Welcome & intro to venticool

Hilde Breesch, Peter Wouters (venticool)

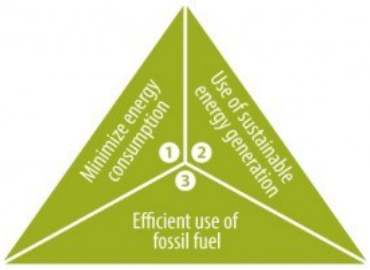
https://venticool.eu

Resilient ventilative cooling in standards, legislation & energy performance calculations

- Energy performance regulations
  - key market drivers
  - Ventilative cooling requires mature assessment thermal comfort & ventilation losses
- Standards, legislation & energy performance calculation need to include
  - Assessment of overheating
  - Assessment of resilient natural & mechanical ventilative cooling
  - Design calculation methods
- venticool's concern = international (CEN, ISO) but also national

venticool
the platform for resilient ventilative cooling

venticool's position



- Ventilative cooling
  - reduce cooling energy need
  - Direct renewable cooling energy source
- Implementation of ventilative cooling is limited
- venticool
  - Asks standards & legislation writers: fair & easy evaluation ventilative cooling performance
  - Provides knowledge & tools for designers to assess potential & limitations
- Focus on resilient cooling -> stimulates uptake of ventilative cooling

venticool
the platform for resilient ventilative cooling

Diamond partners:

NAVENTA NATURAL VENTILATION ASSOCIATION

Reynaers Aluminium

VELUX®

Gold partners:

WINDOW MASTER® Fresh Air. Fresh People.

venticool the platform for resilient ventilative cooling

Associate partners:

activehouse

CIBSE

Covenant of Mayors for Climate & Energy

EuroWindoor

REHVA

7

"Dumb buildings with smart users? Linking building performance & human well being"

timing	subject	speaker
15:30	Welcome & intro venticool – Active House Alliance	Hilde Breesch (KU Leuven/venticool) Yves Lambert (Renson/AHA)
15:40	Rethinking comfort within human-building resilience	Marcel Schweiker (Universitätsklinikum Aachen, Germany)
15:55	The sense of cognitive architecture	Marco Imperadori (Politecnico di Milano, Italy)
16:10	An occupant voting system for continuous feedback	Donya Sheikh Khan (Ramboll, Denmark)
16:25	Active House Comfort score	Bas Hasselaar (DGMR, The Netherlands)
16:40	Questions and answers	

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Active House

- *Healthy Buildings for People & Planet*

1

Active house alliance

The alliance was formed in 2011.
It is based in Belgium with a part-time secretariat.

The Alliance is a network and provides support for local chapters, organises training, symposiums and the AH Awards.

It is a not-for-profit organisation

2022 Active House Awards
The winners are...

activehouse.INFO
NETWORK AND KNOWLEDGE SHARING

activehouse

2

2

Positioning

Human centric design tool for healthier energy efficient buildings

Focus area **Residential**

New build & renovation

Stake holders

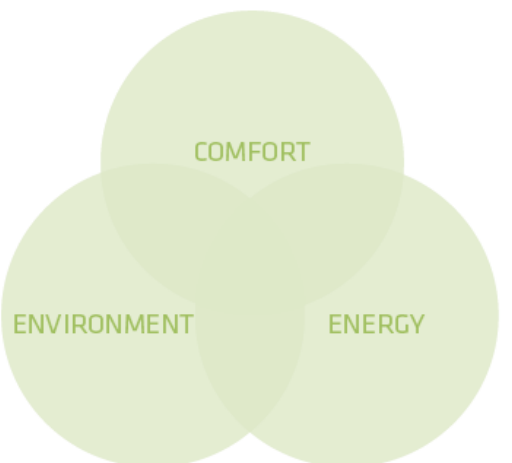
- Architects
- Consultants
- Developers
- End users
- Healthcare
- Housing corporations
- Municipalities
- Professional house builders
- Project developers
- Product suppliers

activehouse

3

3

Active House Principles



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4

International AH alliance partners

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5

ACTIVE HOUSE LOCAL CHAPTERS around the world

activehousenl

Active House Netherlands

Active House China – Active House Academic Committee of the Architectural Society of China (AHAC)

activehouse Canada

Active House Alliance Canada

aktivhus

AktivHus Danmark

UA activehouse

Active House Ukraine

activehouse italia

Active House Italia

activehouseusa

activehouseuk

activehouse Romania

activehouse

6

6

UNIKLINIK RWTH AACHEN

Institute for Occupational, Social and Environmental Medicine

Healthy Living Spaces Lab

Rethinking comfort within human-building resilience*

Marcel Schweiker

Webinar – Dumb buildings with smart users? Linking building performance & human well being

15 November 2022

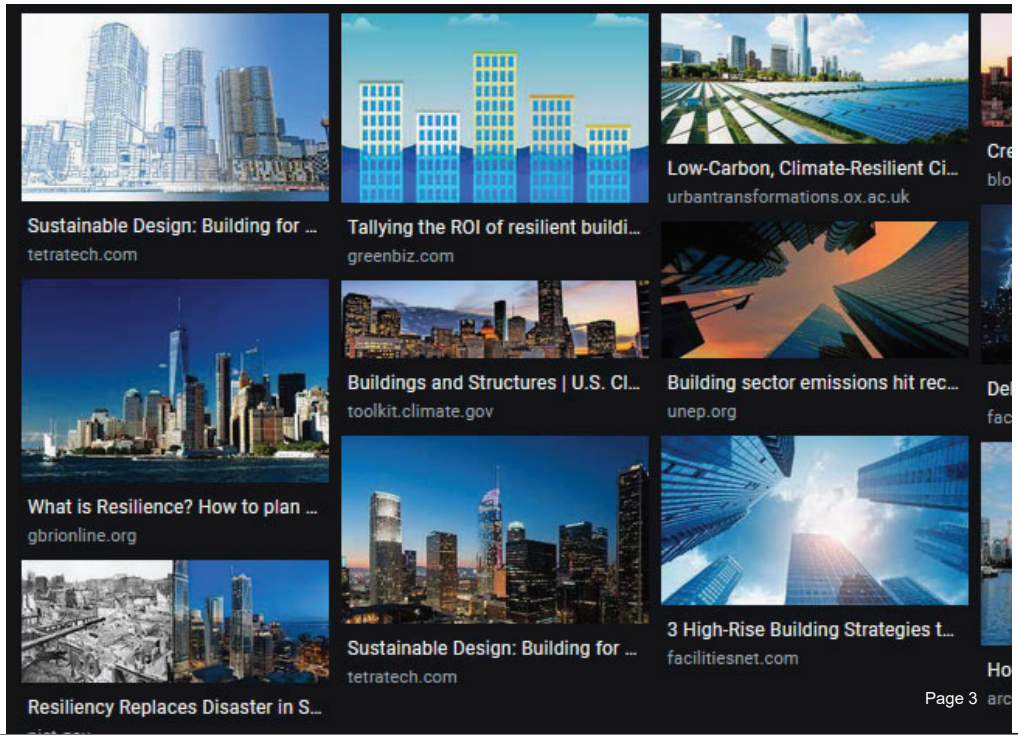
* Schweiker (2022). Rethinking resilient thermal comfort within the context of human-building resilience. In: Nicol et al., **Routledge Handbook of Resilient Thermal Comfort**

UNIKLINIK RWTH AACHEN

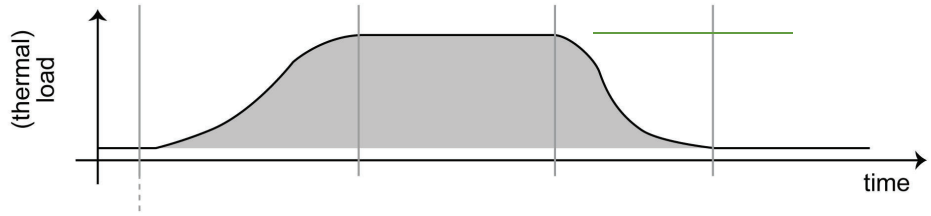
Rethinking resilience

Resilience

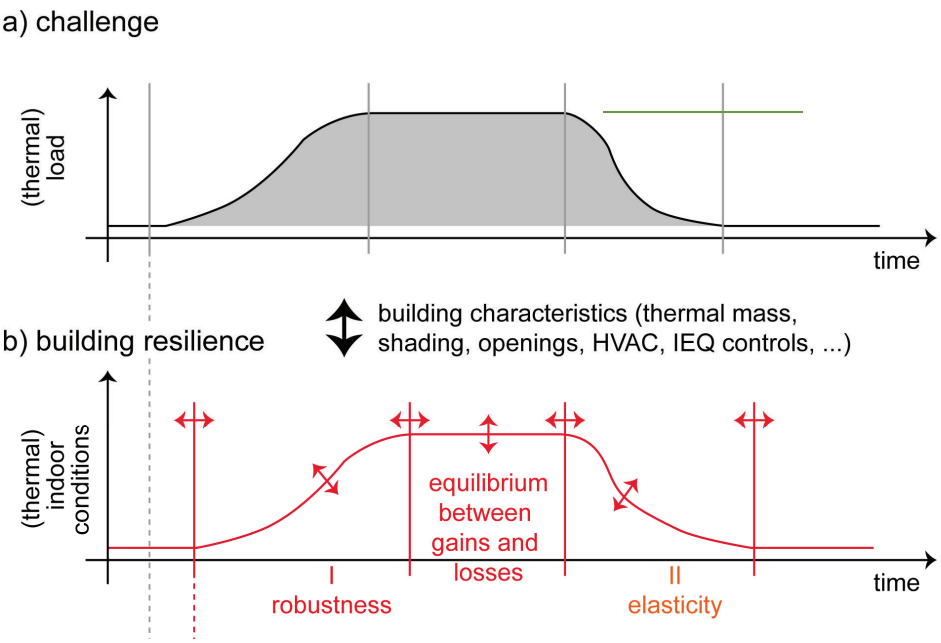
- Resilient buildings



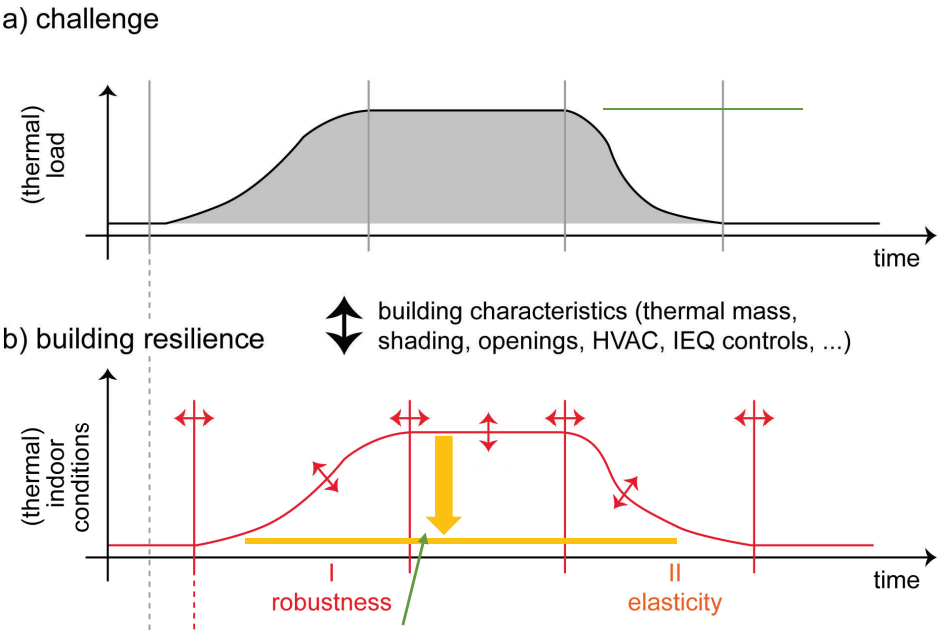
All starts with a challenge…



Building resilience

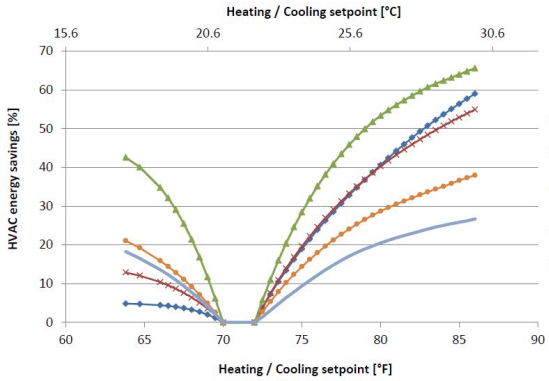


Building resilience – the case of active cooling



max. relief = max. resilience? = max. WB&H?

Misunderstood building resilience



The New York Times

A New, Deadly Risk for Cities in Summer: Power Failures During Heat Waves

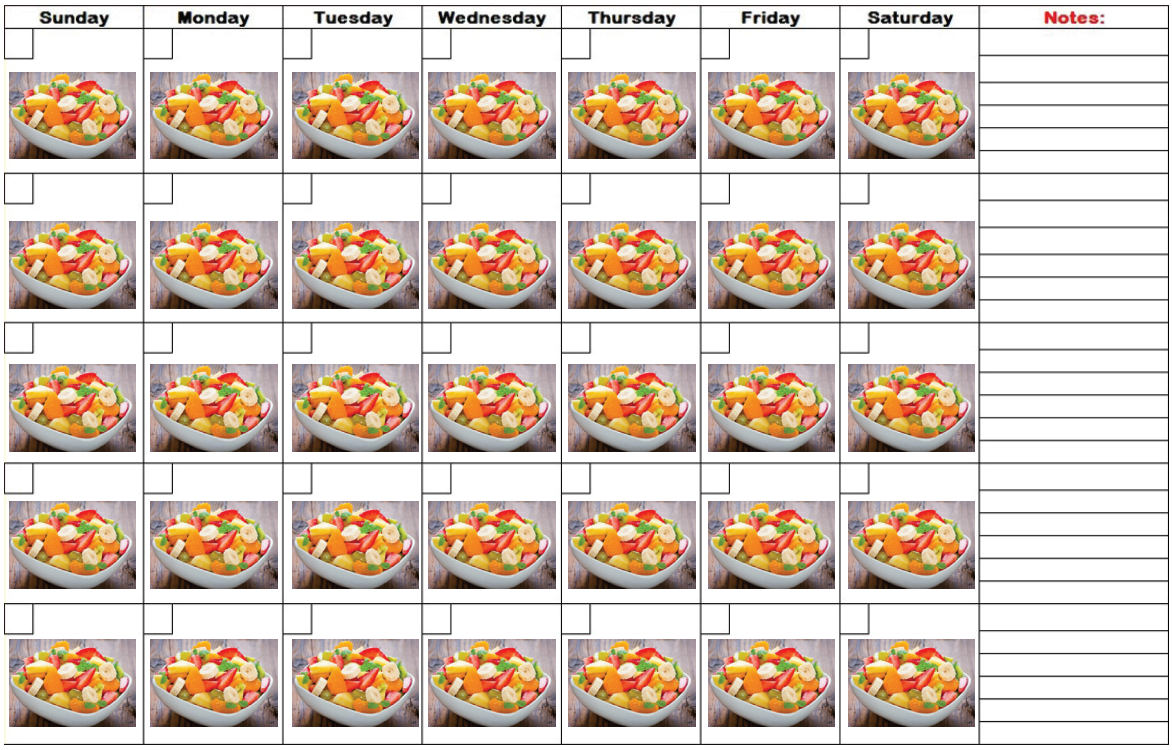
The author of a new study said the combination of blackouts and extreme heat "may be the deadliest climate-related event we can imagine."

Uniklinik RWTH Aachen | Hoyt et al. 2014 Extending air temperature setpoints | *Photo by Douglas LeMoine/*CC BY-ND 2.0 | https://www.nytimes.com/2021/05/03/climate/heat-climate-health-risks.html

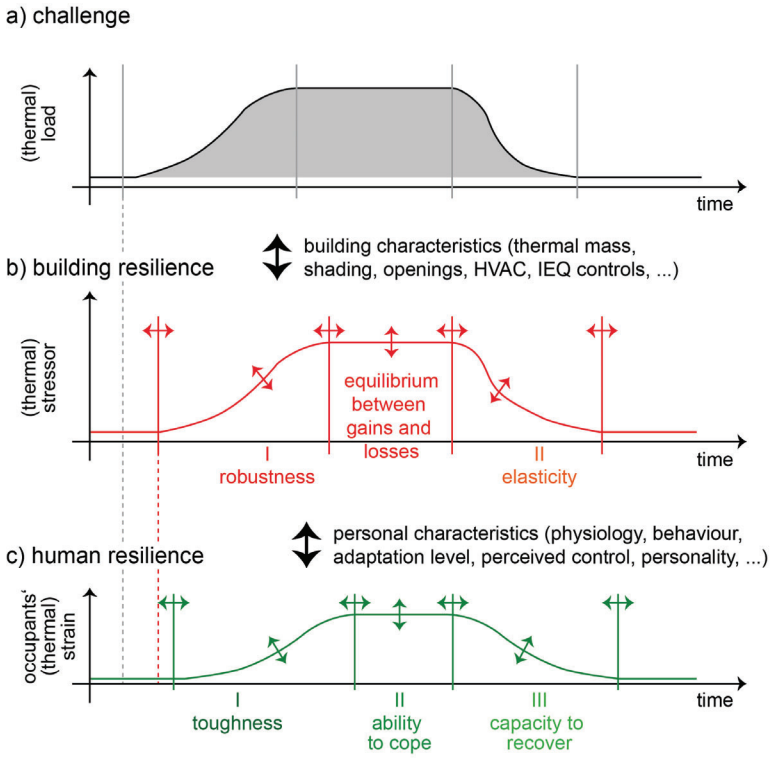
Relief is nice

Uniklinik RWTH Aachen © CC Manh An https://upload.wikimedia.org/wikipedia/commons/e/e2/Summer_fruit_salad.jpg

Relief is nice, but…

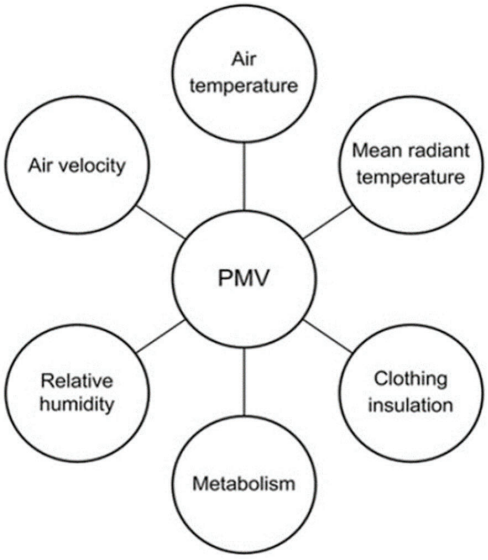


Adding the human dimension



Rethinking comfort

Thermal comfort



- How do you feel right now?

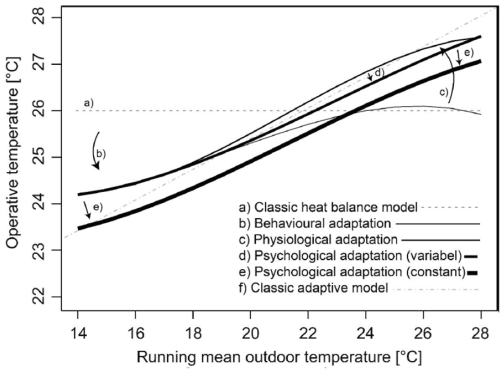
- Hot
- Warm
- Slightly warm
- Neither nor
- Slightly cool
- Cool
- Cold

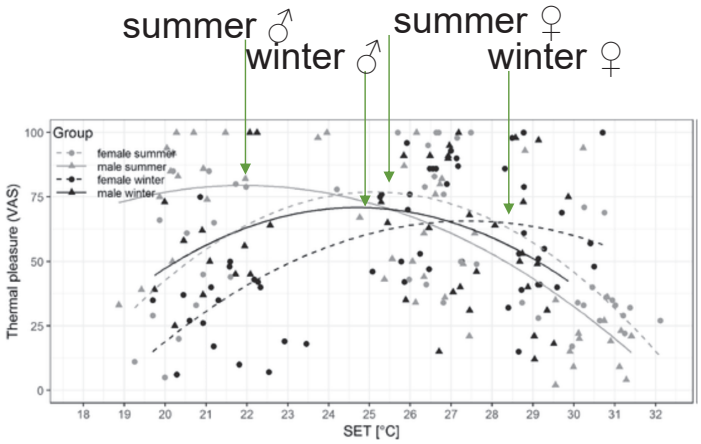
? Comfort/ Neutrality

? Well-being/ health/ resilience

Rethinking comfort

- *(not only) relief*, (the neutrality approach)
- *(but also) encouragement* (adaptation), and
- *enjoyment* (alliesthesia)

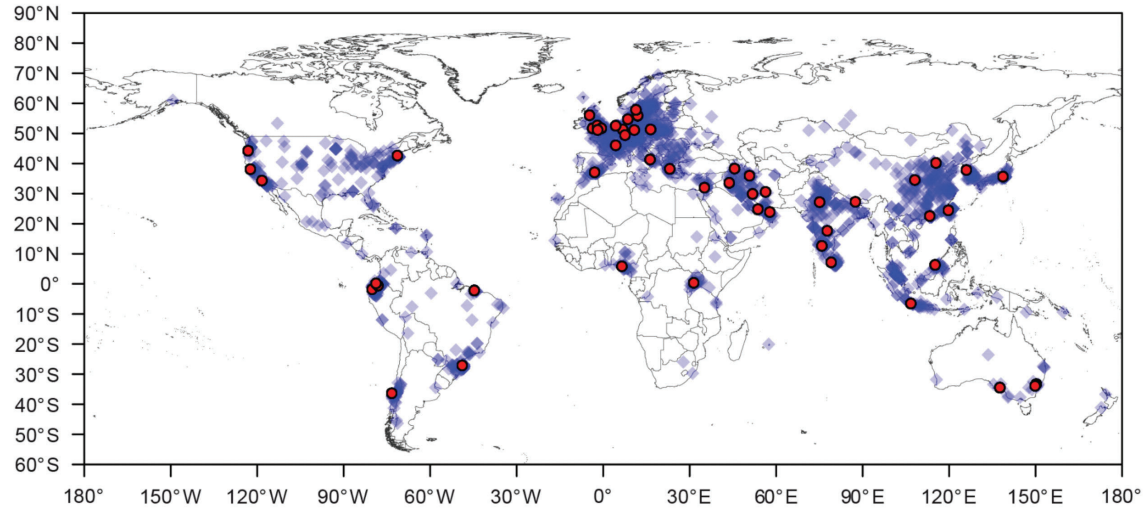




Uniklinik RWTH Aachen | Schweiker and Wagner (2015) https://doi.org/10.1016/j.buildenv.2015.08.018 | Schweiker et al. (2020) https://doi.org/10.1016/j.enbuild.2019.109745 | Schweiker (2022) https://doi.org/10.1111/ina.13018

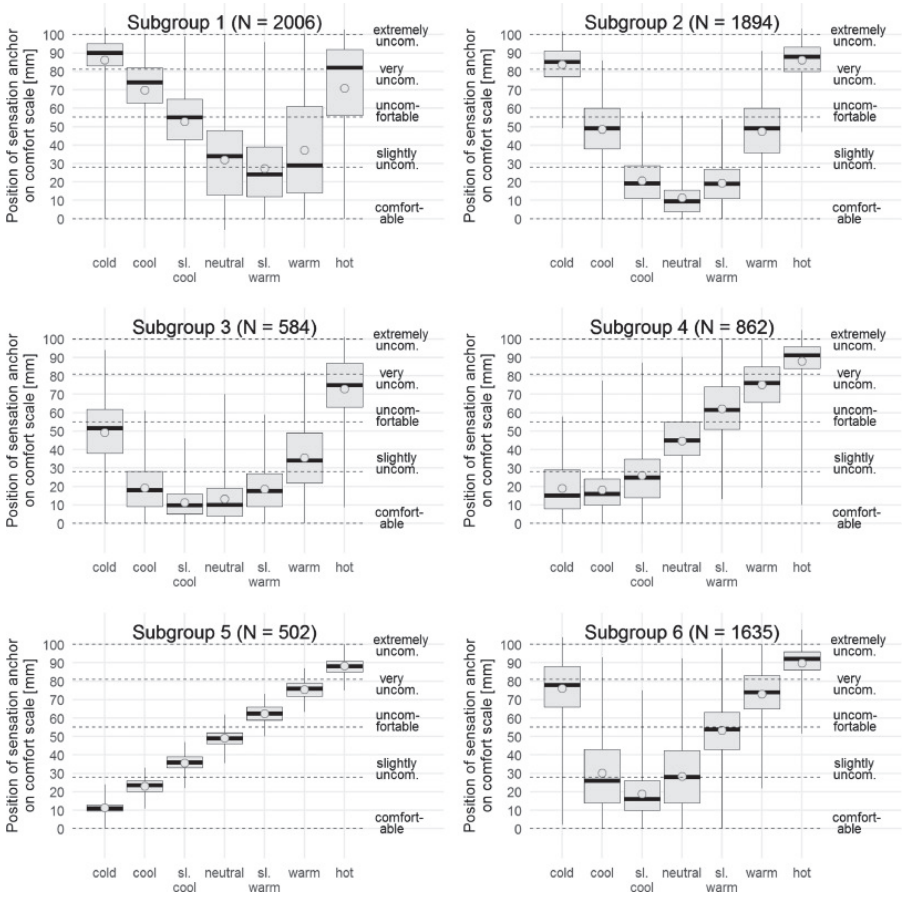
LuF Healthy Living Spaces, Institut für Arbeits-, Sozial- und Umweltmedizin

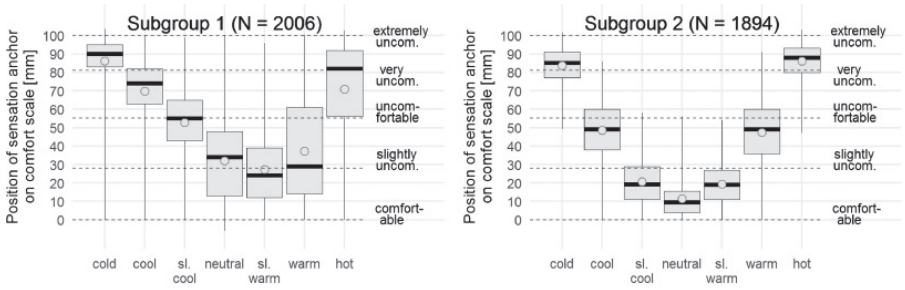
Perception vs. evaluation – the Scales study



N= 90+ Reserchers | 20+ language versions
8225 data sets from 59 cities in 32 countries

Uniklinik RWTH Aachen | Schweiker et al. 2019 https://doi.org/10.1038/s41597-019-0272-6 |
Schweiker et al. 2020 https://doi.org/10.1016/j.enbuild.2020.109761

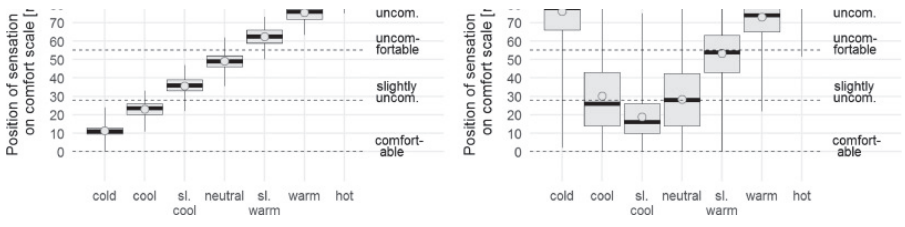




- Hot
- Warm
- Slightly warm
- Neither nor
- Slightly cool
- Cool
- Cold

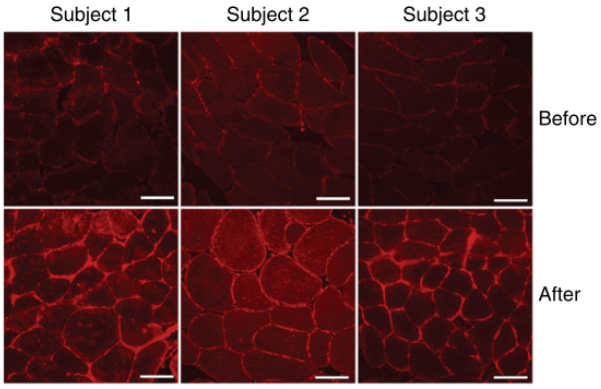
X Comfort/ Neutrality

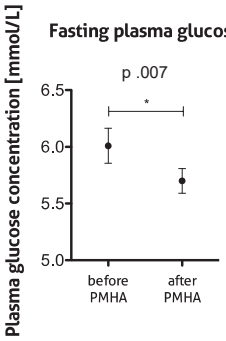
? Well-being/ health/ reslience

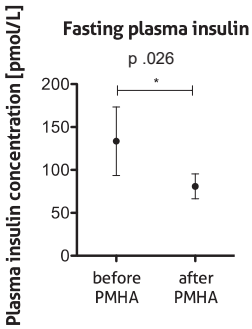


Discomfort and health

- Cold exposure increases insulin sensitivity in patients with type 2 diabetes mellitus (Hanssen et al. (2015).
- Passive mild heat exposure lowers fasting glucose, insulin, mean arterial blood pressure (Pallubinsky et al. 2020)



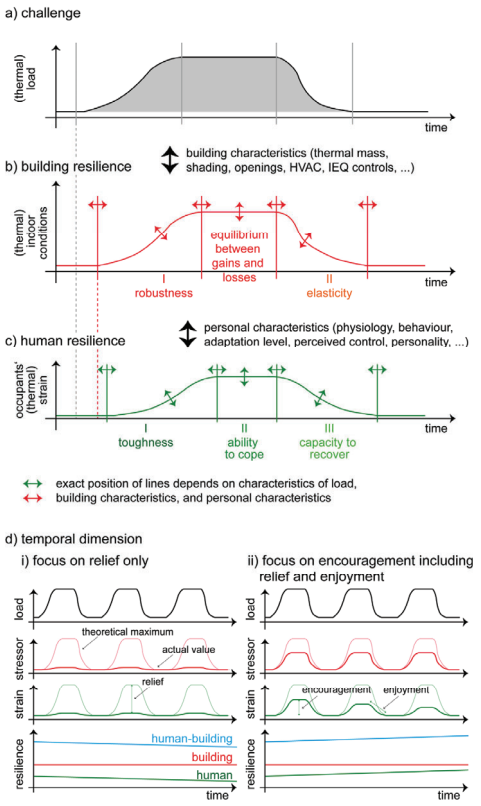




Uniklinik RWTH Aachen | Hanssen et al. 2015 | Pallubinsky et al. 2020

Rethinking human-building resilience

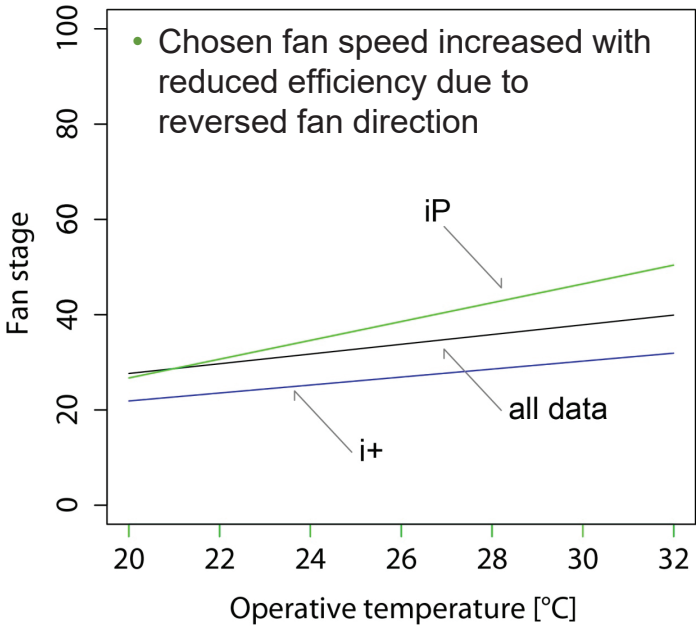
Human-building resilience framework



The intelligent occupant

Subconsciously …

… and sometimes surprising



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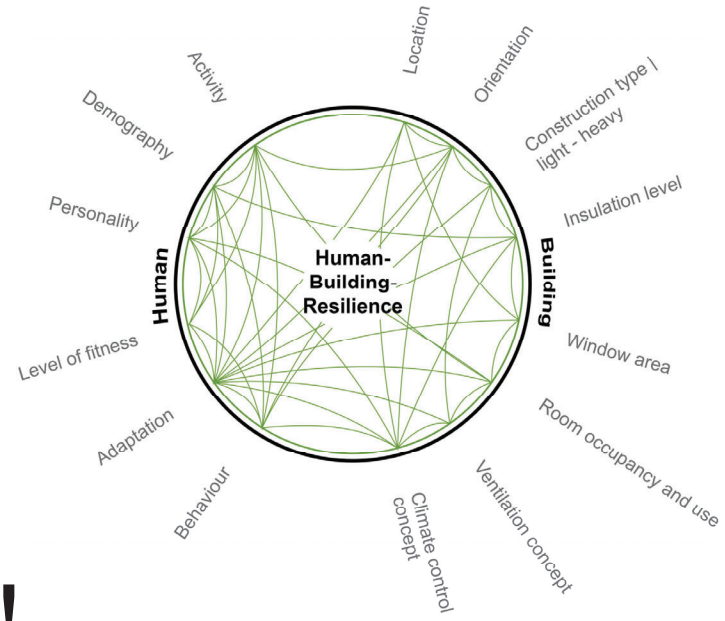


Thank you for your attention!

Any questions?
Contact: mschweiker@ukaachen.de

POLITECNICO
MILANO 1863

The *sense* of Cognitive Architecture

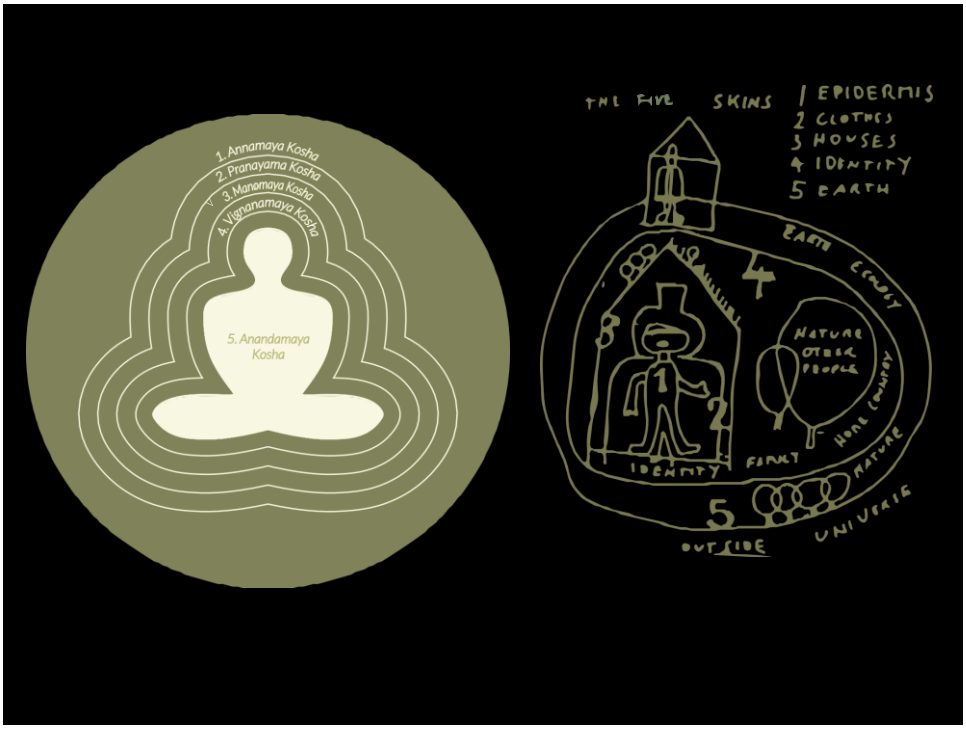
Marco Imperadori
Full Professor, Rector's Delegate Far East
marco.imperadori@polimi.it

15/11/2022

1

Ph. Giacomo Bianchi, Arte Sella

2



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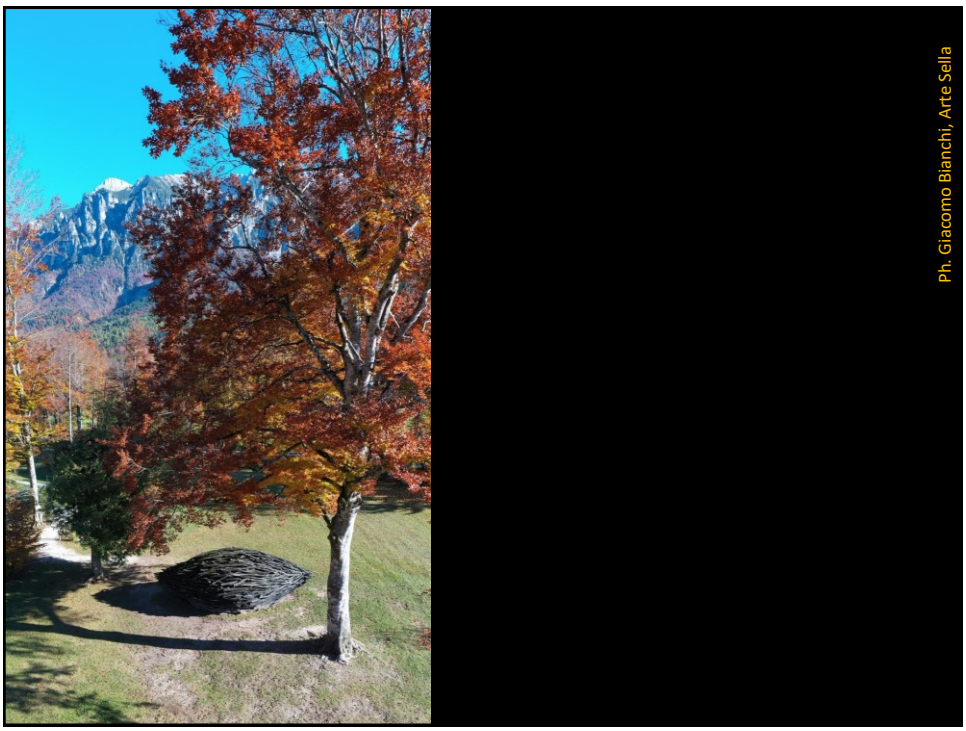


Ph. Giacomo Bianchi, Arte Sella

4

5

Copenhagen International School
Has the **largest European BIPV**—Building Integrated Photovoltaic.

activehouse.INFO
NETWORK AND KNOWLEDGE SHARING

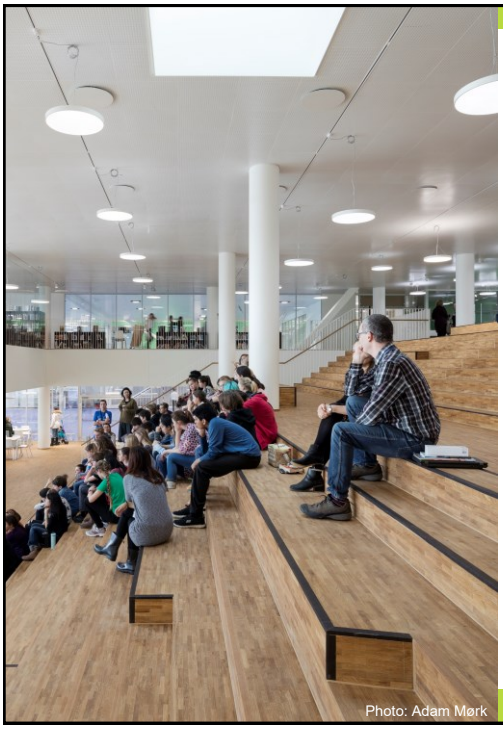
COMFORT – improve focus and learning into a better indoor environment

ENERGY – integrated design between envelope, systems and renewable energy

ENVIRONMENT – NZEB for a lower environmental impact

Credit: Active House Alliance

6



activehouse.INFO
NETWORK AND KNOWLEDGE SHARING

COMFORT – improve focus and learning into a better indoor environment

- DAYlight and LEDlight
- 20% window/floor area
- 21-26°C
  thanks to good insulation and heat recovery ventilation system

ENERGY – integrated design between envelope, systems and renewable energy

- 15 kWh/m2y
- 6000 m2 BIPV
- 69% renewables covering the energy demand

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Green Solution House
the Active House principles under **monitoring survey**

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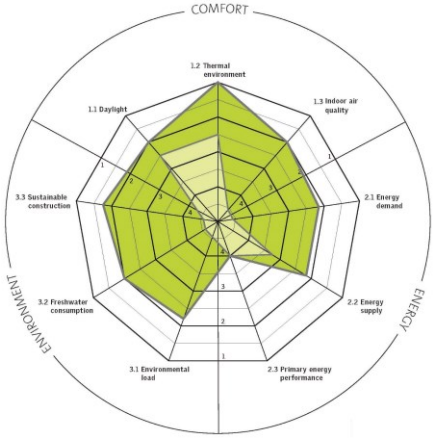
NETWORK AND KNOWLEDGE SHARING



COMFORT – visual comfort in living and working spaces

ENERGY – smart management for lower consumption

ENVIRONMENT – sustainable construction

Credit: Active House Alliance

10

activehouse.INFO
NETWORK AND KNOWLEDGE SHARING

COMFORT – visual comfort in living and working spaces

- Skylights and solar tunnels (DFmin 6,6%)
- greenwall and specific finishing materials to purify indoor air, absorbing pollutant particles and balancing humidity levels.

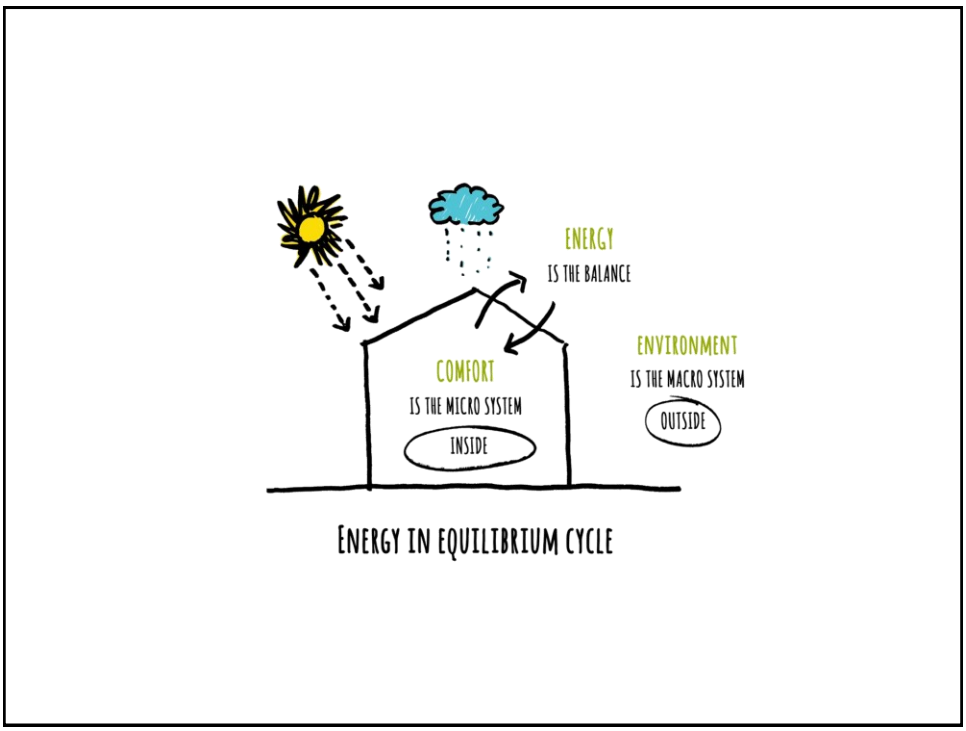
11

Milano, the "impermanent City"

12


courtesy Velux, Indoor Generation

13


ENERGY
IS THE BALANCE
ENVIRONMENT
IS THE MACRO SYSTEM
OUTSIDE
COMFORT
IS THE MICRO SYSTEM
INSIDE
ENERGY IN EQUILIBRIUM CYCLE

14

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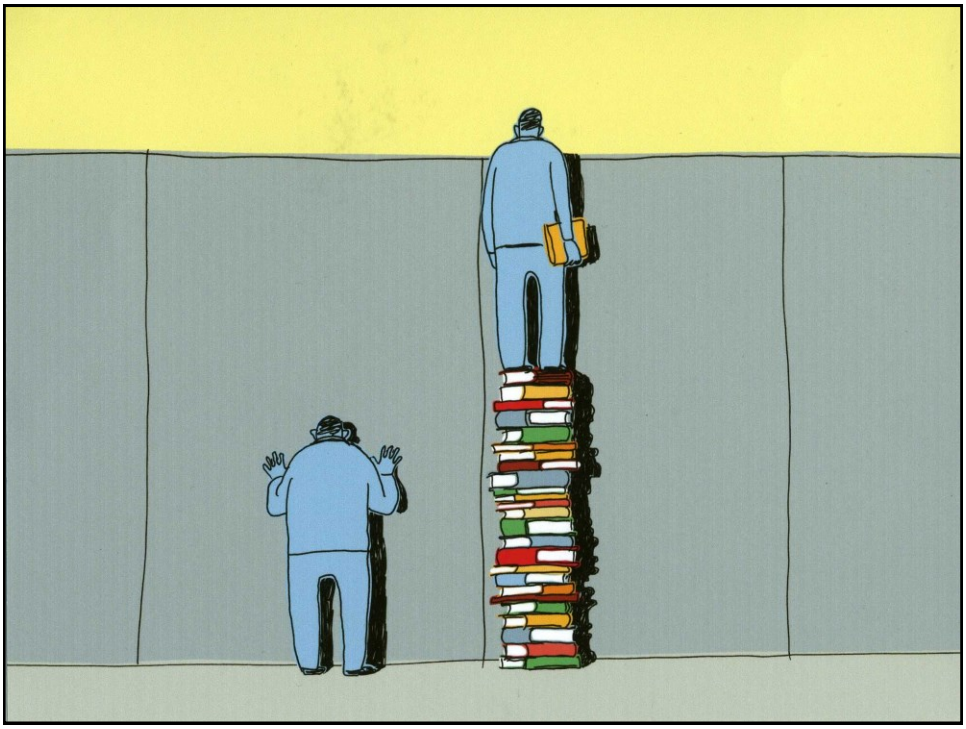

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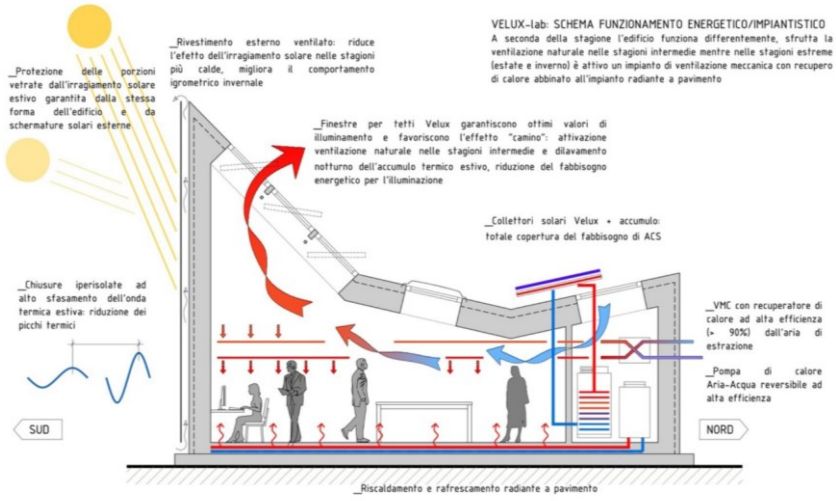
Schematic design



Lighting analysis

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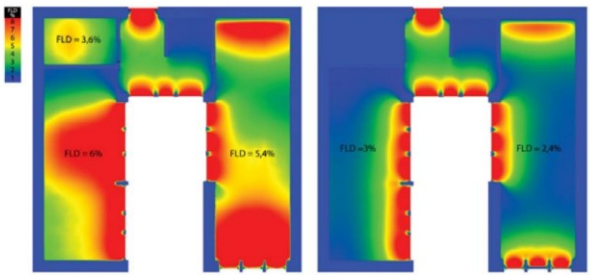
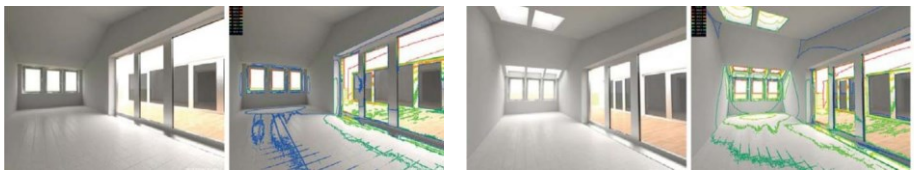
NETWORK AND KNOWLEDGE SHARING



Fattore medio di luce diurna e Rapporto aeroilluminante. Nella situazione reale (a sinistra), la luce zenitale assicura alti valori di FLD e di RAI (0,10 minimo – Comune di Milano), rispetto alla situazione di studio (a destra) priva di aperture zenitali.



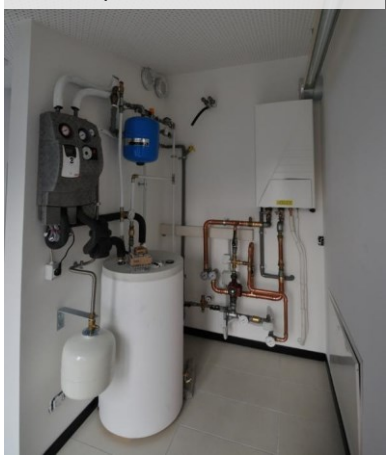
Luminanza. Il confronto della luminanza (21 Giugno - h 12:00) fra la situazione reale (in presenza di lucernari) e di studio (in assenza di lucernari), mostra come la luce zenitale renda i valori più omogeneamente distribuiti all'interno dei locali. Inoltre, il fenomeno dell'abbagliamento è ben controllato dai sistemi di schermatura posti all'esterno.

Energy simulations and machines system

Ventilazione meccanica (portata massima 470 m^3/h) con recuperatore di calore (>90%)

Riscaldamento (90 W/m^2) e raffrescamento (30 W/m^2) radiante a pavimento

Pompa di calore aria-acqua (7 kW riscaldamento, 6.1 kW raffrescamento), solare termico (3 collettori solari, 160l serbatoio di accumulo)



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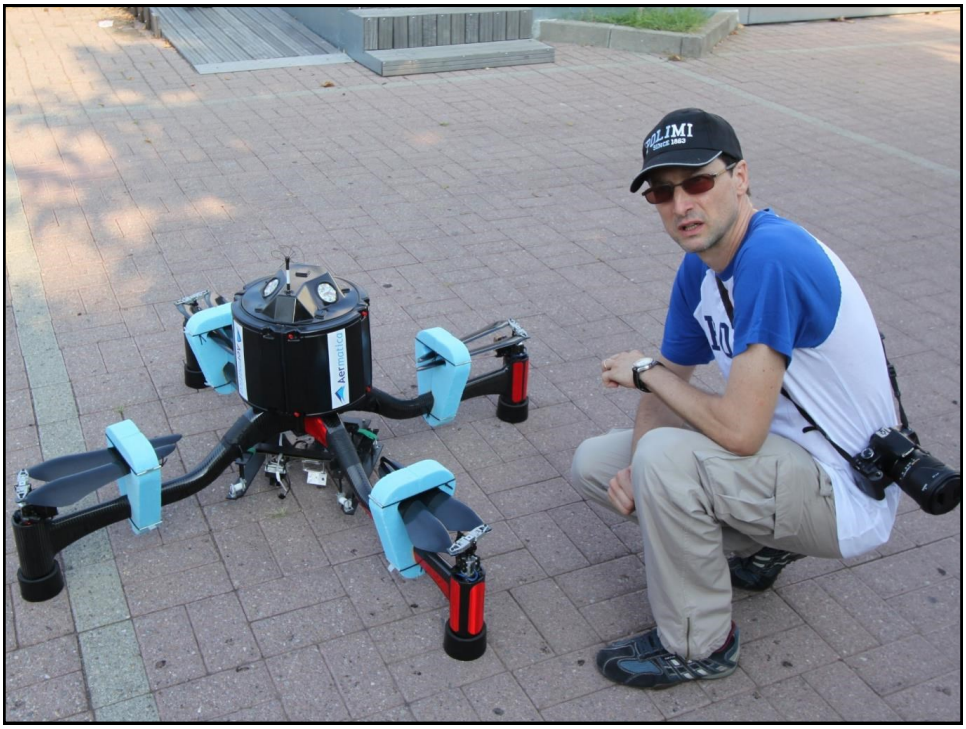
July 2013 – Drone Experiment (Drone experiment)

20



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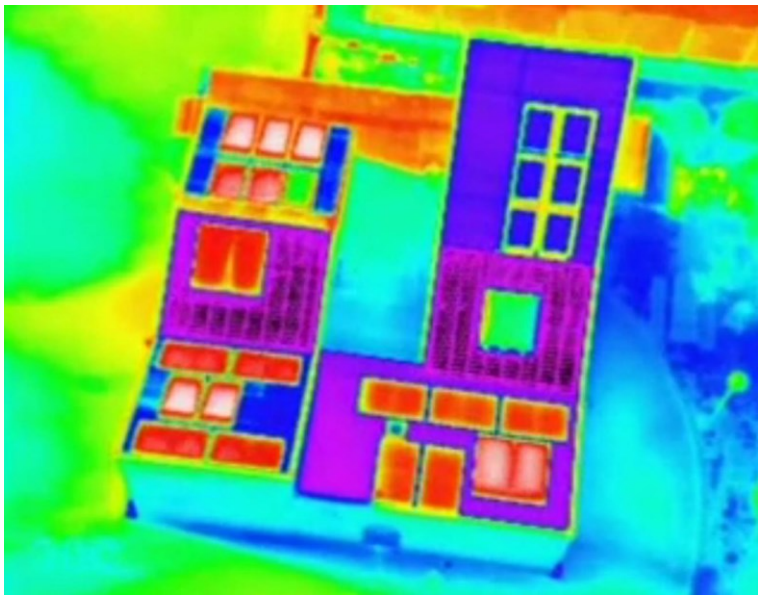
VELUX lab



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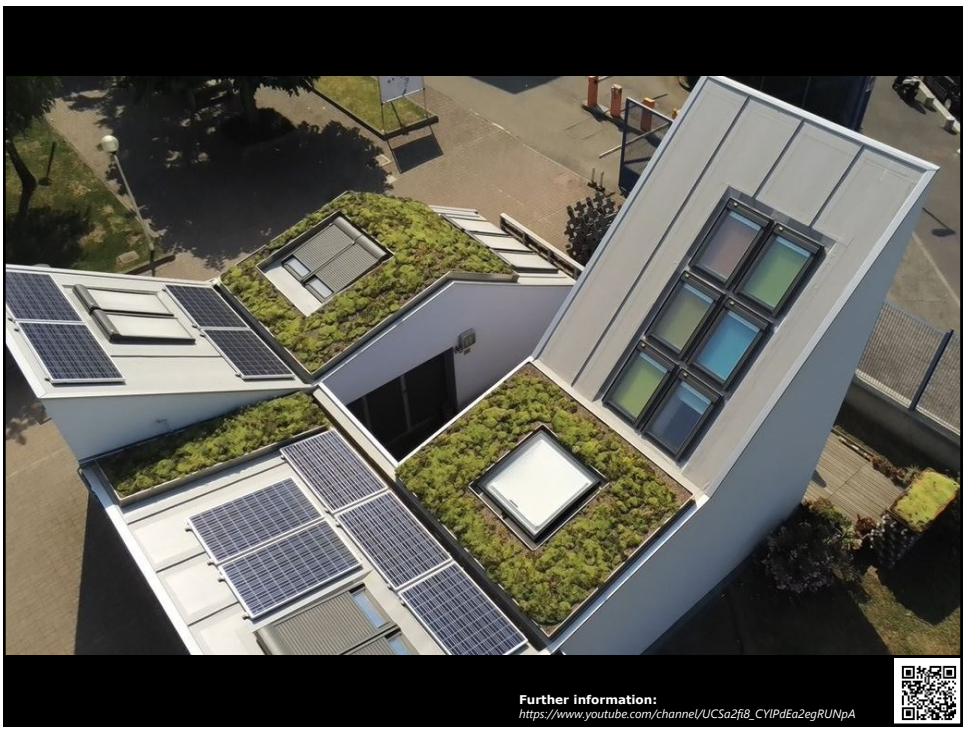

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Ph. Giacomo Bianchi, Arte Sella

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Like a **natural complex systems** as the **Mycelium**, the **plant internet network**.
Phygital activehouse - Eng. PhD Nicole Di Santo

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Toward an implementation taking its origin from **biological inspirations** as these similar different approaches are in our basic **best foundations**.

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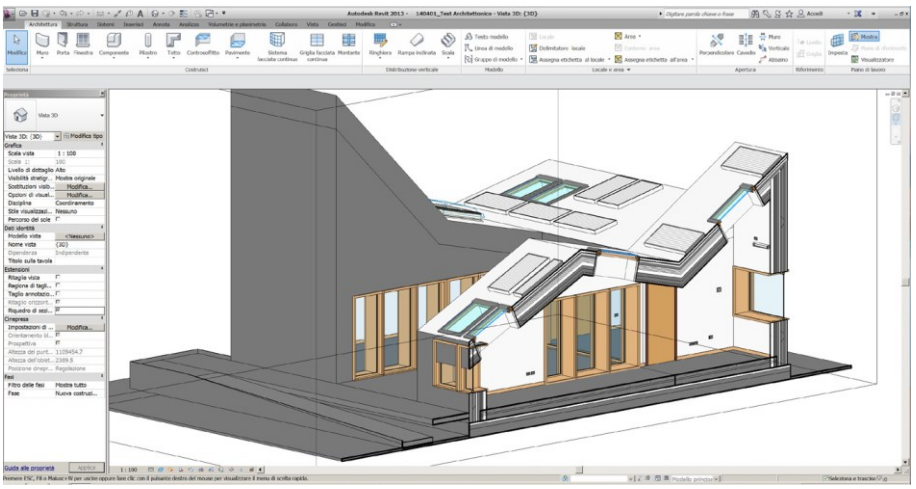
Augmented Reality



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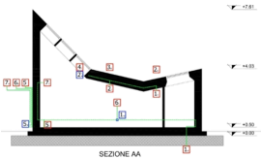
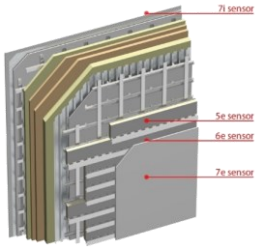
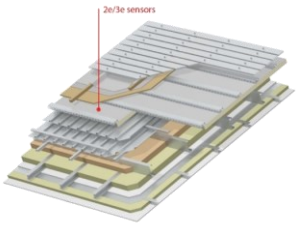
Wireless sensors network monitoring systems







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It is not the strongest nor the most intelligent that survives but the one that is ready to adapt to changements.

Charles Darwin,

The origin of species, 1859

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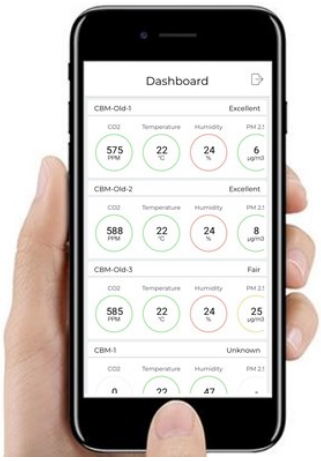
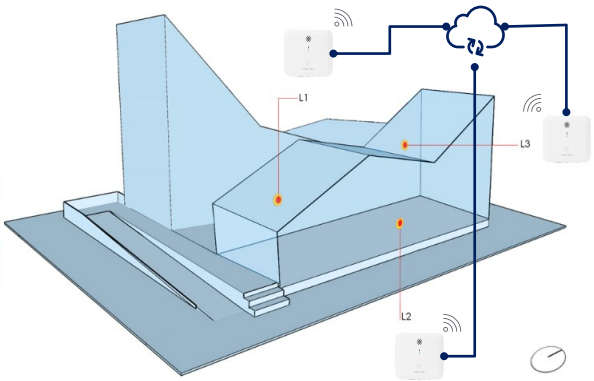
Case study

- VELUXlab: COGNITIVE BUILDING and DATA VISUALIZATION





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Ph. Giacomo Bianchi, Arte Sella

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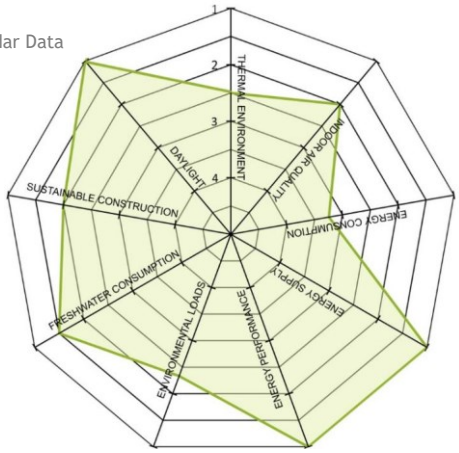
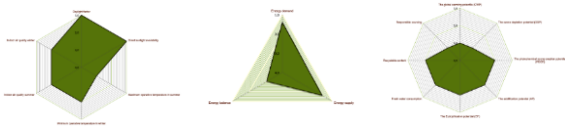
Certification Active House

VELUX lab

Radar Data



Comfort **Energy** **Environment**



activehouse.INFO

NETWORK AND KNOWLEDGE SHARING

First Italian building "Net Zero Energy" in a University Campus

And through the integration of the PV system:

First Italian Active House certified as built

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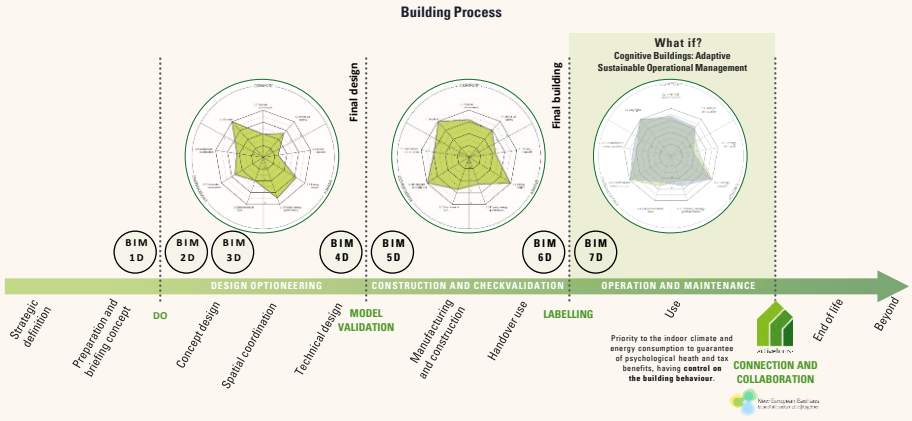
Active House

- a user-centered method for the entire building process



"RIBA Plan of Work 2020 Overview," 2020.

35

"CREATIVITY IS A PLACE WHERE IT RAINS INSIDE ..."

ITALO CALVINO

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Applications and Future Developments

A field study with different cases

The case studies were selected to advance the research into 7D dimension of the asset-construction digitalization **on cognitive buildings** proceeding **from a small** scale to different contexts and larger ones.

Specifically, to pursue the research objective the S-size buildings cases will be tested to evaluate the **reliability** of the approach in **larger scales**.

Arrow = project size category

S-size	10 – 300 mq
M-size	1.000 – 3.000 mq
L-size	4.000 – 30.000 mq
XL-size	100.000 – 200.000 mq

Ring = construction type

- Residences
- Residences / Offices
- Hotel, new construction-retrofitting
- Offices

Ring = construction system

- Wet construction system
- Wet / dry construction system
- Dry construction system

Phygital activehouse - - Eng. PhD Nicole Di Santo

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CPH Village

unit/district

A student housing with two offices surrounded by a calm urban forest, developed under the living small concept.
It is under test for monitoring.

Fig. CPH Village, Jernbanebyen, Copenhagen, Denmark

Phygital activehouse - - Eng. PhD Nicole Di Santo

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CPH Village

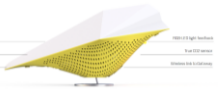
unit/district

The building sensors installed with different benefits.

AirBird

Standard Sensors:

CO2 : 0 - 5000 ppm (±30 ppm ±3% of reading), NDIR
Temperature: -20 to +60 Deg C, (±0.5 ºC)
Relative Humidity : 1- 99% (±3%),



MiniNode

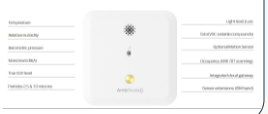
Standard Sensors:

CO2 : 0 - 5000 ppm (±30 ppm ±3% of reading), NDIR
Temperature: -20 to +60 Deg C, (±0.5 ºC)
Relative Humidity : 1- 99% (±3%),

AmbiNode

Standard Sensors:

CO2 : 0 - 5000 ppm (±30 ppm ±3% of reading), NDIR
Temperature: -20 to +60 Deg C, (±0.5 ºC)
Relative Humidity : 1- 99% (±3%),
Barometric pressure: 300 - 1100 hPa (±1%)
Particle Sensor : PM 2.5, PM 10. (±15ug/m3)
Lux meter (Lumens /SqM):
Decibel Meter : 30-110 dBA (20 Hz – 20 kHz), ±1 dB



https://leapsight.leapcraft.com/.

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CPH Village

unit/district

Phygital activehouse - Eng. PhD Nicole Di Santo








https://leapsight.leapcraft.com/; https://en.climaid.dk/; https://cphvillage.com/: https://www.velux.it/.

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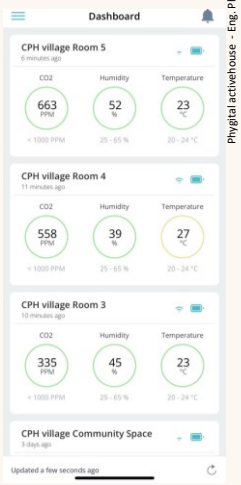
CPH Village

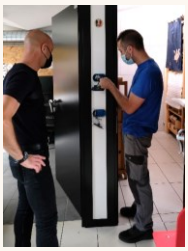
unit/district

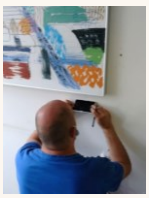


https://leapsight.leapcraft.com/; https://en.climaid.dk/; https://cphvillage.com/; https://www.velux.it/.

VELUXlab

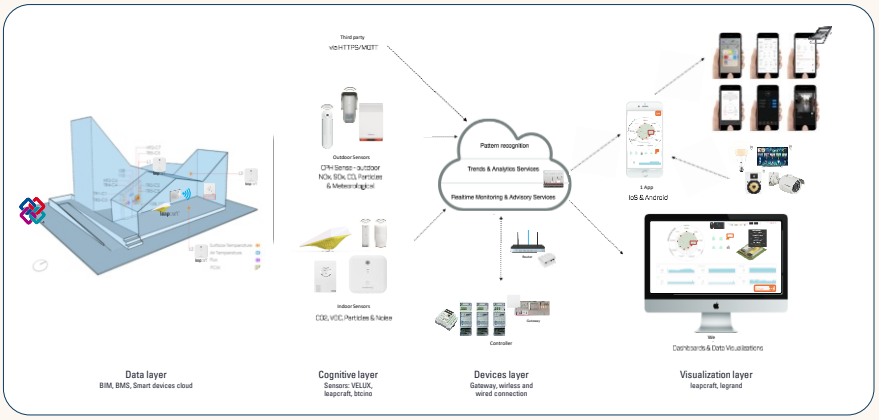
Installation VELUX-BTCINO-POLIMI



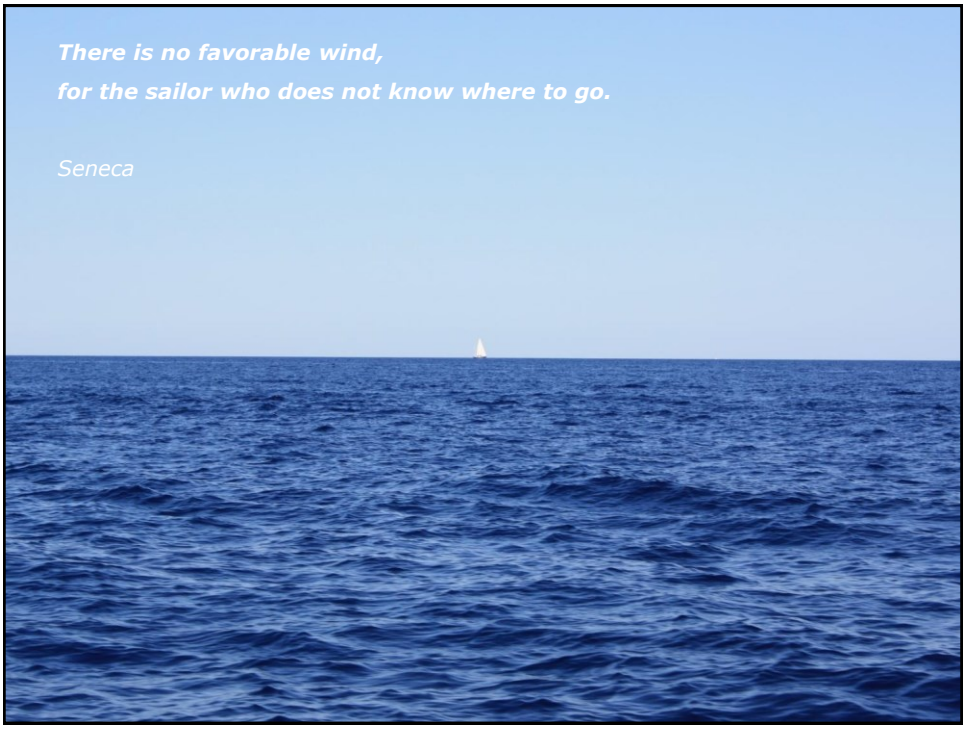


VELUXlab

unit – the interconnection



Phygital activehouse - Eng. PhD Nicole Di Santo


There is no favorable wind,
for the sailor who does not know where to go.
Seneca

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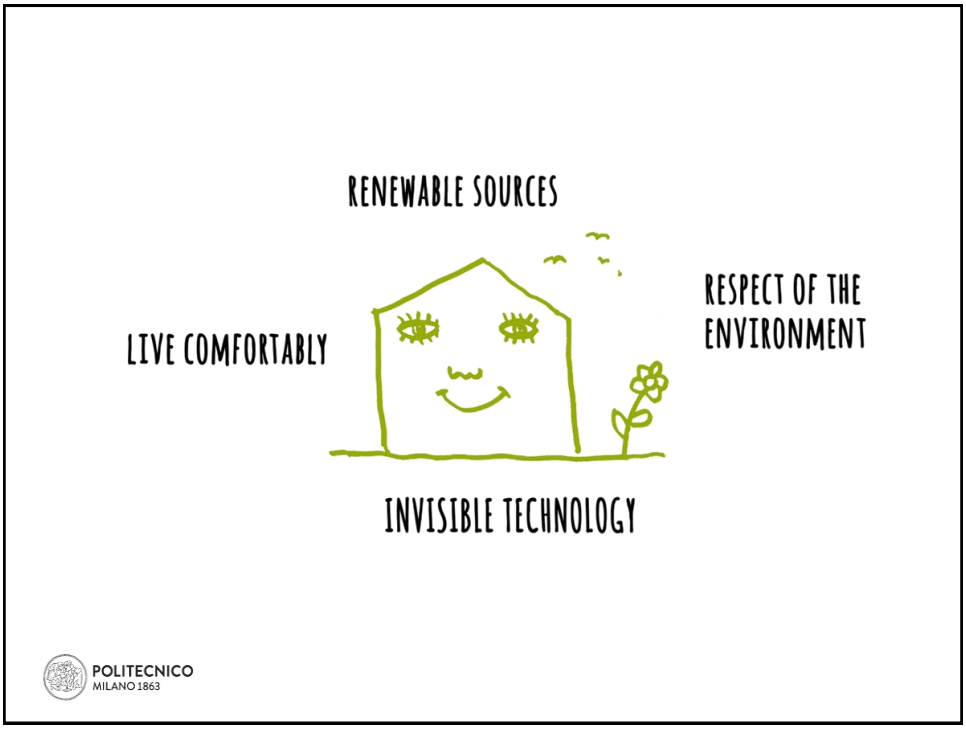
RENEWABLE SOURCES
LIVE COMFORTABLY
RESPECT OF THE ENVIRONMENT
INVISIBLE TECHNOLOGY
POLITECNICO
MILANO 1863

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47

48

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Occupant voting systems for continuous feedback

Presenter

Donya Sheikh Khan, PhD, Arch Eng
Senior Specialist, Ramboll

Agenda

01 Why is occupants' feedback important?

02 How do we collect their feedback?

03 Why use occupant voting systems?

04 Considerations for using occupant voting system

05 Example of application of OVS – case study

06 Recap

Assessing building performance in use 4: the Probe occupant surveys and their implications

Intelligent Buildings International

RESEARCH ARTICLE

The value of post-occupancy evaluation for building occupants and facility managers

Vivian Loftness[1*], Azizan Aziz[1], JoonHo Cho
Kevin Powell[2], Mike Atkinson[2], Judith Heerw

[1]Center for Building Performance and Diagnostics, Carnegie Mel
Pittsburgh, PA, 15213, US
[2]Public Buildings Service, US General Services Administration, 1
Washington, DC 20405-0002, US
[3]J.H. Heerwagen and Associates, 2716 NE 91st Street, Seattle, W

User satisfaction studies and measured performance studies re
between the design intent and the performance of buildings an
shifts. Whether this gap is due to failures in the design, construct
however, is often unclear – mandating that user satisfaction studi
and measured performance studies to fully understand the perform
over time. The article introduces the General Services Administr
Assessment Toolkit (NEAT) field study tools and database and
goals of high-performance buildings that meet ongoing occupanc
The NEAT studies undertaken by the Carnegie Mellon University's
the GSA have been used to illustrate the value of instrumented po
occupants as sensors and controllers; identify technologies and
impacts health and productivity; ensure investment where it m
behaviour on environmental gains; and to catalyse innovation.

Keywords: building performance; field evaluation and measure
indoor environmental quality; post-occupancy evaluation; produ
air quality evaluation

PRECEDENTS IN POST-OCCUPANCY EVALUATION WITH FIELD MEASUREMENTS

The addition of physical and environmental measurements to post-occupancy evaluation (POE) has a long-standing tradition, introduced in

*Corresponding author. E-mail: loftness@cmu.edu

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© 2009 Earthscan ISSN: 1750-8975 (print), 1756-6932 (online) www.earthscan

Adrian Leaman[1] and Bill Bordass[2]

...ilding Use Studies Ltd, 42–44 Newman Street, London W1P 3PA, UK
E-mail: adrianleaman@usablebuildings.co.uk

Building and Environment 68 (2013) 66–76

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ELSEVIER

Occupant satisfaction in LEED and non-LEED certified buildings

Sergio Altomonte[a], Stefano Schiavon[b,*,1]

[a]Department of Architecture and Built Environment, University of Nottingham, University Park, Nottingham NG7 2RD, UK
[b]Center for the Built Environment, University of California, 390 Wurster Hall, Berkeley, CA 94720-1839, USA

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Indoor environmental quality
Rating tools

ABSTRACT

Occupant satisfaction with indoor environmental quality (IEQ) in office buildings has been positively correlated to self-estimated job performance and, potentially, to overall company productivity. LEED is a voluntary, consensus-based, market-driven program that provides third-party certification of green buildings, contributing to promote sustainability in the mainstream of building design and construction. From the literature, however, it is unclear the extent to which LEED certification also improves occupant satisfaction with IEQ. The aim of this paper is to study if LEED certified buildings lead to a higher, equal or lower satisfaction with indoor environmental quality than non-LEED rated buildings. Occupant satisfaction has been evaluated on a subset of the Center for the Built Environment Occupant Indoor Environmental Quality Survey database featuring 144 buildings (65 LEED certified) and 21,477 individual occupant responses (10,129 in LEED buildings). Differently from previous studies of the CBE database, the results show that occupants of LEED certified buildings have equal satisfaction with the building overall and with the workspace than occupants of non-LEED rated buildings. The difference in mean satisfaction scores between LEED and non-LEED buildings for other 15 IEQ parameters investigated is always lower than 6% with a negligible effect size. Therefore, it can be concluded that there is not a significant influence of LEED certification on occupant satisfaction with indoor environmental quality, although the analysis of mean votes of satisfaction reveals that occupants of LEED buildings tend to be slightly more satisfied with air quality, and slightly more dissatisfied with amount of light.

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1. Introduction

The satisfaction of occupants in office buildings is affected by thermal, acoustic and visual parameters, by air quality, and by other features of the workspace – and of the building – such as view, furniture layout, amount of privacy, cleanliness and level of personal control over the internal environment [1]. The satisfaction of occupants has been correlated to the self-estimated job performance of office workers [2], this having an effect on frequency and duration of absenteeism and intention to quit work and, potentially, to overall company productivity [3]. Therefore, occupant satisfaction is an important factor in the design, operation and management of buildings.

LEED (*Leadership in Energy and Environmental Design*) is a voluntary, consensus-based, market-driven program that provides third-party certification of green buildings [4]. LEED is the most popular building rating tool in the United States, and its market share is continuing to grow, both in the US and internationally [5]. Irrespective of the LEED product used for the certification, there is a general perception amongst the actors of the building industry that LEED – as well as other rating tools such as BREEAM in UK, Green Mark in Singapore, Green Star in Australia, etc. – has effectively contributed to bring sustainability into the mainstream of building design and construction [6,7]. However, less clear from the literature is the extent to which the use of a rating tool can actually improve indoor environmental quality and workplace satisfaction for the occupants of the certified buildings. In this context, it should be mentioned that the evidence of the energy savings effectively facilitated by rating tools has also been analyzed by studies that have looked at actual energy use of LEED certified buildings versus a comparable dataset of existing commercial buildings in the US [8,9]. The outcomes concluded that it is complex to provide a comprehensive calculation of the effective reduction in primary (source) energy use in commercial buildings certified by LEED compared to not-rated office spaces.

In the following paragraphs, this paper will introduce the LEED program, the Center for the Built Environment (CBE) Occupant Indoor Environmental Quality Survey, and will analyze the results of previous studies focusing on the relationship between indoor environmental quality, LEED/green rating and occupant satisfaction.

* Corresponding author. Tel.: +1 510 859 3811; fax: +1 510 643 5571.
E-mail address: stefanoschiavon@berkeley.edu (S. Schiavon).
[1] URL: http://ced.berkeley.edu/ced/faculty-staff/stefano-schiavon/.

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ELSEVIER

A review of operating performance in green buildings: Energy use, indoor environmental quality and occupant satisfaction

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

ELSEVIER

Building energy certification versus user satisfaction with the indoor environment: Findings from a multi-site post-occupancy evaluation (POE) in Switzerland

Luisa Pastore*, Marilyne Andersen

Laboratory of Integrated Performance in Design (LIPID), School of Architecture, Civil and Environmental Engineering (ENAC), École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland

ARTICLE INFO

Keywords:
Green buildings
Comfort
Indoor environmental quality (IEQ)
Energy certification
Minergie
Post-occupancy evaluation (POE)

ABSTRACT

Voluntary green-rating systems exist in different forms worldwide to certify the sustainability of residential and commercial buildings and help national policies promote energy-efficient design practices. Despite the general assumption that sustainable buildings also provide high comfort and healthy conditions, existing studies on green-rated buildings led to controversial conclusions in this regard.

This paper aims to report the results of a post-occupancy evaluation (POE) conducted on four Swiss green buildings certified with the Minergie label to analyse their ability in providing comfort to their occupants. The POE protocol included winter and summer environmental monitoring campaigns (long-term and instantaneous measurements) as well as extensive and point-in-time comfort surveys.

From the study it was found that, although the observed environmental factors were most of the time complying with the norm prescriptions, the indoor conditions were never attaining the commonly used 80% satisfaction threshold by the users. Temperature and air quality appeared, in particular, as the most critical factors, with satisfaction rates never greater than 50% in three out of the four case studies.

Design factors related to the personal control on the indoor environment as well as personal factors like gender, climate of origin and duration of residence in the country were also found to have an impact in the comfort rating.

Professionals involved in the design and management of these buildings all agreed that feedback of this kind from building in use could help inform the design and operational process and move towards more effective green building certification systems and regulations.

1. Introduction

Energy performance certification is a strategic policy instrument that assists governments in decreasing the energy footprint of the built environment. Certification schemes can be applied on a mandatory or voluntary base. Voluntary energy labels have spread in different forms worldwide to certify the sustainability of both residential and commercial buildings. For these latter, besides the obvious positive environmental consequences, the main benefits for the companies are the actual cost saving in energy over time and a publicly recognized environment-friendly profile that can largely help in the brand promotion.

Incentives to seek for energy certification also derive from the fact that green buildings are often argued to provide a better indoor environmental quality (IEQ) which should result in a more satisfying and productive workplace for the building occupants. Despite this general assumption, several post-occupancy evaluation (POE) studies conducted globally for more than a decade revealed the absence of a global unambiguous evidence [1]: while some studies comparing occupant comfort satisfaction in green-rated offices against general building stock showed that green buildings definitely provide more satisfying conditions [2–6], other researchers found that certified buildings are not necessarily perceived as more comfortable and productive workplaces [7–9]. For example, some POEs demonstrated that, although IEQ ratings scores for green buildings tended to be globally better than in standard buildings, chronic environmental problems and most of the irritations often reported in conventional offices were still endemic even in sustainable buildings, especially with respect to personal environmental control [10], hot temperature and stuffiness of the air in summer [11], lighting and acoustics [12] or overall workstation designs [13]. In an Australian study, Menadue et al. [14] detected that

* Corresponding author.
E-mail address: luisa.pastore@epfl.ch (L. Pastore).

https://doi.org/10.1016/j.buildenv.2019.01.001

...formance of green buildings in ...sfaction. A total of 925 related ...e study also compared the ac- ...nes, with information collected ...ed as follows: 1) Though with ...e average better than the con- ...gap between the designed and ...ved less energy than expected; ...ilding certification level could ...mparable in different countries ...buildings generally had higher ...bjective data from the U.S. did ...orthy further investigations in ...lata collection technologies and

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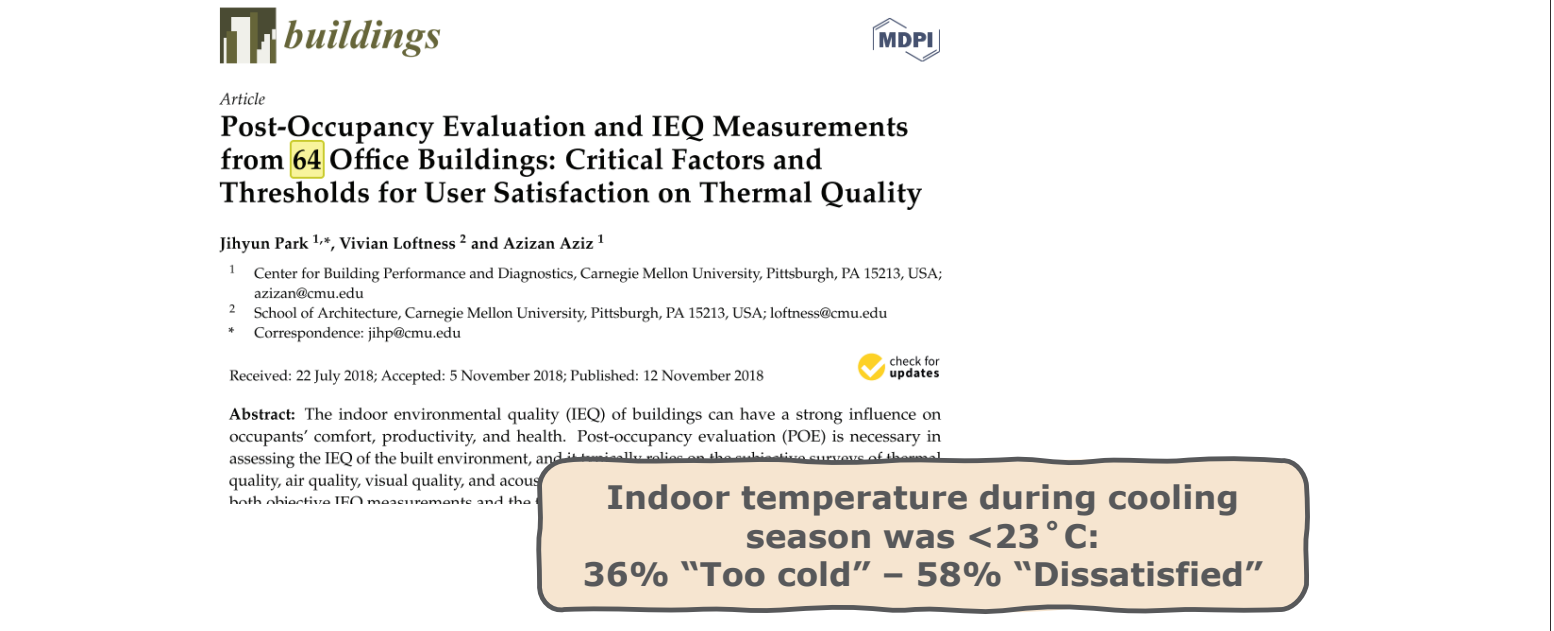
...]. Meanwhile, a number of ...loped to facilitate the green ...es [6,7], such as Leadership ...LEED) in the United States, ...Bauen (DGNB) in Germany, ...d (BREEAM) in the United ...ustralia Green Star in Aus- ...re, Comprehensive Assess- ...fficiency (CASBEE) in Japan ...China. ...een building, an increasing ...ucted on various aspects of ...nethods/tools, technical as- ...pects and economic aspects ...udies were design-oriented, ...nly focused on what tech- ...pt at the design stage and ...during the operation. The ...eline for the design of green ...he expected performance of ...le, Zuo et al. [8] pointed out



buildings

MDPI

Article

Post-Occupancy Evaluation and IEQ Measurements from 64 Office Buildings: Critical Factors and Thresholds for User Satisfaction on Thermal Quality

Jihyun Park [1,*], Vivian Loftness [2] and Azizan Aziz [1]

1 Center for Building Performance and Diagnostics, Carnegie Mellon University, Pittsburgh, PA 15213, USA; azizan@cmu.edu
2 School of Architecture, Carnegie Mellon University, Pittsburgh, PA 15213, USA; loftness@cmu.edu
* Correspondence: jihp@cmu.edu

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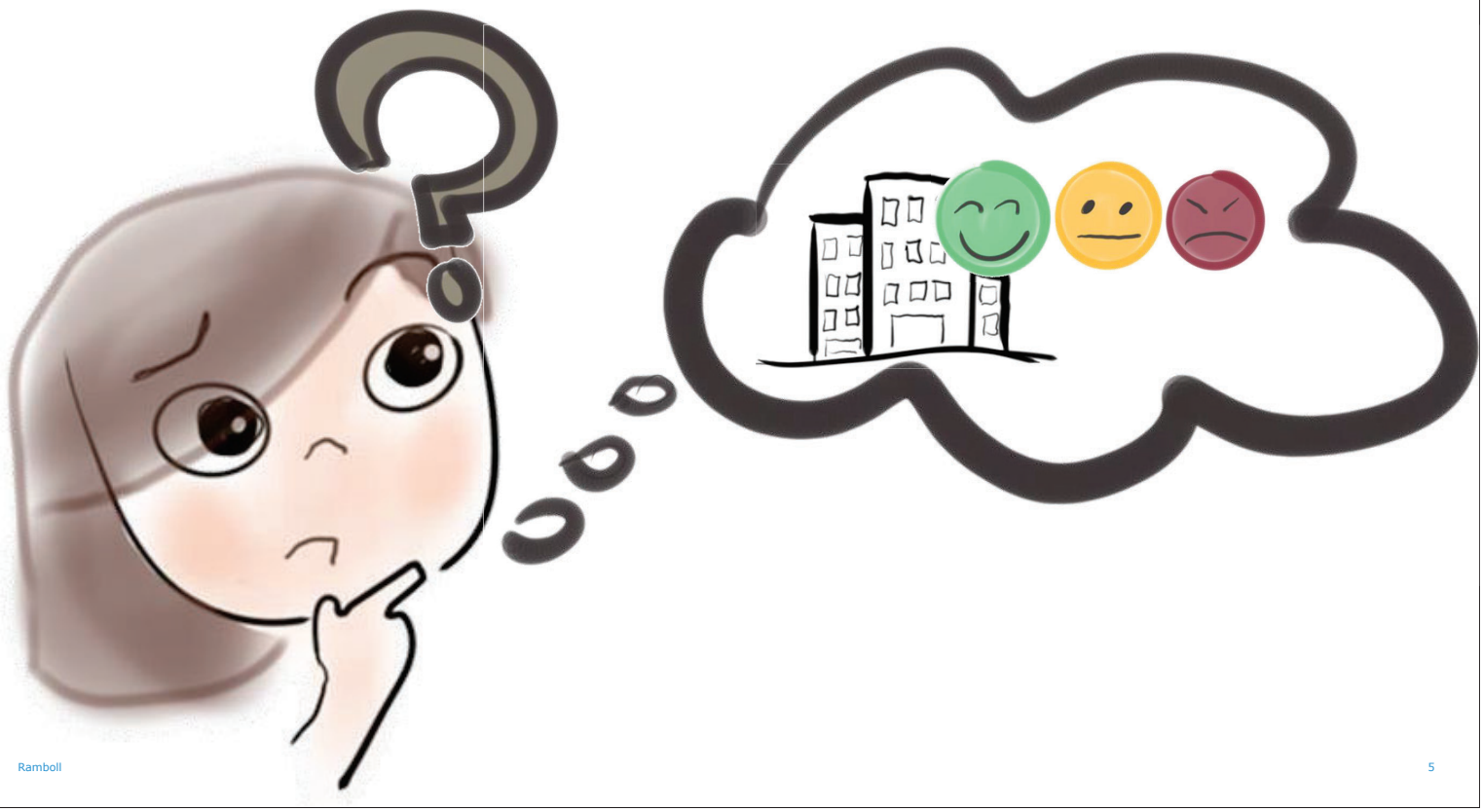
check for updates

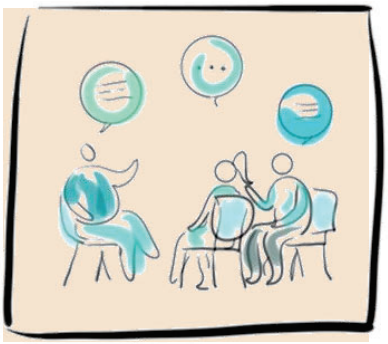
Abstract: The indoor environmental quality (IEQ) of buildings can have a strong influence on occupants' comfort, productivity, and health. Post-occupancy evaluation (POE) is necessary in assessing the IEQ of the built environment, and it typically relies on the subjective surveys of thermal quality, air quality, visual quality, and acous... both objective IEQ measurements and the ...

Indoor temperature during cooling season was <23°C:
36% "Too cold" – 58% "Dissatisfied"



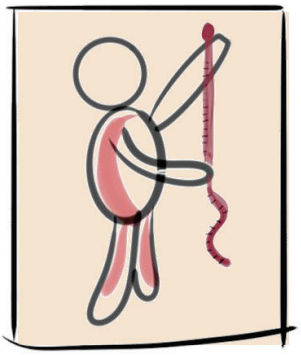
Systematic data collection

Social-idealist



- Observations
- Interview
- Focus group
- Logbook/ photovoice

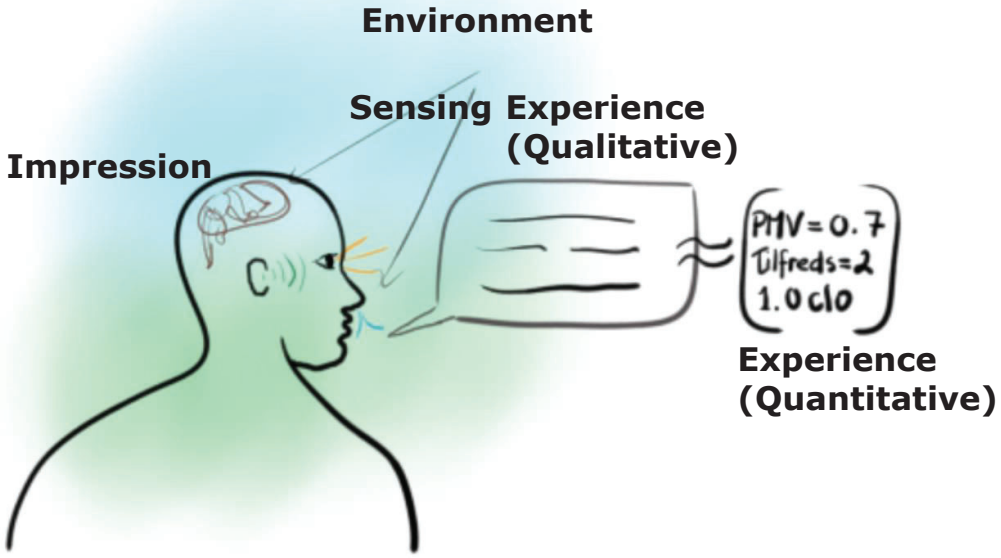
Technical-idealist



- Questionnaire
- Voting
- Sensor
- Interaction

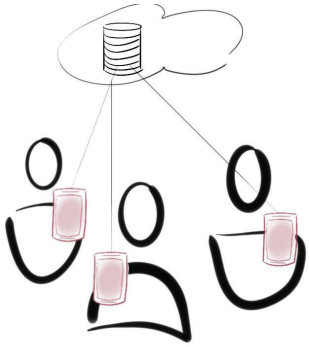
The terms social- and technical-idealist is based on M. Earl, Jour. of Management IS, 18, 1 (2001)

Human as a sensor



CMMS (Helpdesk)

Questionnaire



Occupant Voting System (OVS)

Tablet or panel of feedback buttons

Wearable

Smartphone

Interface & User friendliness

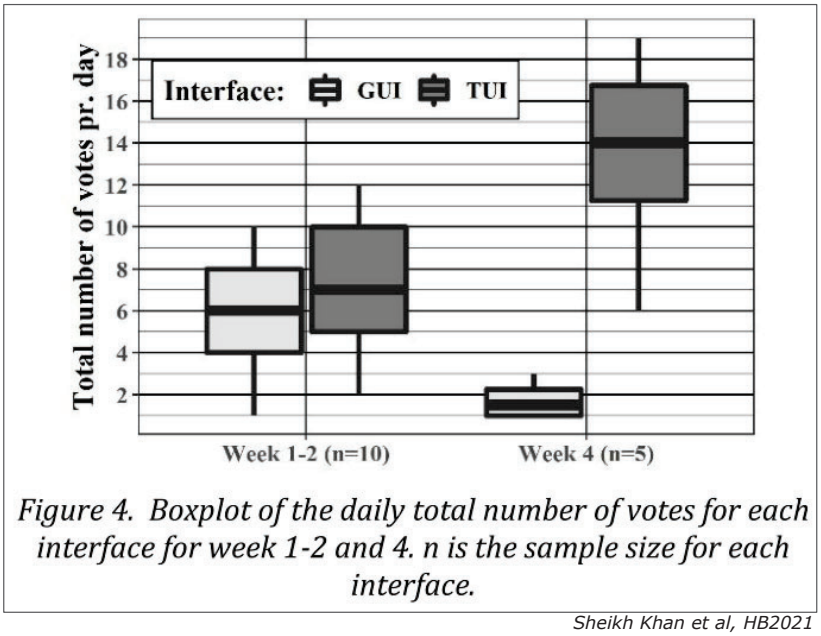
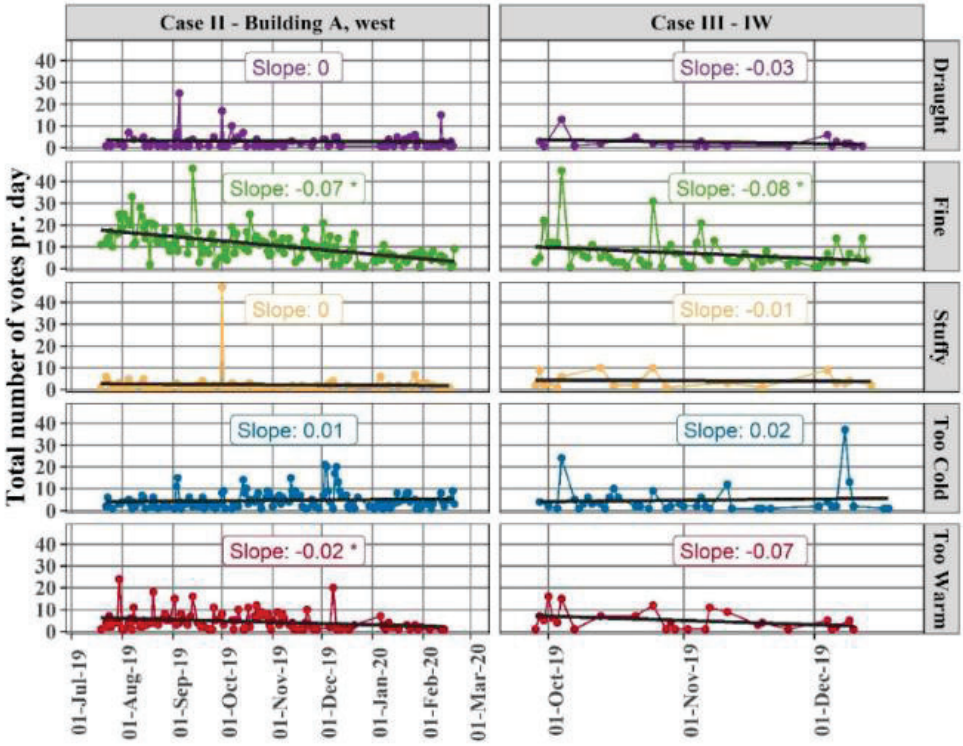


Figure 4. Boxplot of the daily total number of votes for each interface for week 1-2 and 4. n is the sample size for each interface.

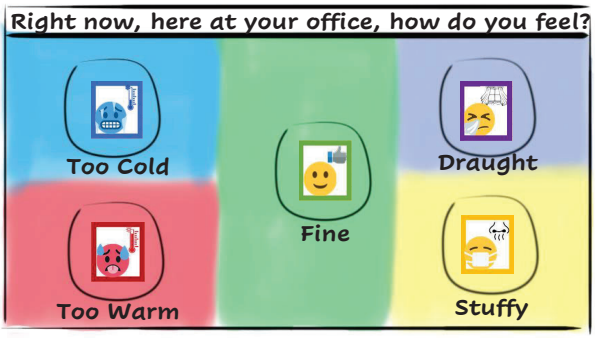
Sheikh Khan et al, HB2021

”Novelty” effect

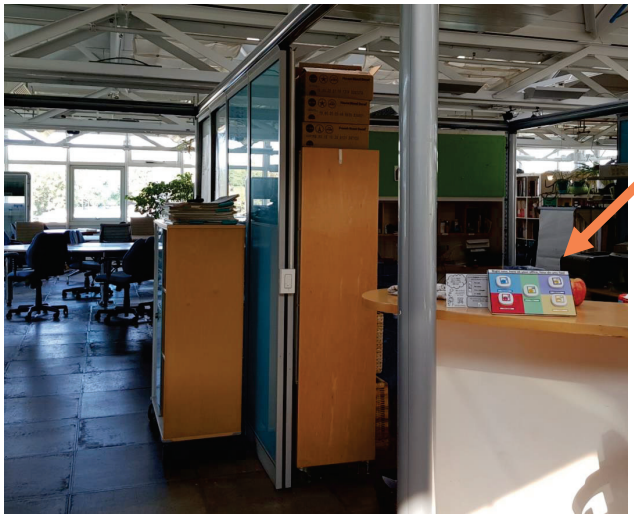


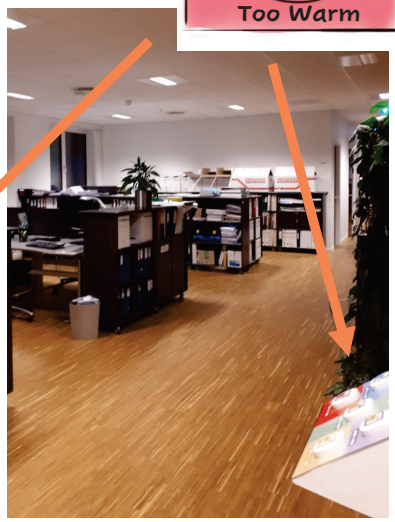
Sheikh Khan et al, Frontiers in Built Environ., March, 2021

Non-intrusive



TiAQ, Sheikh Khan





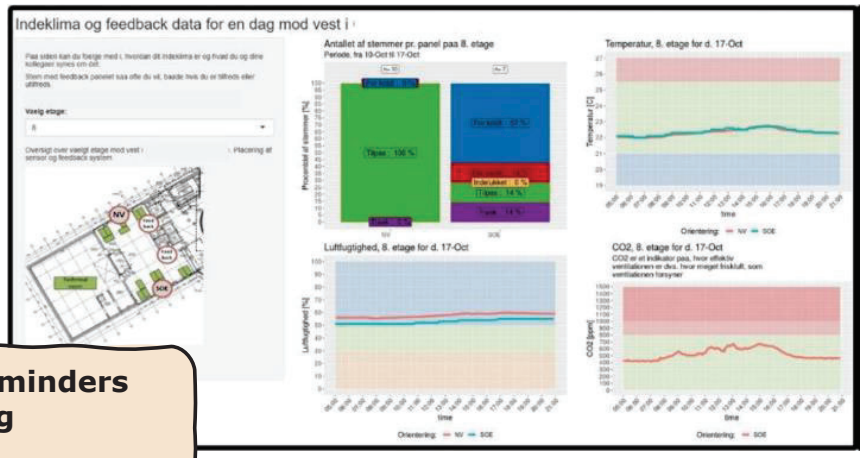
Mini-Orb, Rittenbruch et al

Feedback on Feedback

Expected that TiAQ would be used to control the indoor climate

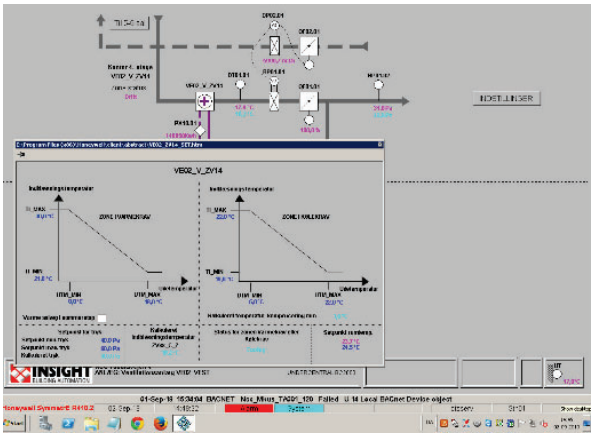
Expected reminders for providing feedback

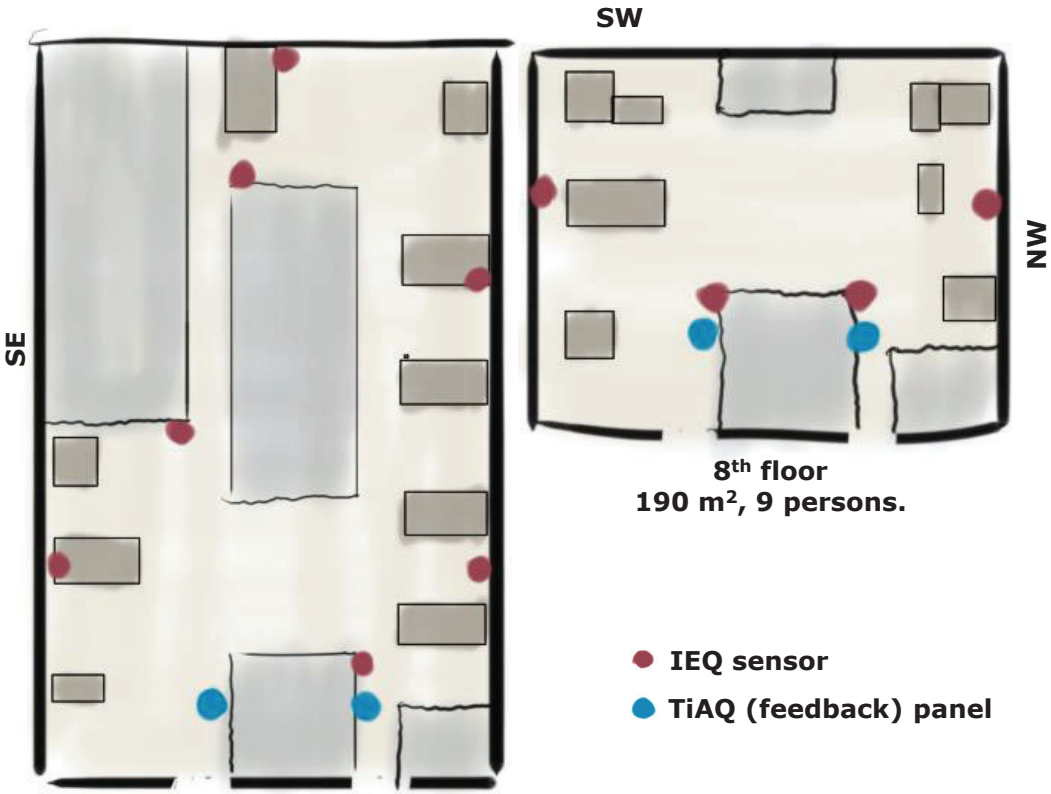
Expected feedback to be used by the building operator

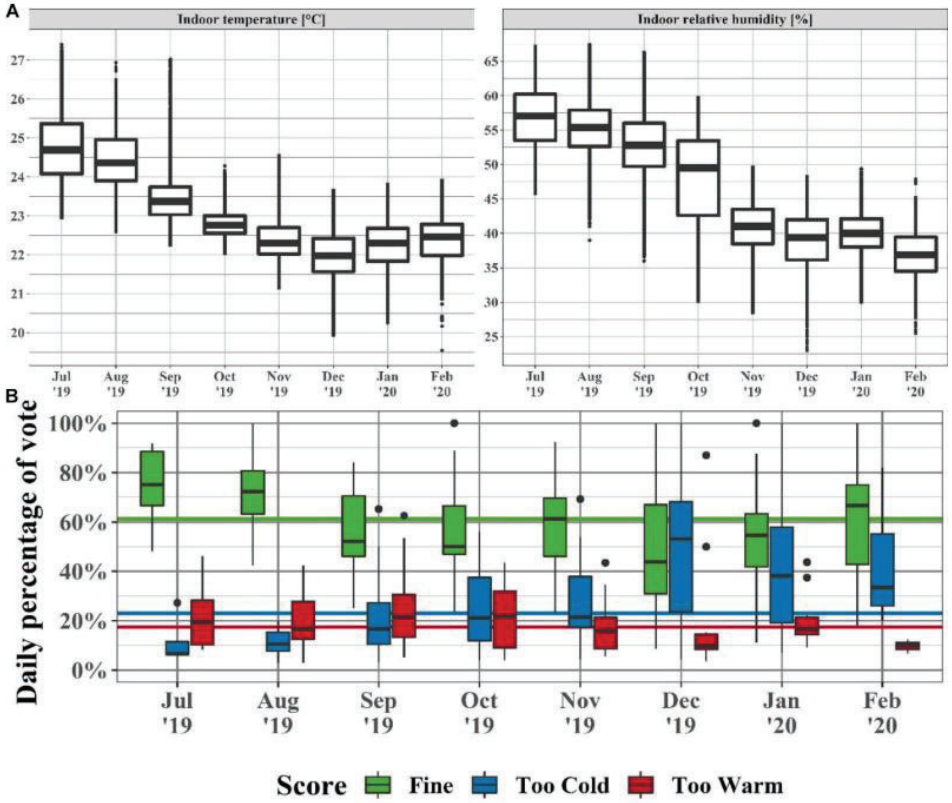


Dashboard for users showing indoor climate and feedback, Sheikh Khan

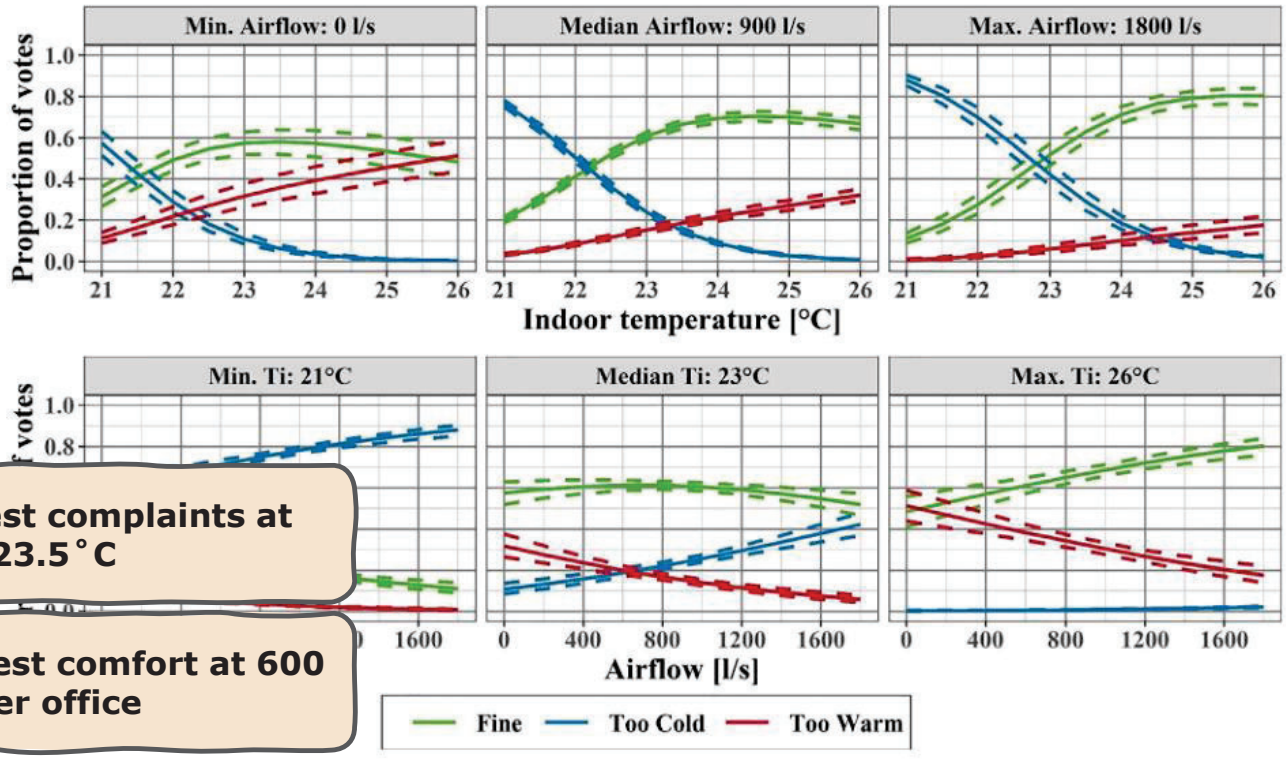
- **Occupant feedback**
- **TVOC, CO_2, RH, Ti**
- **Airflow, Tinlet.**
- **Energy consumption**
- **Tout, sunshine-hours**







Sheikh Khan et al, Frontiers in Built Environ., March, 2021



Lowest complaints at Ti = 23.5˚C

Highest comfort at 600 l/s per office

Sheikh Khan et al, Energy & Buildings 251 111363, 2021

Lowest complaints at Ti = 23.5˚C

Highest comfort at 600 l/s per office

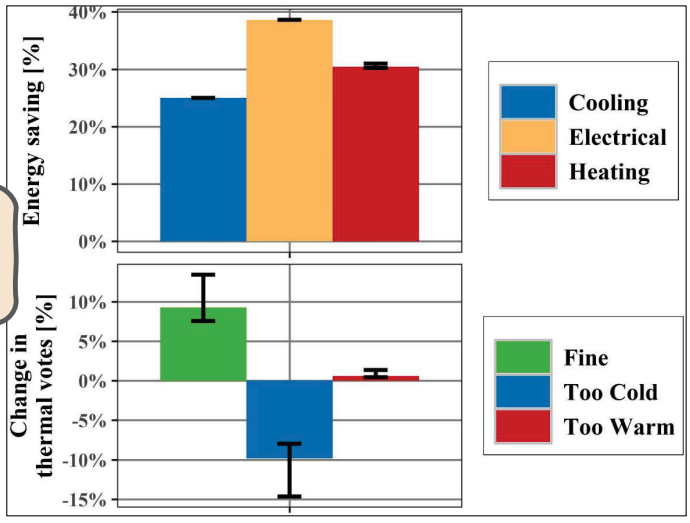
Suggested control:

Current airflow reduced by 25%

&

Temperature set point changed from 24˚C to 23.5˚C

~40% energy reduction & ~10% increased comfort



Recap

1. Occupant feedback is important information to include in optimizing HVAC operation
2. Solicited and unsolicited here-and-now feedback can be collected with OVS
3. OVS design and implementation is important for getting quality feedback data
4. Feedback data used by building operator, can identify control settings for improving energy consumption and occupant comfort

Thanks

Donya Sheikh Khan
dskh@ramboll.dk

Active House - Comfort Score

activehouse

Bas Hasselaar bha@dgmr.nl

15-11-2022

1

Vision

CREATING BUILDINGS FOR PEOPLE AND PLANET

Active House is a vision of buildings that create healthier and more comfortable lives for their occupants without impacting negatively on the climate – moving us towards a cleaner, healthier and safer world.

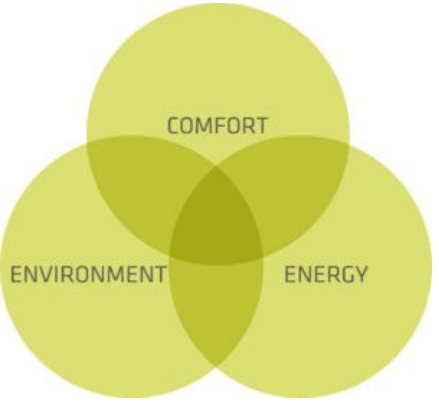
2

2

COMFORT – ***creates a healthier and more comfortable life***
An Active House creates healthier and more comfortable indoor conditions for the occupants, ensuring a generous supply of daylight and fresh air, combined with a comfortable indoor temperature and absence of disturbing noise. Materials used have a neutral and where possible positive, impact on comfort and indoor climate.

ENERGY – ***contributes positively to the energy balance of the building***
An Active House is energy efficient. It utilises smart energy sourcing, energy needed is supplied by renewable energy sources integrated in the building or from the most sustainable source from the nearby collective energy system or electricity grid.

ENVIRONMENT – ***has a positive impact on the environment***
An Active House interacts positively with the environment through an optimised relationship with the local context, focused use of resources, and its overall environmental impact throughout its life cycle.



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Key principles

KEY PRINCIPLES OF ACTIVE HOUSE

THE ACTIVE HOUSE KEY PRINCIPLES ARE AS FOLLOWS

COMFORT
- a building that provides an indoor climate that promotes health, comfort and sense of well-being
- a building that ensures good indoor air quality, adequate thermal climate and appropriate lighting levels and acoustical comfort
- a building that provides an indoor climate that is easy for occupants to control and at the same time encourages responsible environmental behaviour.

ENERGY
- a building that is energy efficient and easy to operate
- a building that substantially exceeds the statutory minimum in terms of energy efficiency
- a building that exploits a variety of energy sources integrated in the overall design.

ENVIRONMENT
- a building that exerts the minimum impact on environmental and cultural resources
- a building that avoids ecological damage
- a building that is constructed of materials with focus on re-use and re-purpose.

LangFang Office, Beijing China.
Photo: *Velux China.*

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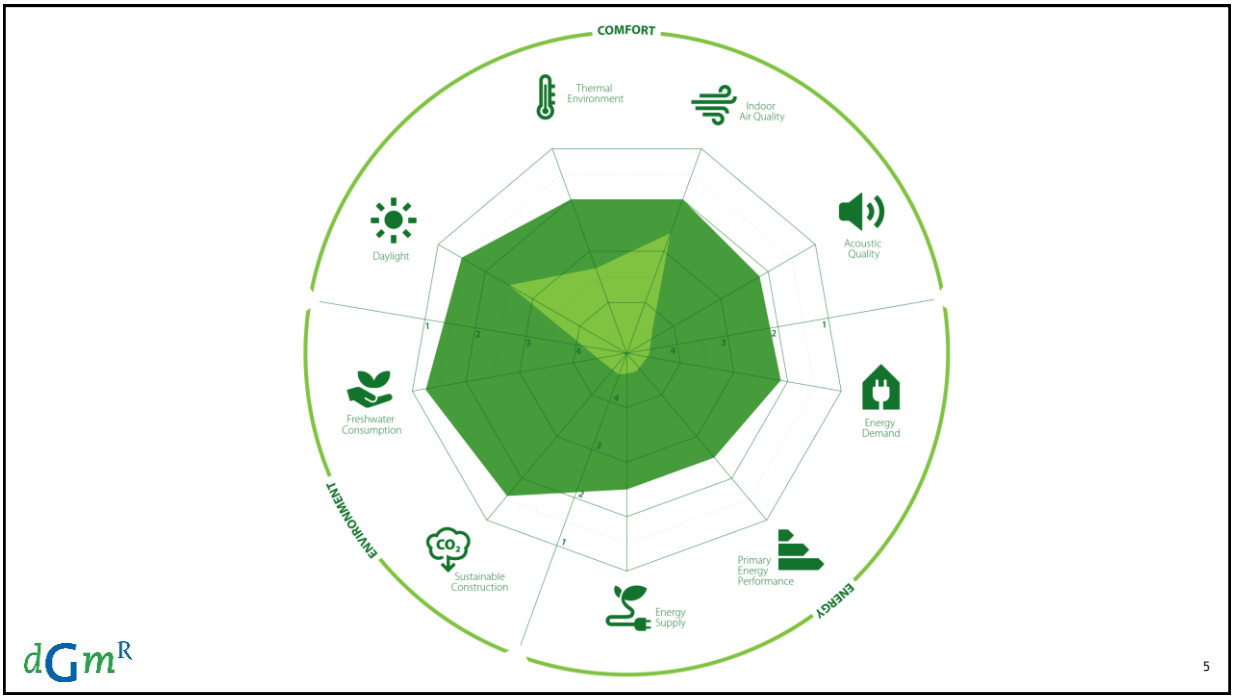
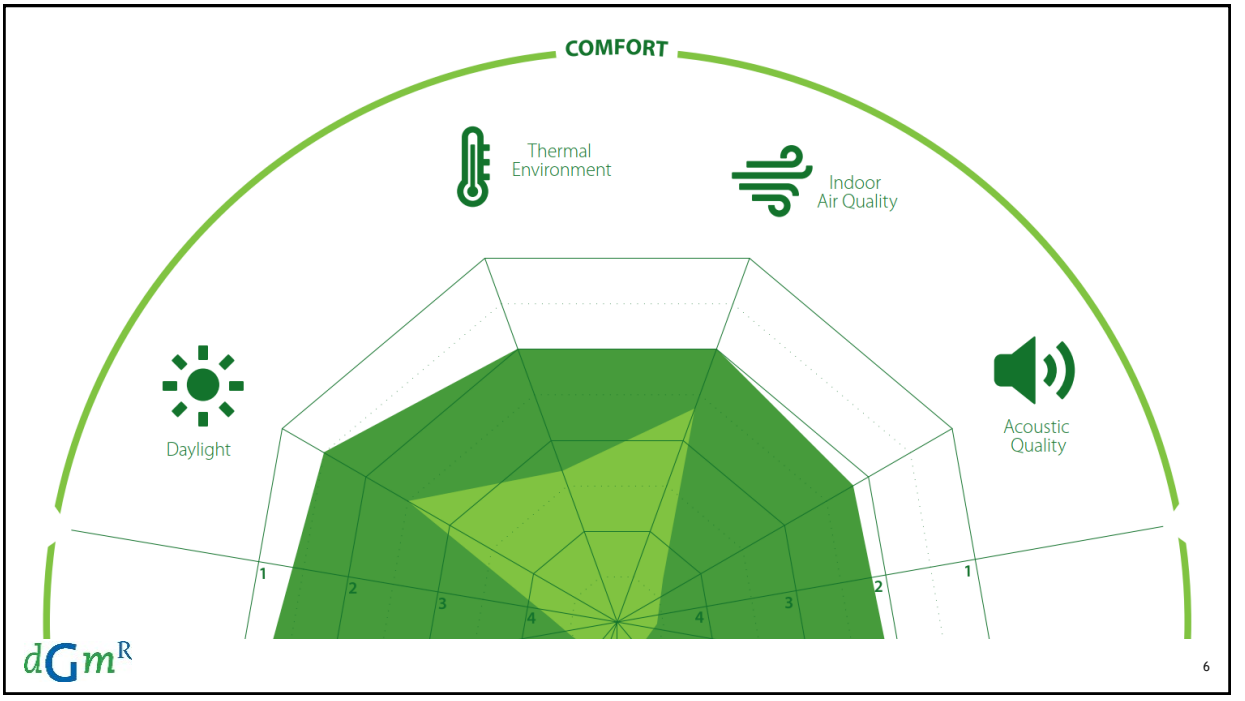

COMFORT
Thermal Environment
Indoor Air Quality
Acoustic Quality
Energy Demand
Primary Energy Performance
Energy Supply
Sustainable Construction
Freshwater Consumption
Daylight
ENVIRONMENT
ENERGY
1
2
3
4
dGmR
5

5


COMFORT
Thermal Environment
Indoor Air Quality
Daylight
Acoustic Quality
1
2
3
4
dGmR
6

6

EXAMPLE OF THE USE OF QUALITATIVE CRITERIA, BASED ON CHAPTER 2.1 ENERGY DEMAND.

ASPECT	CRITERIA	ARGUMENTS	YES/NO
Demand on individual products and construction elements	Have the chosen products and construction solutions been evaluated from a cost-effective, life cost perspective and maintenance view?	All main solutions (roof, wall, foundation and windows) have been calculated from a cost-effective perspective within the individual solutions' lifetime. An evaluation of maintenance of technical solutions will be carried out.	YES
Architectural design solutions	Have architectural design solutions been used to reach a holistic approach of the building and to reach a low energy demand?	During the design phase, alternative design solutions have been modelled in BIM and the predicted performance of energy, indoor comfort and environment has been evaluated. The results were used to adjust and optimise the architectural design solution.	YES
Demand on individual appliances	Have the best energy performing solutions for appliances been chosen?	All white goods are minimum class A+ and all installed/in-built lamps are LED and evaluated for light quality.	YES

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TABLE 1: EXAMPLE CALCULATION OF AVERAGE DAYLIGHT FACTOR USING DEFAULT NUMBERS FOR DIFFERENT ROOMS IN A HOUSE

ROOM	DF SCORE		HOURS		NO. OF PEOPLE		WEIGHTED SCORE
Kitchen	3	x	**2.5**	x	3	=	22.5
Living room	2	x	**3**	x	3	=	18
Bedroom parents	1	x	**0.5**	x	2	=	1
Bedroom child	2	x	**1.5**	x	1	=	3
SUBTOTAL			19				44.5
TOTAL AVERAGE SCORE							2.3

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Daylight

ASPECT	CRITERIA	ARGUMENTS	YES/NO
View	Are windows located to offer the best possible views to the exterior environment (sky and surroundings)?		
Visual transmittance	Are windows that provide a view to the outdoors selected to have the highest possible visible transmittance?		
Glare management	Is dynamic shading present to avoid risk of glare?		
Daylight in secondary rooms	Have circulation zones and bathrooms access to daylight?		
Blinding of bedrooms	Do bedrooms have the possibility to block out all light coming from windows to create a full dark environment to sleep in?		
Room reflectance	What surface reflectances have been used in the daylight calculations? It is recommended to use the following values (typical ranges in brackets) Ceiling: 0.7 (0.7 to 0.9) Walls: 0.5 (0.5 to 0.8) Floor: 0.2 (0.2 to 0.4)		
Single or multiple openings	Does the room have access to daylight from more than one orientation and/or height?		
Simulation method	Has dynamic model simulation been used to determine the DA, rather than determining the DF?		

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Daylight option 1 - daylight factor (standardized method)

ASPECT	VALUE	CRITERIA	SCORE
Daylight factor per room		The amount of daylight in a room is evaluated through the fraction of the room, $F_{plane,\%}$, that have a daylight factor higher than the target daylight factor (D_T): 1. $F_{plane,\%}$ > 70 % of the occupied space 2. $F_{plane,\%}$ > 60 % of the occupied space 3. $F_{plane,\%}$ > 50 % of the occupied space 4. $F_{plane,\%}$ > 40 % of the occupied space Daylight factors are calculated using a validated daylight simulation program according to EN 17037.	

D_T depends on location and by that the median external diffuse illuminance $E_{v,d,med}$. Values of $E_{v,d,med}$ for different nations / capitals are shown in Annex 1 together with the corresponding values of D_T.

$$D_r = \frac{Illuminance\ level}{E_{v,\,d,\,med}} = \frac{illuminance\ level}{E_{v,\,d,\,med}} = \frac{300\ lx}{E_{v,\,d,\,med}}\ x100\ \{\%\}$$

$E_{v,d,med}$ can be calculated using hourly values of the diffuse horizontal illuminance from the sky using yearly weather data. $E_{v,d,med}$ is median of the 4380 highest hourly values, equivalent to the 75th percentile of the yearly data.

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Daylight option 2 - daylight autonomy (dynamic calculations)

The calculation preconditions for the climate based daylight-modelling relies on the method described in EN17037 - Daylight in Buildings, Daylight provision calculation method 2. For a space with vertical and/or inclined opening with a given target illuminance of 300 lx, at least 25% of the yearly hours, the results shall be above the target value. The minimum illumination limit is 300 lx in residential buildings. In case office or other public buildings are evaluated, the limit is 500 lx.

ASPECT	VALUE	CRITERIA	SCORE
Target daylight level per room		The amount of daylight in a room is evaluated through daylight levels with a target illuminance of 300 lux in dwellings or 500 lx in office or other public buildings. $DA_{300/50}$ 1. > 70% of the occupied space 2. > 60% of the occupied space 3. > 50% of the occupied space 4. > 40% of the occupied space	

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Thermal environment

ASPECT	CRITERIA	ARGUMENTS	YES/NO
Individual control, winter	Is it possible to adjust the temperature at room level according to momentary needs, e.g. with adjustable thermostats?		
Individual control, summer	Is it possible to manually influence the thermal conditions in each room, e.g. by opening windows or adjusting solar shading? In the case of mechanical cooling systems, is it possible to adjust the temperature at room level, e.g. with adjustable thermostats?		
Night cooling	Is it possible to remove excess heat that has built up during the day, through high volume night-time ventilation with cool outdoor air?		
Overheating, winter	Is it possible to remove unwanted excess heat in winter, e.g. on sunny days, without creating uncomfortable draughts?		
System interface	Have the climate system interfaces (e.g. wall thermostats) been selected to be as intuitive and simple as possible?		
Draught	Have ventilation openings (including windows, ventilation grilles and mechanical ventilation devices) been located and detailed so that discomfort caused by draught is minimised? Typical airspeeds within the living zone should remain below 0.2 m/s in winter and 0.5 m/s in summer **Note:** *Adjustability (e.g. of operable windows and ventilation grilles) is an important issue to take into account in this context.*		

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Thermal environment

Maximum temperature

ASPECT	VALUE	CRITERIA	SCORE
Maximum operative temperature per room		The maximum indoor temperature limits apply in periods with an outside T_{rm} of 12°C or more. For rooms/spaces in buildings without mechanical air conditioning and with adequate opportunities for natural (cross or stack) ventilation, the maximum indoor operative temperatures are: 1. $T_{i,o} < 0.33 \times T_{rm} + 20.8$°C 2. $T_{i,o} < 0.33 \times T_{rm} + 21.8$°C 3. $T_{i,o} < 0.33 \times T_{rm} + 22.8$°C 4. $T_{i,o} < 0.33 \times T_{rm} + 23.8$°C T_{rm} is the Running Mean outdoor temperature as defined in 'paragraph 3.12 External temperature, running mean' of EN 16798-1. For rooms/spaces in buildings with air conditioning, the maximum operative temperatures are: 1. $T_{i,o} < 25.5$°C 2. $T_{i,o} < 26$°C 3. $T_{i,o} < 27$°C 4. $T_{i,o} < 28$°C For bedrooms (especially at night time), a 2°C lower value than indicated above should be used as people are more sensitive to high temperatures when sleeping or trying to fall asleep. Also, in kitchens higher temperatures than indicated can be allowed periodically, e.g. during cooking activities. The system should be designed to achieve recommended values. The users can, however, choose their own settings. Reference: EN 16798-1.	

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Thermal environment

Minimum temperature

Minimum operative temperature per room		The minimum indoor temperature limits apply in periods with an outside T_{rm} of 12°C or less. For living rooms, kitchens, study rooms, bedrooms etc. in dwellings, the minimum operative temperatures are: 1. $T_{i,o} > 21$°C 2. $T_{i,o} > 20$°C 3. $T_{i,o} > 19$°C 4. $T_{i,o} > 18$°C The system should be designed to achieve recommended values. The users can, however, choose their own settings.	

1.1.2. QUANTITATIVE CRITERIA EVALUATION METHOD

- To objectify the risk of overheating, a dynamic thermal simulation tool is used to determine hourly values of indoor operative temperature at room level (e.g. in living rooms, kitchens and bedrooms, or office spaces). In buildings without mechanical cooling systems (like central air conditioning), adaptive temperature limits are used in the summer months. This means that the maximum allowable temperature inside is linked to the weather outside: limits go up during warmer periods.
- Requirements should be met for a minimum of 95% of occupied time.
- The score is based on the weighted average of all evaluated rooms. Occupancy hours should be included in the weighting.

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Indoor air quality

ASPECT	CRITERIA	ARGUMENTS	YES/NO
Individual control	Is it possible to manually influence the air exchange rate in the rooms (especially living room, kitchen and bedrooms), e.g. by opening windows, temporarily closing air grills, or if mechanical ventilation is installed, is it possible to adjust the airflow rate at three or more levels?		
Dampness	Is it guaranteed that there is sufficient extraction in rooms with periodic moisture-production peaks (esp. kitchens, bathrooms and toilets)? **Note:** *The minimum exhaust air flow for toilets, bathrooms and kitchens should be 35, 50 and 70 m3/h, according to category II of EN16798-1.*		
Low-emitting building materials	Have indoor climate-labelled materials been used? **Note:** *many labels exist, for example, Danish Indoor Climate label, M1 label, AgBB, GUT label, Blue Angel, GreenGuard Gold label.*		
Kitchen	Is a kitchen hood present with a capacity of at least 300 m^3/h with the exhaust directly to the outside?		
Outdoor air filtration	In case the building is situated at a location with poor outdoor air quality, is filtration present in the fresh air supply.		

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Indoor air quality

1.3.2. QUANTITATIVE CRITERIA EVALUATION METHOD

- Fresh air supply can be evaluated by examining indoor CO_2 concentrations at room level during occupancy. CO_2 is a good indicator of the amount of bio-effluents, pollutants from humans, in the air.
- CO_2 emission per person should be set at 20 l/h and 13.6 l/h per person for living rooms and bedrooms respectively (reference: EN 16798-1).
- The requirements should be met for a minimum of 95% of occupied time.
- The classification of the air quality is determined as the use-time-weighted hourly average of all room scores.
- The minimum requirements as specified in national codes should always be followed.

ASPECT	VALUE	CRITERIA	SCORE
Standard fresh air supply per room		The fresh air supply shall be established according to the below limit values for indoor CO_2 concentration in living rooms, bedrooms, study rooms and other rooms with people as the dominant source and that are occupied for prolonged periods: 1. < 400 ppm above outdoor CO_2 concentration 2. < 550 ppm above outdoor CO_2 concentration 3. < 800 ppm above outdoor CO_2 concentration 4. < 1100 ppm above outdoor CO_2 concentration	

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Acoustic quality

ASPECT	CRITERIA	ARGUMENTS	YES/NO
Inside system noise	Has extra attention been given to rooms that require extra quietness, such as bedrooms and study rooms?		
Acoustic privacy	Are inner walls and floor divisions designed to reduce noise transmission between rooms?		
External spaces	In case external spaces are present, such as a garden or balcony, have measures been taken to create a quiet environment?		

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Acoustic quality

1.4.2. QUANTITATIVE CRITERIA EVALUATION METHOD

- All main occupied spaces should be assessed.
- If the building has one or more bedrooms, the lowest scoring bedroom determines the overall score for the inside system and outside noise criteria. In that case, it supersedes the weighting of different rooms.
- Rather than assessing the minimum sound-insulating value of outer wall constructions, the resulting maximum indoor sound level is assessed. This way, the construction can be optimised for different locations with different external sound levels, with buildings on quiet locations needing fewer measures than buildings on sound heavy locations, while still scoring the same.
- The levels are aimed at setting ambitions for calculations at the design stage. After completion, when questions arise whether the ambitions are achieved, measurements can be done. These can be done by a professional, but also with a noise meter app on a smartphone.
- The limit values are based on ISO 140-4

ASPECT	VALUE	CRITERIA	SCORE
Inside system noise		The limit values are: 1. < 25 dB or noise level at or below background noise level 2. < 30 dB 3. < 35 dB 4. < 40 dB After completion, noise from all mechanical services in continuous operation is measured in all main occupied spaces. In case an adjustable mechanical ventilation system is present, the noise levels should at least be met at the ventilation rate that meets the indoor air quality ambition level. The noise levels from the table above can temporarily be exceeded to the next level, when the ventilation flow rate is increased due to removal of pollutants or humidity such as during cooking or showering.	
Outside noise		The maximum indoor noise levels from outdoor sources are: 1. < 25 dB 2. < 30 dB 3. < 35 dB 4. < 40 dB Noise from outside sources such as traffic or industry should be prevented from entering the building. Local outdoor noise level data can normally be found in so called noise contour maps that are made available online by local government. Assuming that calculations/measurements are done with operable windows and outside doors closed.	
Acoustic privacy		Within connected dwellings, such as apartment buildings, neighbours can be a source of noise, so it is important to have walls and floors that limit the noise transfer. Difference is made between airborne sound ($D_{nT,A}$) and contact sound ($L_{nT,A}$). The limit values are: 1. $D_{nT,A} \geq 62$ dB and $L_{nT,A} \leq 43$ dB 2. $D_{nT,A} \geq 57$ dB and $L_{nT,A} \leq 48$ dB 3. $D_{nT,A} \geq 52$ dB and $L_{nT,A} \leq 53$ dB 4. $D_{nT,A} \geq 47$ dB and $L_{nT,A} \leq 58$ dB	
		AVERAGE SCORE:	

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19

19

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20

20