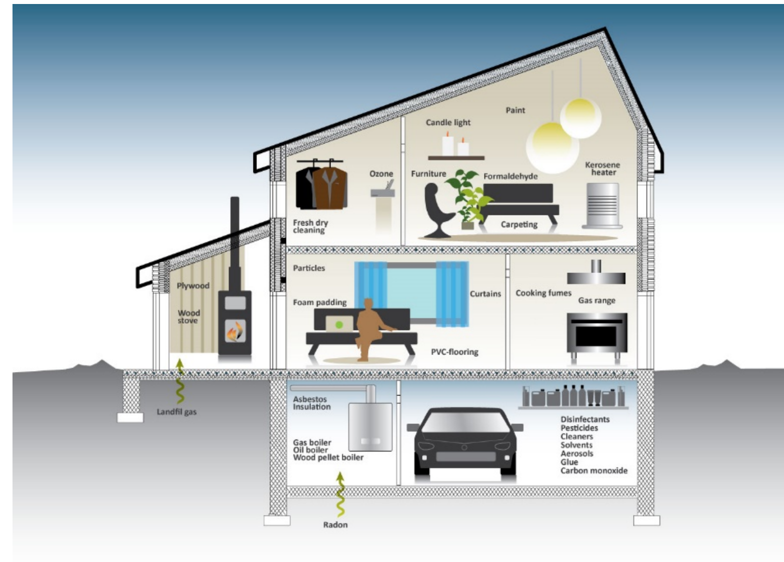
EBC Annex 68: High Indoor Air Quality in Low Energy Buildings



EBC Webinar:
The Science and Communication of Energy-Efficient Indoor Environments

10th November 2020

Prof. Carsten Rode, Technical University of Denmark

Indoor Air Quality Design and Control in Low Energy Residential Buildings

Energy in Buildings and Communities Programme

To achieve nearly net zero energy use, buildings shall be more efficient and optimized.

Buildings shall be airtight, and ventilation rate will be limited to what is necessary.

Minimal fresh air supply increases the risk of poor IAQ.

P+ test and demonstration building Changzhou, China (source: Nanjing University)

Project goal: comfortable and healthy indoor environments in energy efficient residential buildings.

Ideal balance between energy efficiency and the need for ventilation while considering indoor pollutants.

We have gathered data tools, and case studies to provide some practical guidances for practitioners.

Project Participants

Country	Organization
Austria	Universität Innsbruck
Belgium	Ghent University
Canada	British Columbia Institute of Technology
China	Nanjing University
Czech Republic	Czech Technical University of Prague
Denmark	Technical University of Denmark
Estonia (observing country)	Tallinn University of Technology
France	Université La Rochelle LOCIE, Université de Savoie Saint-Gobain Recherche
Germany	TU Dresden
Korea	Korea Institute of Civil Engineering & Building Technology
The Netherlands	TU Eindhoven
New Zealand	Building Research Association of New Zealand
Norway	Norwegian University of Science and Technology Norwegian Institute for Wood Technology Norwegian University of Life Sciences
United Kingdom	University College London
USA	Syracuse University

A total of 39 institutions from the above countries have contributed to the project.

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Main Activities of the Project

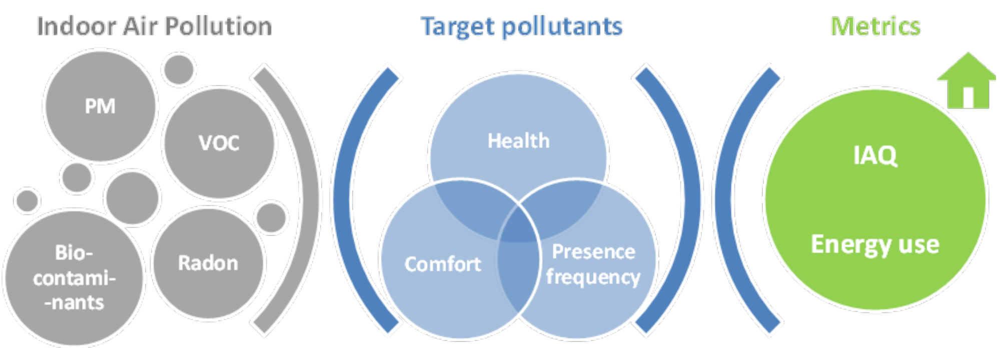
1. Definition of indicators for IAQ and energy
2. Pollution loads in residential buildings
3. Modelling - analysis and classification
4. Building design and control strategies
5. In-situ measurements and case studies

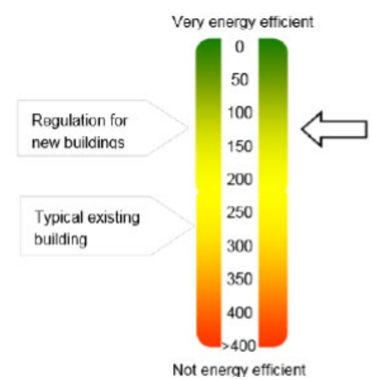
1. Definition of Indicators for IAQ and Energy

M. Abadie, Université La Rochelle, France

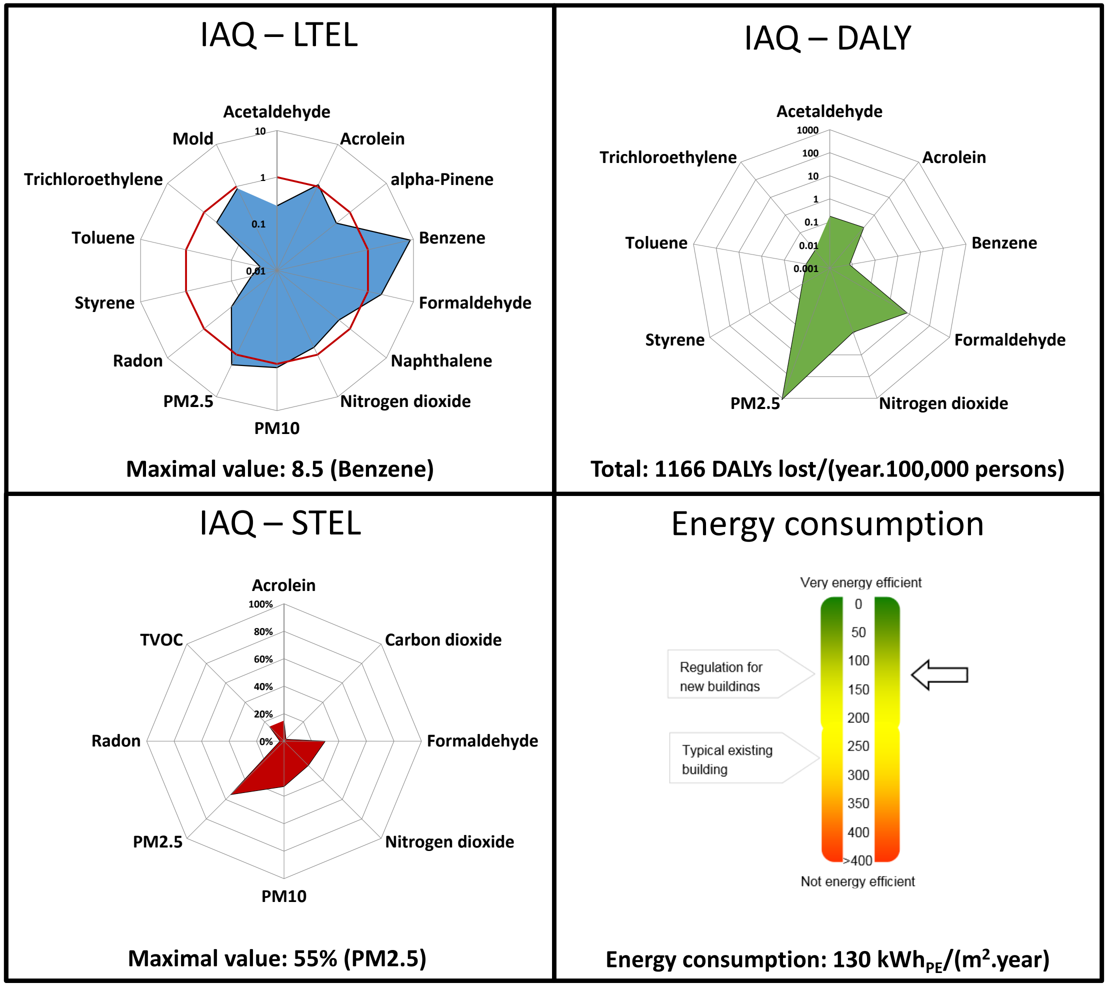
Objectives:

- Identify indices and markers to quantitatively:
  - describe IAQ
  - allow comparison with indices describing energy use.
- The metrics should allow quantifying the benefits of different methods to achieve high IAQ and compare with consequences for energy use.





IAQ and Energy Dashboard



LTEL:
Long Term Exposure Limit

STEL:
Short Term Exposure Limit

DALY:
Disability Adjusted Life Years

Excel tool provided

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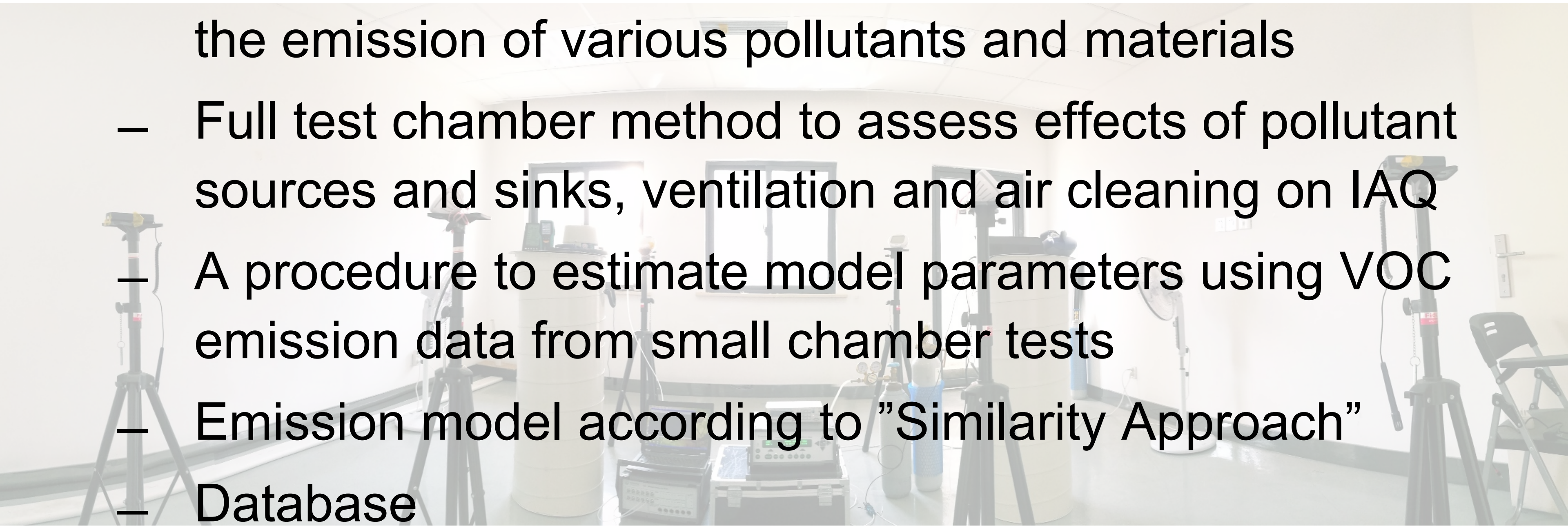
2. Pollution Loads in Residential Buildings

M. Qin, Technical University of Denmark



- Analysis of the effects of temperature and humidity on the emission of various pollutants and materials
- Full test chamber method to assess effects of pollutant sources and sinks, ventilation and air cleaning on IAQ
- A procedure to estimate model parameters using VOC emission data from small chamber tests
- Emission model according to ”Similarity Approach”
- Database
- Reference buildings and “Common Exercises”

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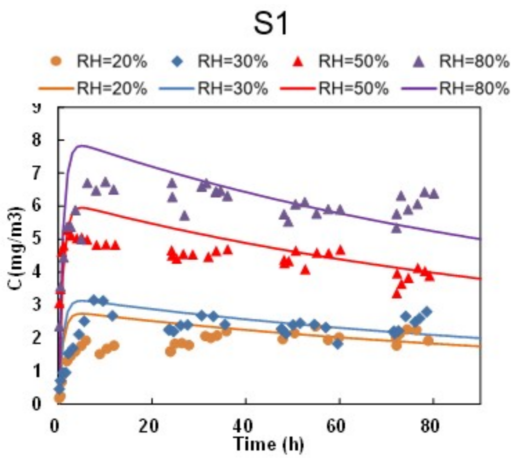
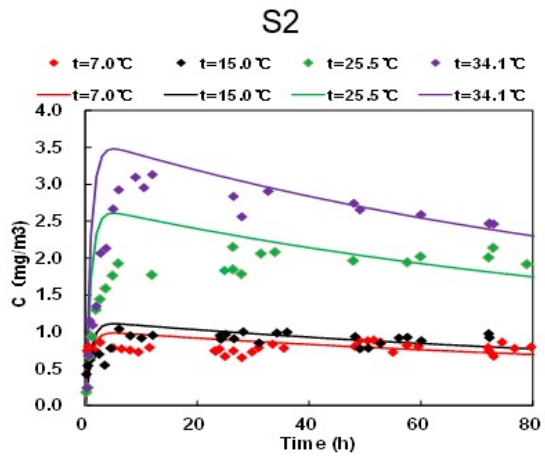
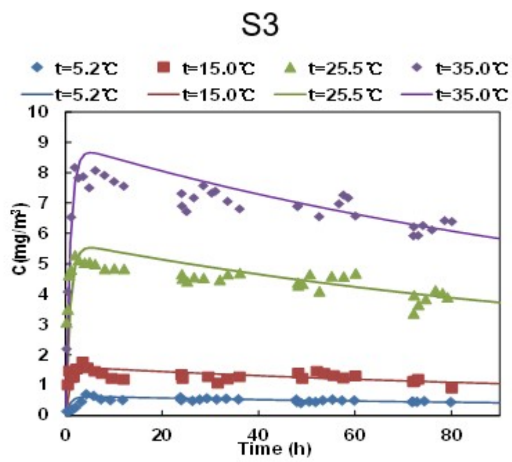
New Data on T and RH Effects on Emissions



C_0 (mg/m³)	D_m (m²/s)	K (—)
1.75×10^6	3.40×10^{-14}	6340
2.00×10^6	3.36×10^{-14}	5514
3.80×10^6	3.50×10^{-14}	5340
5.20×10^6	3.14×10^{-14}	3128



C_0 (mg/m³)	D_m (m²/s)	K (—)
7.90×10^5	3.00×10^{-14}	9467
8.50×10^5	3.15×10^{-14}	7844
1.75×10^6	3.40×10^{-14}	6340
4.30×10^6	3.57×10^{-14}	4570



C_0 (mg/m³)	D_m (m²/s)	K (—)
4.93×10^5	2.90×10^{-14}	9752
1.14×10^6	3.15×10^{-14}	7280
3.80×10^6	3.50×10^{-14}	5340
1.10×10^7	3.60×10^{-14}	3450

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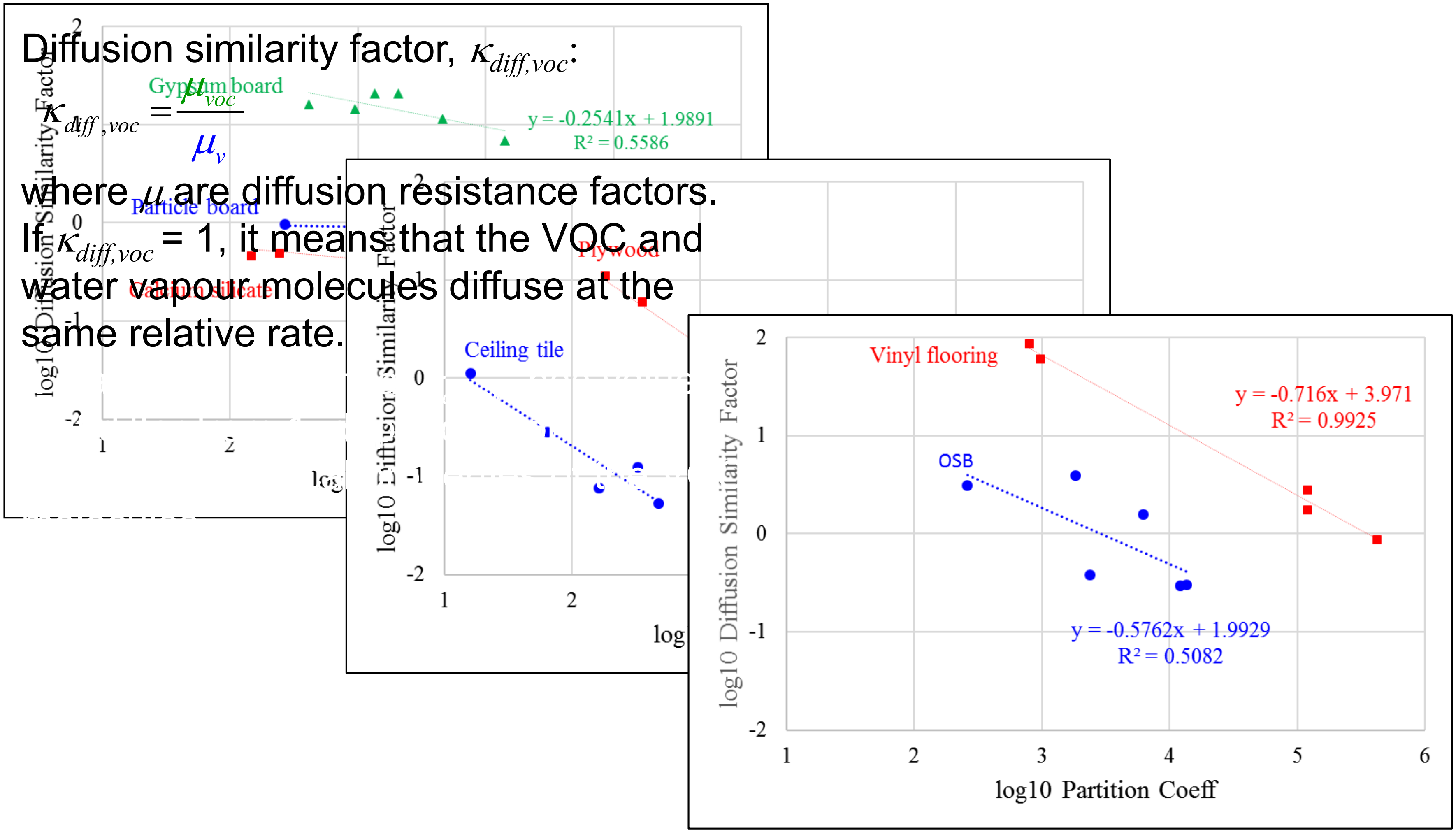
Database of Diffusion Similarity Factors

Diffusion similarity factor, $\kappa_{diff,voc}$:

$$\kappa_{diff,voc} = \frac{\mu_{voc}}{\mu_v}$$

where μ are diffusion resistance factors.

If $\kappa_{diff,voc}$ = 1, it means that the VOC and water vapour molecules diffuse at the same relative rate.



3. Modelling - Analysis and Classification

J. Grunewald, TU Dresden, Germany

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- Practical integration of building performance simulation tools.
- A reference case with description of a problem, input parameters and solution → a “Common Exercise”
- Classification of the tools available according to their strengths and weaknesses
- Features and implementations required following the analysis of the lack of available tools
- Proposals for improving quality assurance standards in the development of simulation tools

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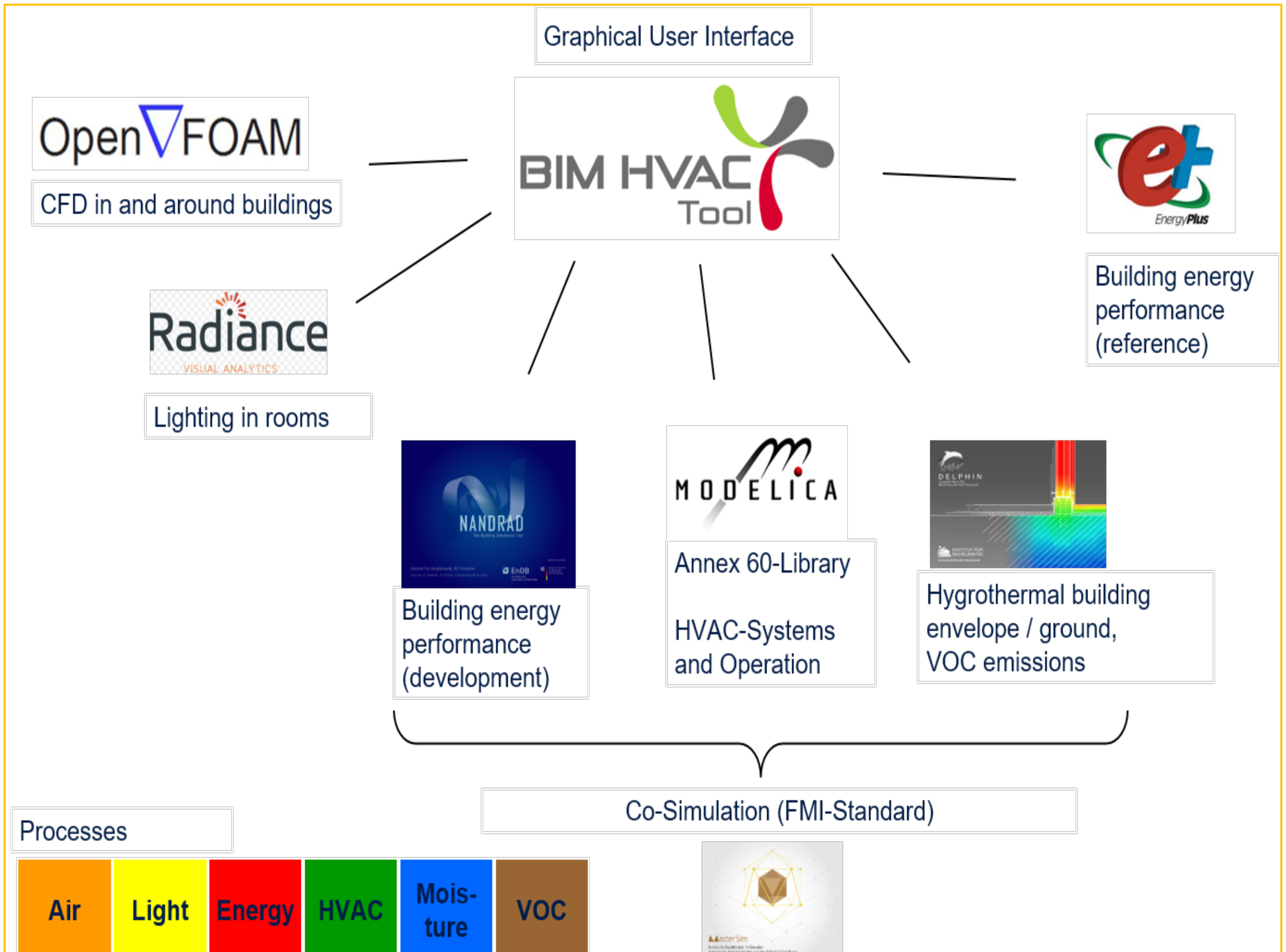
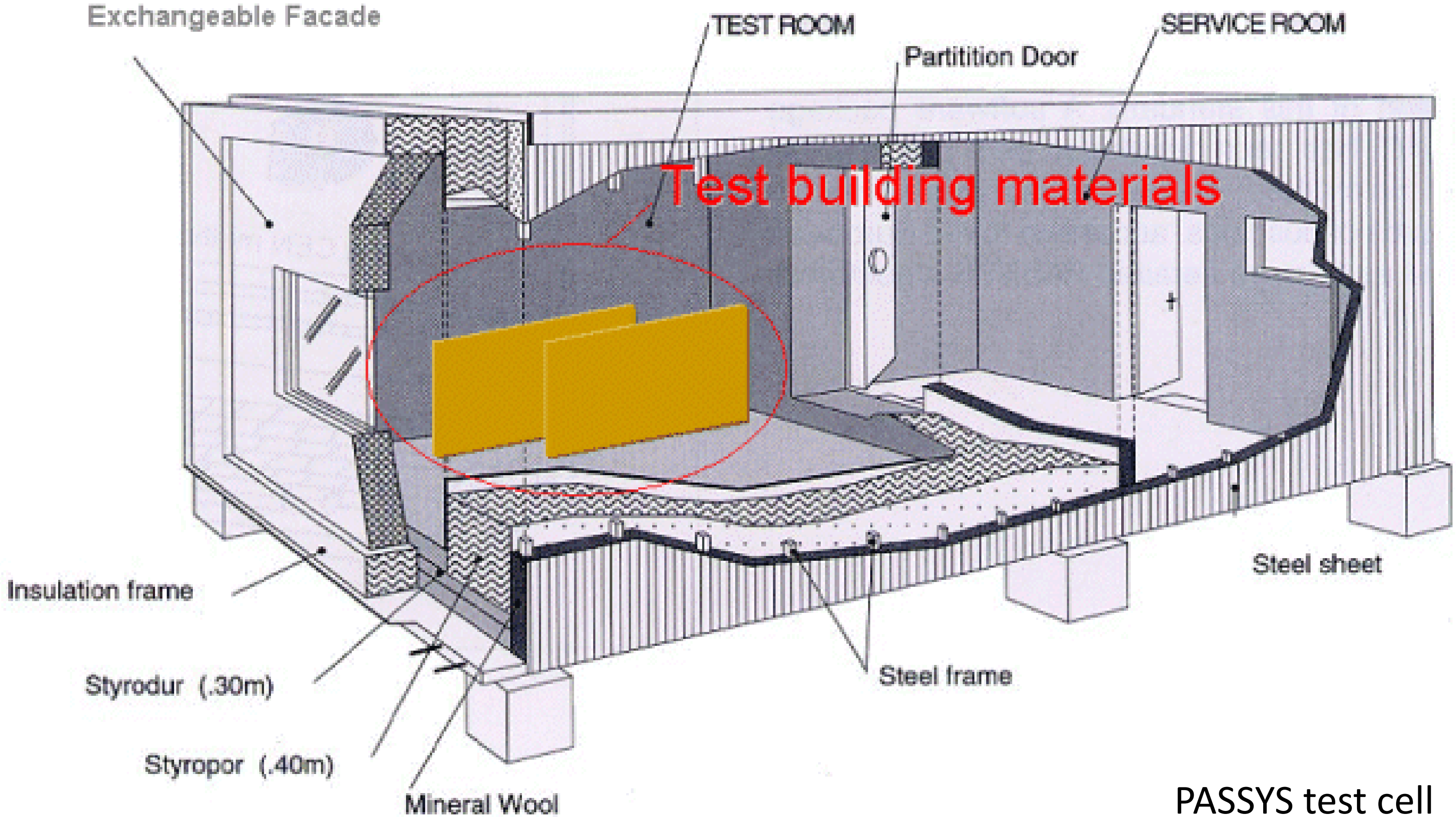
Modelling Platform



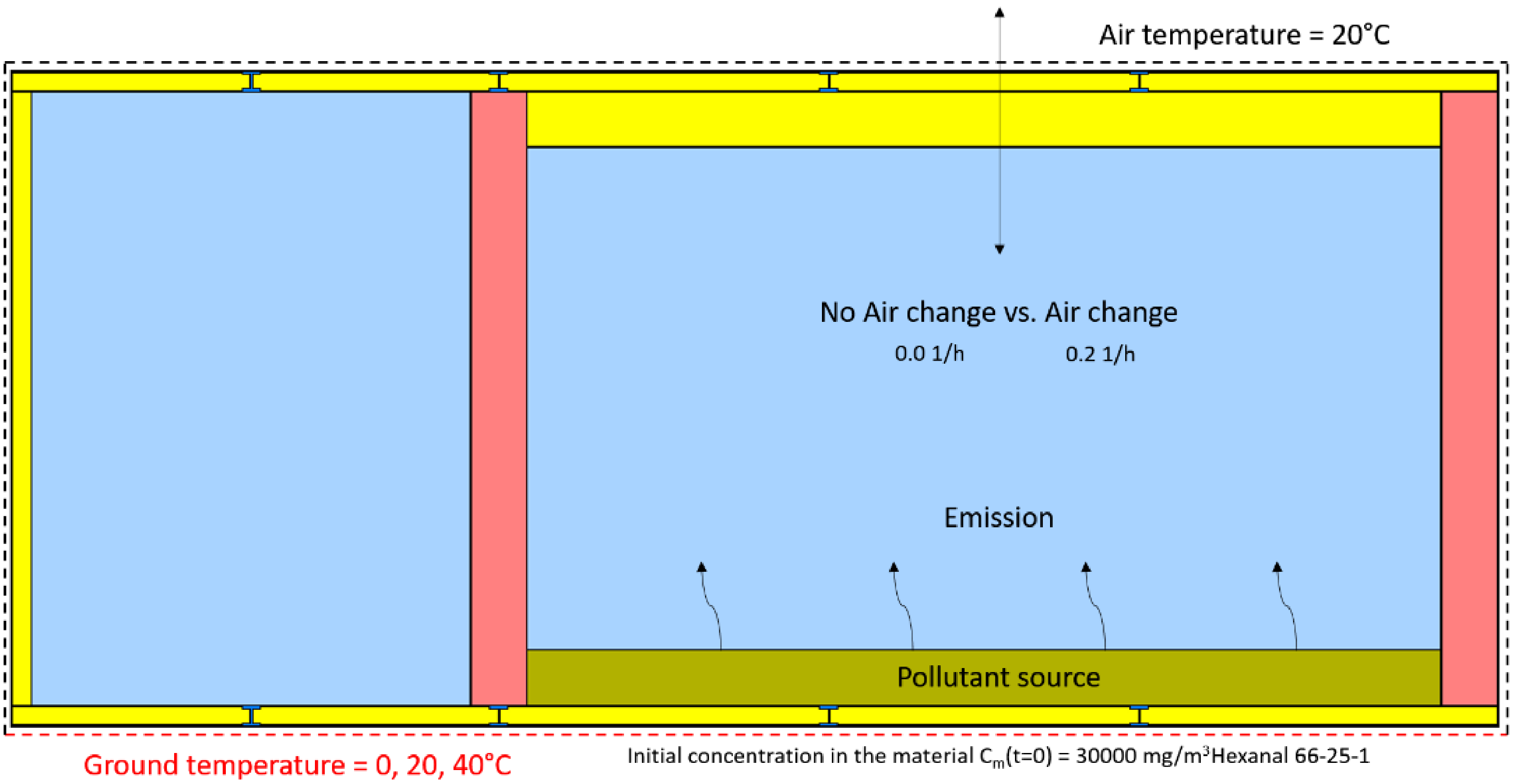
Multi-scale and multi-disciplinary modelling platform for Combined Heat, Air, Moisture and Pollutant Simulation (CHAMPS)

Common Exercise (Modelling)



PASSYS test cell

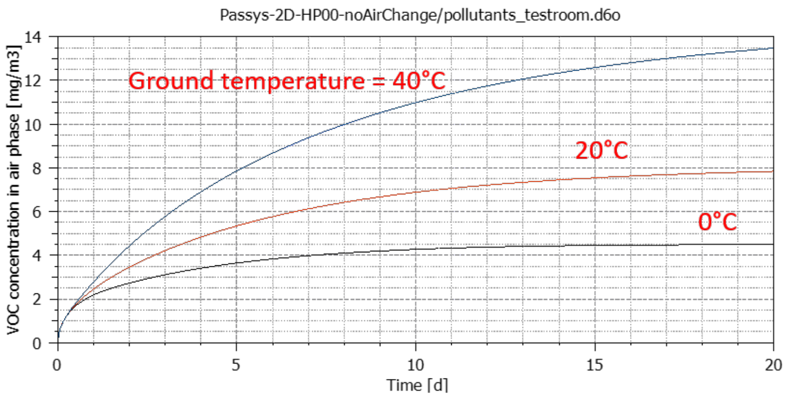
Common Exercise (Modelling)



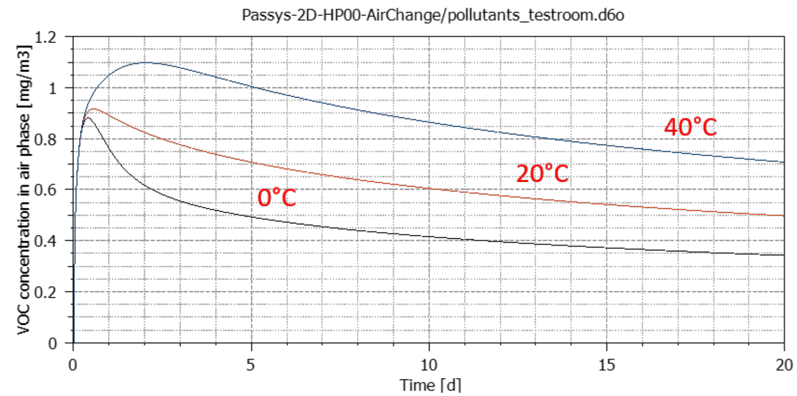
Modelling setup of the PASSYS test cell for non-isothermal test case

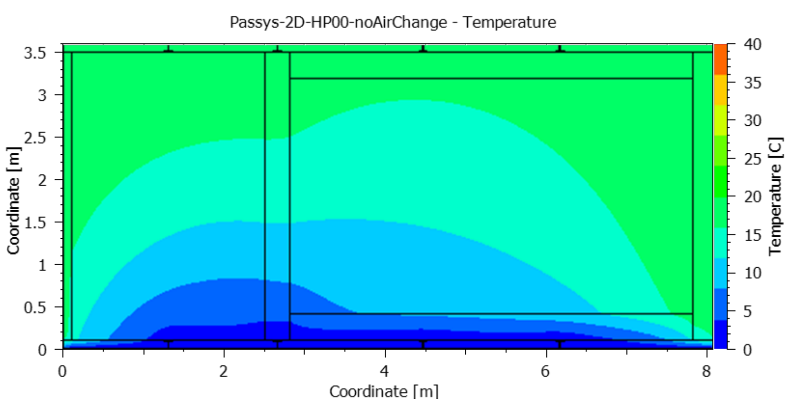
Common Exercise (Modelling)

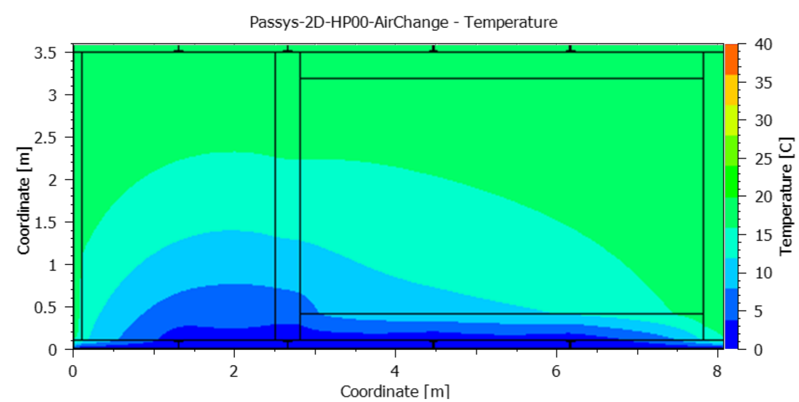
No Air change



Air change







VOC concentration in the PASSYS test cell with and without air change

4. Building Design and Control Strategies

J. Kolarik, Techical University of Denmark

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Transition from theory to practice:

- Bibliographic study
- Series of interviews with key stakeholders in the building sector (architects and ventilation designers, facility managers, property developers and public authorities) regarding implementation of standards and codes.

Inspiration for design and operation:

- Catalogue of case studies presented according to:
  - "Objectives, description and methods",
  - "Main results and findings",
  - "Conclusions and lessons“
  - "Further reading".

Bibliographic Study and Interviews

"Transition from requirements to practice"

National building codes & Standards

Supporting information sources for practitioners:

- Official guidelines (building research institutes, ministries etc.)
- Brochures
- Road-maps
- Web-based knowledge canters

Stakeholder survey:

- Ventilation designers/Consultants
- Facility management
- Public authorities
- Housing developers
- Producers of ventilation systems

Catalogue of Case Studies

		Design			Construction, Comissioning & Operation	
Chapter	Case study	Assessment methods	Assessing ventilation concepts	Novel ventilation solutions	Quality assurance	Assessing in-use performance
3.1	Alternative ducting options for balanced mechanical ventilation systems in multifamily housing					
3.2	Ambient air filtration in highly energy efficient dwellings with mechanical ventilation					
3.3	Development of a compact ventilation system for facade integration					
3.4	Volatile Oorganic Compounds exposure due to Floor heating systems versus Radiator heating					
3.5	Control strategies for mechanical ventilation in Danish low-energy apartment buildings					
3.6	Response of commercially available Metal Oxide Semiconductor Sensors under air polluting activities typical for residences					
3.7	Impact of multi zone air leakage modelling on ventilation performance and indoor air quality assessment in low-energy houses					
3.8	Towards a better integration of indoor air quality and health issues in low-energy dwellings					
3.9	List of key pollutants for design and operation of ventilation in low-energy housing					
3.10	Definition of a Reference Residential Building Prototype for Evaluating Indoor Air Quality and Energy Efficiency Strategies					
3.11	Temperature dependent emissions of Volatile Organic Compounds from building materials					
3.12	Detailed modelling of Indoor Air Quality to improve ventilation design in low energy houses					
3.13	Mechanical ventilation system in deep energy renovation of a multi-story building with prefabricated modular panels					
3.14	Simplifying Mechanical Vventilation with Heat Recovery systems					
3.15	Design of room-based ventilation systems in renovated apartments					
3.16	Introduction to the Coupled Heat, Air, Moisture and Pollutant Simulation CHAMPS modeling platform					
4.1	House owners' experience and satisfaction with Danish Low-energy houses - focus on ventilation					
4.2	Development and test of quality management approach for ventilation and indoor air quality in single-family buildings					
4.3	Applications of the Promevent protocol for ventilation systems inspection in French regulation and certification programs					
4.4	Long-term durability of humidity-based demand-controlled ventilation: results of a ten years monitoring in residential buildings					
4.5	Practical use of the Annex 68 Indoor Air Quality Dashboard					
4.6	Performance evaluation of Mechanical Extract Ventilation (MEV) systems in three 'low-energy' dwellings in the UK					
4.7	Indoor air quality in low energy dwellings: performance evaluation of two apartment blocks in East London, UK					
4.8	Continuous-commissioning of ventilation units in multi-family dwellings using controller data					

Addressed topics:

- Health & Comfort
- Spatial requirements
- Cost & Energy consumption
- Refurbishment
- Comissioning
- Quality of installation
- User satisfaction

5. In-situ measurements and case studies

J. Laverge, Gent University, Belgium

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- Analysis of the experimental possibilities available for the assessment of IAQ in residential buildings.
- Execution of experiments to provide validation data for digital models. Three levels of increasing complexity:
  - a highly controlled single room,
  - a small student studio,
  - an occupied house
- Compilation of results of IAQ measurements in residential buildings with low energy consumption

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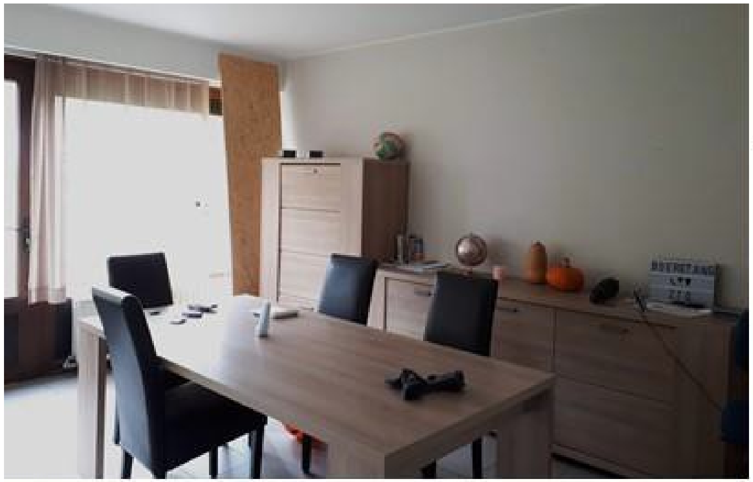
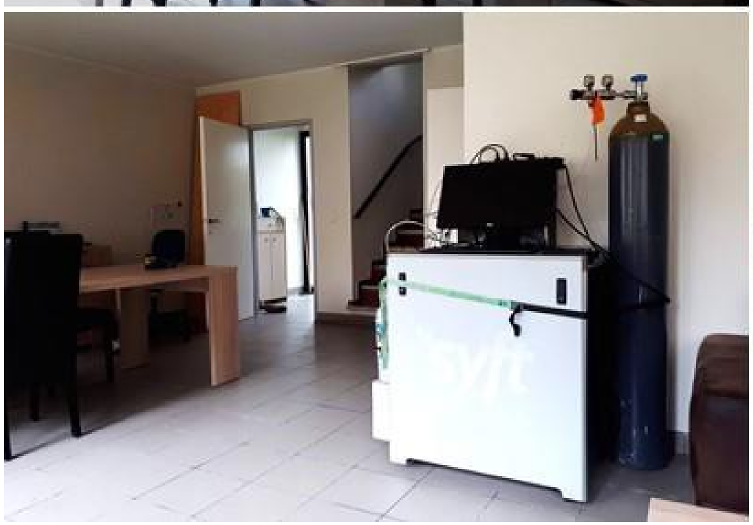
Case Studies





Spaces of investigated house (living room and dining room) during experiment

Case Studies

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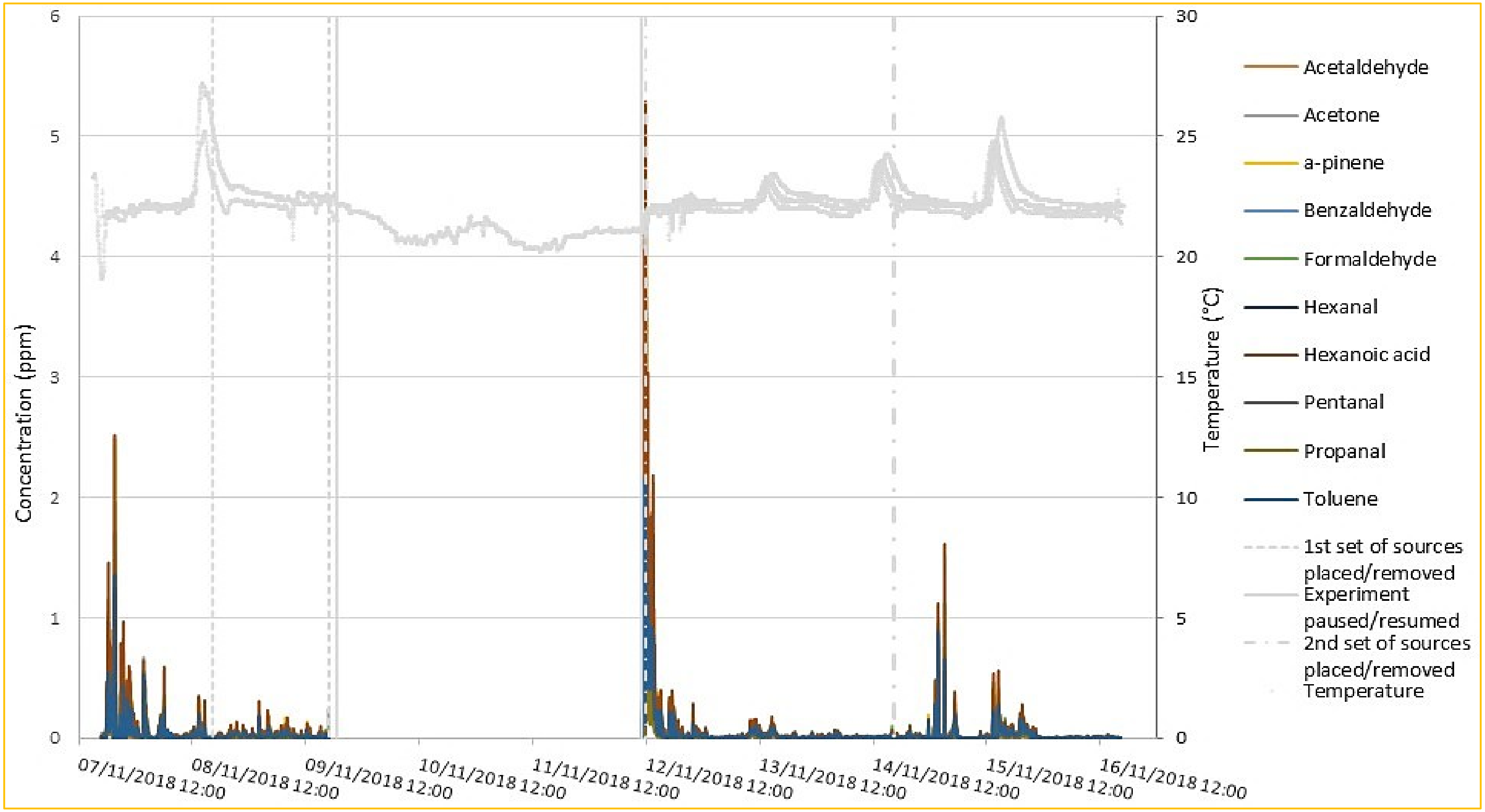

Evolution of the VOC concentration in the house

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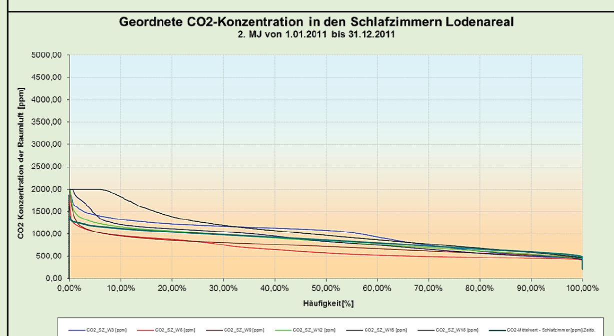
Case Studies

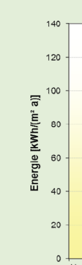
Subtask 5: Case Studies - 1. CaseStudy_AT_UIBK1
Annex 68 Design and Operational Strategies for High IAQ in Low Energy Buildings

Project Title:	**Lodenareal**			
Contributor	**Name**	Gabriel Rojas		
	Country	Austria		
	Institution	University of Innsbruck		
General	**Building Location**	Innsbruck, Austria		
	Building Type	Multi-Unit Low-rise	Ground + 5 topfloors	
	Year of Construction	2009		
	Major Renovation Year (if applicable, for older buildings)			
	Building Floor Area (m²)	26000	354 apartments (apt)	
	Reference (URL or Citation: Report, Journal, Conference)	https://doi.org/10.1080/17512549.2015.1040072 https://passivehouse-database.org/index.php?lang=en#d_1225		

Building Description	**Building envelope**	**Construction type**	**mass wall construction**		
		Window to Wall ratio (%)			
		Above Grade Wall R-value (K.m²/W)	7,7	(U-value: 0,13 W/K.m²)	
		Below Grade Wall R-value (K.m²/W)			
		Roof R-value (K.m²/W)	9,1	(U-value: 0,11 W/K.m²)	
		Slab on grade R-value (K.m²/W)	7,7	(U-value: 0,13 W/K.m²)	
		Window U-value (W/K.m²)	0,72		
		Airtightness (ACH at 50 Pa)	0,18		
	Interior finishing		**Type**		
		Interior paint			
		Flooring	Wood laminat		
		Window cover (fabric, plastic, wood etc.)	plastic		
	Mechanical systems		**Terminal unit**	**Equipment/Source**	
		Heating	underfloor heating	Wood pellets, gas boiler and solar thermal	
		Cooling	no		
		Heat/Energy recovery	Heat Recovery		
		Humidity control	No		
	Ventilation		**Ventilation type**	**Ventilation strategy**	**Design Ventilation rates**
		Heating season	Mechanical Ventilation	Continious	0.35-0.4 ACH
		Cooling season	Hybrid	Continious	>0.4 ACH
		Shoulder seasons	Mechanical Ventilation	Continious	0.35-0.4 ACH

Building Performance Monitoring & Measurement Techniques	**Occupancy**	**Typical Occupant Density (person/m2)**		
		Typical Occupant Type (mainly office workers, elders living, family with children)		
	IAQ		**Sensors used**	**Sampling locations**
		Temperature (°C)	E+E Elektronik	18 apt. In living room thereof also in bedro
		Relative Humidity (%)	E+E Elektronik	18 apt. In living room thereof also in bedro
		CO_2 (PPM)	E+E Elektronik	18 apt. In living room thereof also in bedro
		Formaldehyde (PPM)		
		TVOC (PPM)		6 apt.
		Particulate matter (µg/m³)		
		Other	Ambient T, RH	
	Energy	**Temperature control--Thermostat**	Constant	
		Heating set point (°C)	Occupant	
		Cooling set point (°C)	n/a	
		Energy measurement (KWh)	Hourly or less	
		Total Building Energy use--on site (KWh/m²/a)	98	
		Total Thermal Energy use--on site (KWh/m²/a)	41,7	
	Occupants' perception of the their unit IAQ		Good	Question refered to v
	Occupants' view of their unit thermal comfort		Comfortable	Question refered to l
	Photos of typical instrumentations for IAQ measurements			**Photos of typical i**





Lesson learned	**Problems identified**	
	Elevated summer temperatures in some top floor apartments due to not installed external shading (but planned).	External shading dev
	Even with relative low nominal ventilation rates, 30% of occupants perceived indoor air as too dry.	Extended cascade ve extended cascade ve
	The use of passive volumenflow control valves (two in a row) to provide 3 level control did not prove to be a very reliable solution.	No adaption was ma

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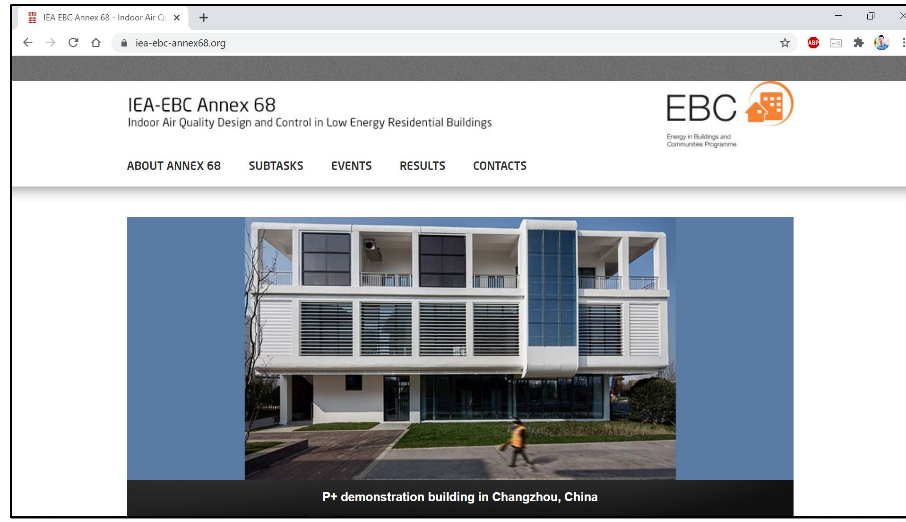
Publications and Homepage

Final Reports:

Homepage:



https://www.iea-ebc-annex68.org/

Thank you!

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