. I think this project brings more than most students would recognize during their study. During my study a lot of students didn't want to participate on the multi project and preferred a research project. I guess they had a bad memory of the bachelor multi project.

What the future will bring I don't know, I guess nobody really knows. But one thing is for sure, if it were up to me I'll still be working in diverse and stimulating projects the first few years and later on I fancy a more managing role in the company.
I am still in contact with students and alumni of Mollier. It's always fun meeting other alumni from time to time to recollect all the great activities we've had during our years at Mollier. My advice to the Mollier members would be: Enjoy your time as students, make sure you take full advantage of this time to make friends and everlasting memories.

I look forward to see everyone again at the next activity of Schoone Leij or Mollier where former students are also invited! ■

Main sponsors

bam

Building the present, creating the future

Johnson Controls

Een wereld creëren die comfortabeler, veiliger en duurzamer is

---

Stichting Promotie Installatietechniek (PIT)

Het bevorderen van de technische, economische en wetenschappelijke ontwikkeling van de installatiebranche

Sponsors


FELLOW/fse
Stichting Fellowship FSE WO²
Eindhoven


heijmans


LBP|SIGHT
Bouw | Ruimte | Milieu


VALSTAR SIMONIS
ADVISEURS INSTALLATIETECHNIEK


Kuijpers


nelissen
ingenieursbureau


Stabiplan


Strukton
Worksphere


BOUWKUNDE
BEDRIJVENDAGEN

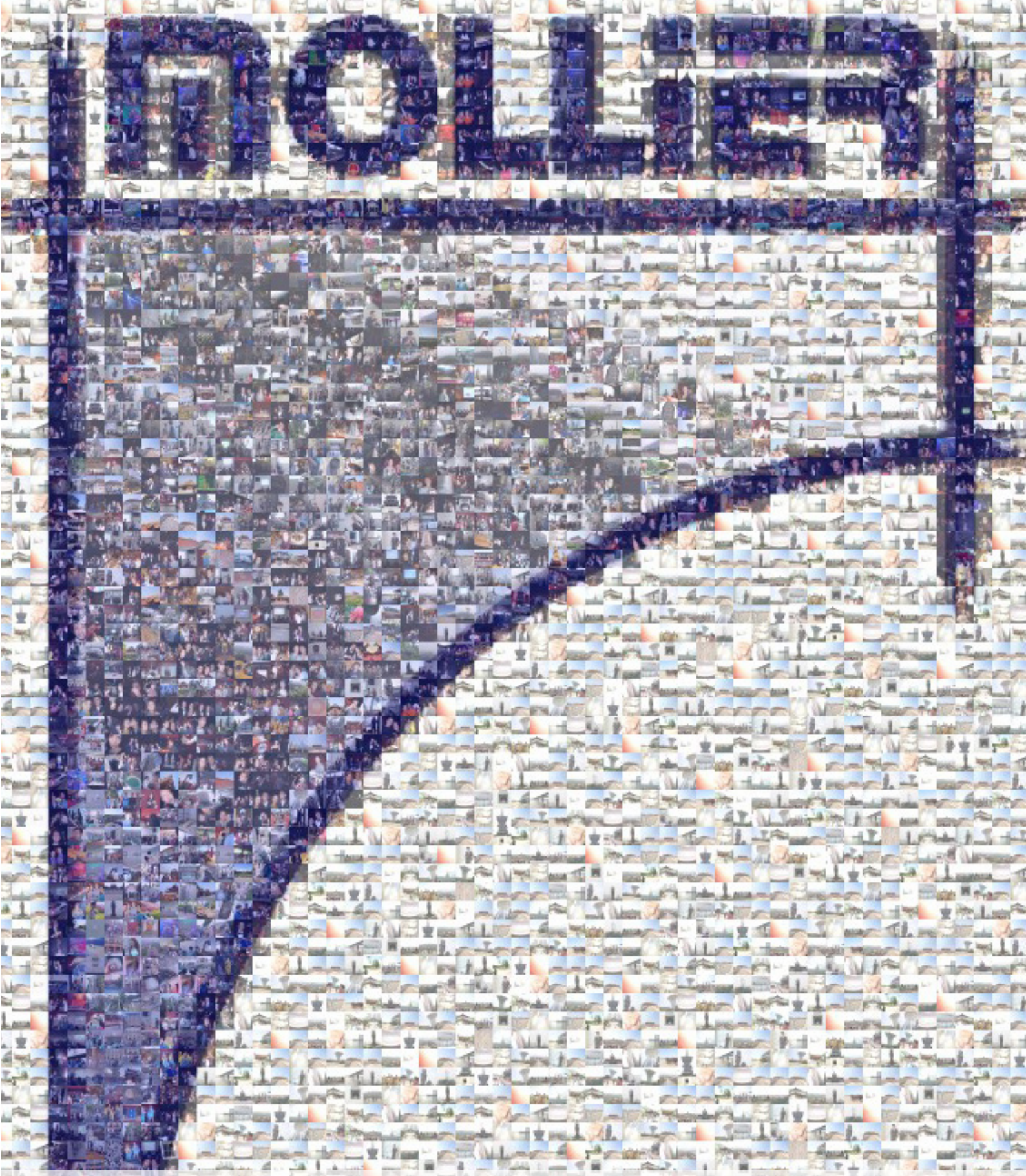

Deerns


KP&T
CONNECTING TECHNICAL PROFESSIONALS


ARCADIS
Design & Consultancy
for natural and
built assets


techniplan adviseurs bv
RAADGEVEND INGENIEURSBUREAU


vanhout
adviseurs en installateurs



s.v.b.p.s. Mollier
Eindhoven University of Technology
PO Box 513
5600 MB Eindhoven
Secretariaat, BPS, Vertigo 6
T +31 (0)40 247 4406
E: info@mollier.nl
www.mollier.nl

MOLLIER

Study Association
Building Physics and Systems