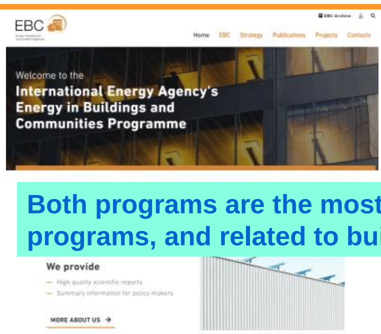
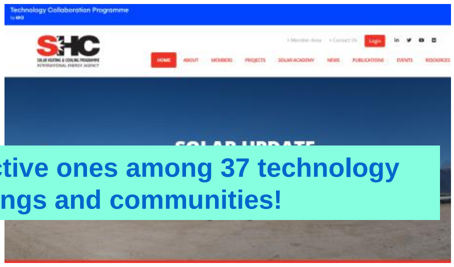
Welcome to joint webinar between IEA programs on "Buildings & Communities (EBC)" and "Solar Heating & Cooling (SHC)"

Takao Sawachi
Chair, Buildings and Communities program

11th June 2021

IEA EBC and SHC programs





Both programs are the most active ones among 37 technology programs, and related to buildings and communities!

Country members: 26
Ongoing & completed projects: 20, 71

Country members: 19
Organization members (EU, industries): 9
Ongoing & completed projects: 8, 58

EBC

Collaboration between the programs

- Collaborative projects

  SHC Task 61 & EBC Annex 77 “Solutions for Daylighting and Electric Lighting” (2018-2021) **Ongoing**

  SHC Task 59 & EBC Annex 76 “Renovating Historic Buildings Towards Zero Energy” (2017-2021) **Ongoing**

  SHC Webinar on 15th June (Tue)

  SHC Task 40 & EBC Annex 52 “Net Zero Energy Solar Buildings” (2008-2013) **Completed**

- Joint committee meetings at least every three years

EBC

Expected future collaborations

- Use of solar energy especially for space heating and DHW should be promoted in appropriate climatic conditions.
- Solar techniques should be combined with other techniques for envelope and technical systems.
- Practitioners are waiting for standards and guidelines describing concretely how they should design and install.
- **Mutual reviews and understanding of completed existing deliverables of two programs**, and **findings of common problems and interests** are a starting point of further collaboration and joint projects.

Thank you for your attention and
Please enjoy technical presentations!

EBC and National Research Priorities in the Netherlands

Daniël van Rijn
EBC Executive Member for the Netherlands
Netherlands Enterprise Agency

11th June 2021

The Netherlands

41.543 km²
17,5 million inhabitants
moderate maritime climate
built environment, mostly suburban

EBC

Built environment

7,9 mill. houses
460 mill m2 utility buildings
Most houses built after 1950

About 40% rowhouses

90% individual heating systems with natural gas
Enormous variety in energy performance...

Shortage of new houses

EBC

Dutch Climate Agreement

Dutch Climate Agreement
Over 100 organisations involved to set agenda for policies to reduce CO_2 emissions

- 2030: 1,5 million houses more sustainable and free of natural gas
- 2050: Sustainable Build environment. Well insulated and free of natural gas

EBC

Approach

- New buildings: BENG (used to be EPC), related to EPBD
- Existing buildings and neigbourhoods:
  - Neigbourhood-oriented approach: *Program for neighbourhoods free of natural gas*
  - Starter motor for the rental sector
  - Other instruments (a.o. non residential buildings)
- Innovation: Mission Built Environment

EBC

Mission Built environment

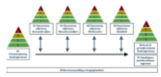
- Multi-year Mission-Driven Innovation Programmes (MMIPs)
  …Relations with IEA-EBC and other IEA TCP's…

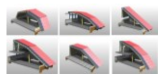
Mission Built Environment	MMIP 2	Renewable electricity generation on land and in the built environment
	MMIP 3	Acceleration of energy renovations in the built environment
	MMIP 4	Sustainable heat and cold in the built environment
	MMIP 5	Electrification of the energy system in the environment

Mission Built environment

Industrial research en experimental development:
- *2019: tender MMIP ¾*
- *2020: tender MOOI, theme Built environment*
- *2020: tender Urban Energy*

Pilots and demonstrations:
- *2019: DEI+ free of natural gas*
- *2020: DEI+ free of natural gas*





IEA Energy in Buildings and Communities TCP

Mission Built environment and EBC

Technology Collaboration Programme
by iea

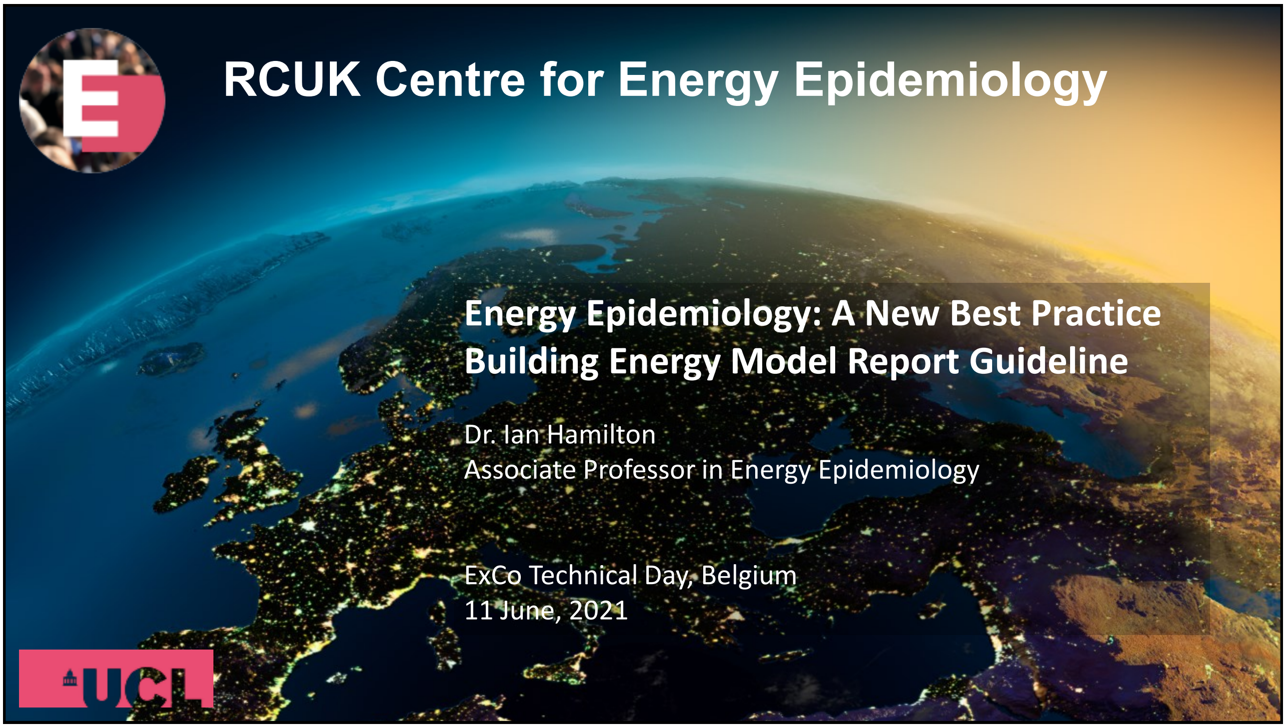
IEA Energy in Buildings and Communities TCP

EBC

Thank you

Technology Collaboration Programme

by iea


RCUK Centre for Energy Epidemiology
Energy Epidemiology: A New Best Practice Building Energy Model Report Guideline
Dr. Ian Hamilton
Associate Professor in Energy Epidemiology
ExCo Technical Day, Belgium
11 June, 2021
UCL

1


Shifting to a zero-carbon, efficient and resilient building stock

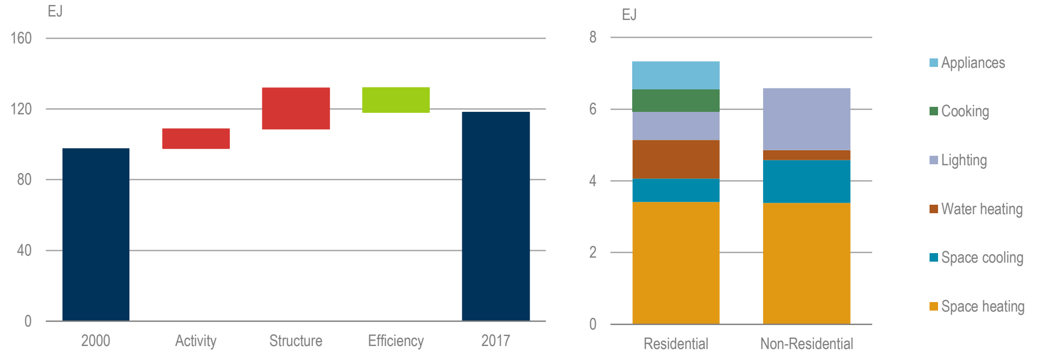
2

UCL Energy Institute

UCL

Buildings sector energy use continues to rise

Decomposition of buildings global final energy use, 2000-17 (left) and end-use contribution to efficiency savings (right)



Sources: Adapted from IEA (2018a), *Energy Efficiency Indicators 2018* (database) and IEA Energy Technology Perspectives Buildings model (www.iea.org/etp/etpmodel/buildings/).

RCUK **Centre for Energy Epidemiology**

Growth in building sector energy use is linked to increasing floor space and appliance ownership. Space heating is driving savings across both all building types.

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Why change our current research and practice?

Many countries have plans to **significantly reduce energy use** or **improve energy intensity** from the building stock.

Much of this reduction needs to come through more **energy efficient built environments**, which are responsible for almost 40% of global emissions.

Globally energy efficiency refurbishment is estimated to result in the **investments of trillions of dollars**.

RCUK **Centre for Energy Epidemiology**

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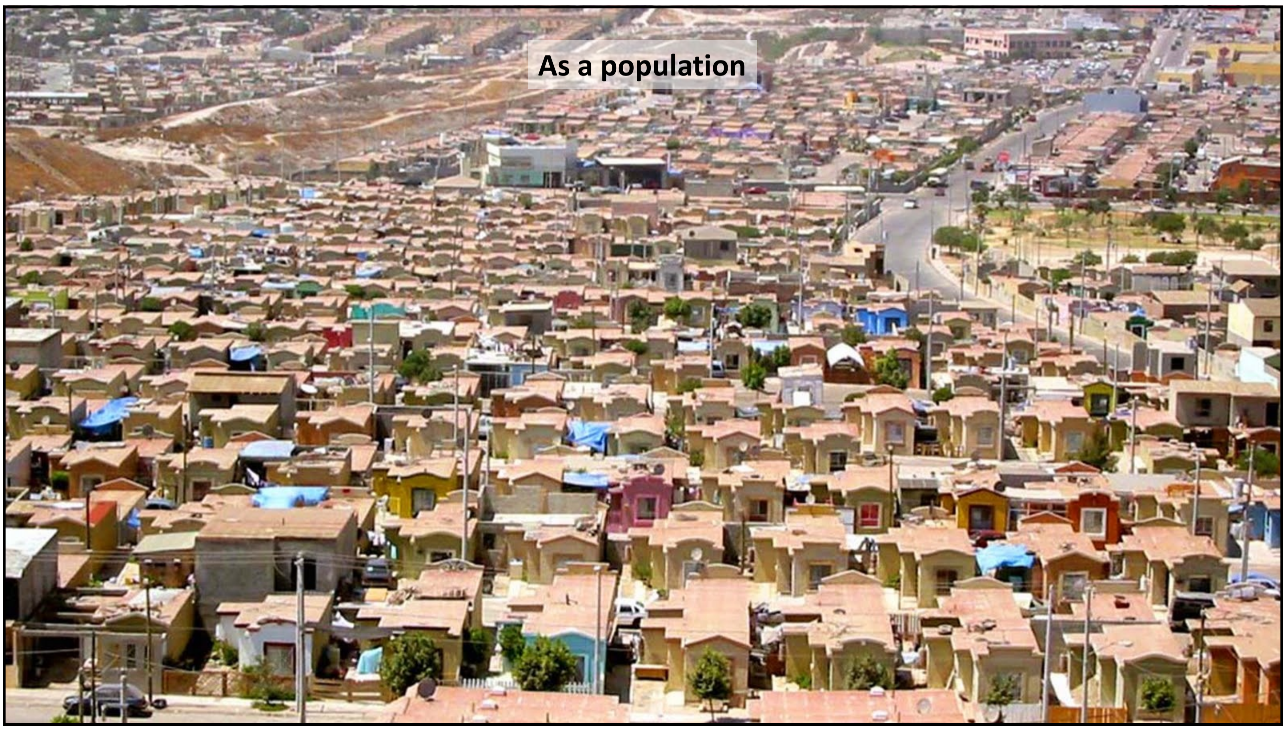
Studying the building… as a group

RCUK **Centre for Energy Epidemiology**

5



6

UCL Energy Institute

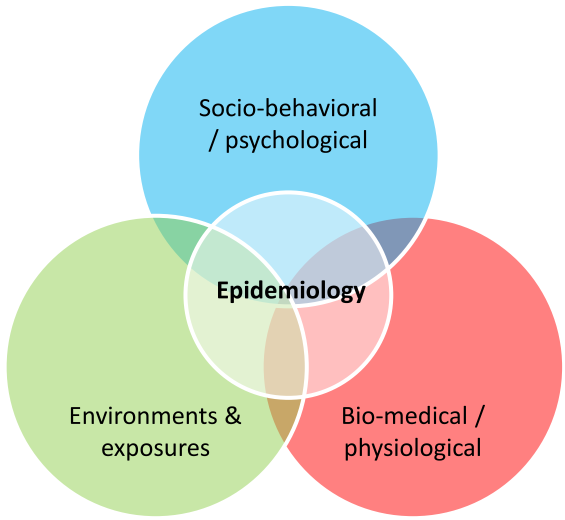
What is 'Epidemiology' and why is it relevant to energy use in buildings?

Epidemiology…

Is **data driven**, emphasis is on empirical evidence, distribution of a condition, understanding of underlying / driving factors

Focuses on understanding what is affecting the **spread and severity** of a condition

Uses research findings to inform **past/future practices and policy**



RCUK Centre for Energy Epidemiology

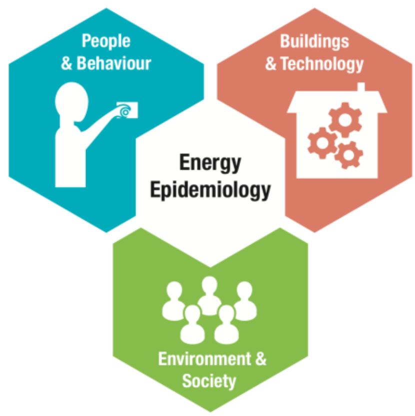
UCL Energy Institute

What is energy epidemiology?

epidemiology "epi" - **upon;** "demos" - **the people;** "ology" - **logic, study.** The study of what is upon the people – normally applied to the study of health.

energy epidemiology

The systematic study of the distributions and patterns of energy use and their causes or in luences in populations.



RCUK Centre for Energy Epidemiology

How would the research landscape change, if excessive energy demand were treated like a health risk?

Framework for **interdisciplinary** research

Large-scale **population studies** on the distributions of *prevalence and incidence,* and identifying and understanding the factors affecting theses distributions, using **empirical data**!

Have established data collection **protocols**, analysis, and archiving as a shared resource, and place detailed studies in context.

Protocols for **feedback of findings** (e.g. failure rates, adverse outcomes, unintended consequences) and **systematic reviews** of evidence

Emphasis on **research translation and engagement** with policymakers and industry as part on an on-going progressive research programme.

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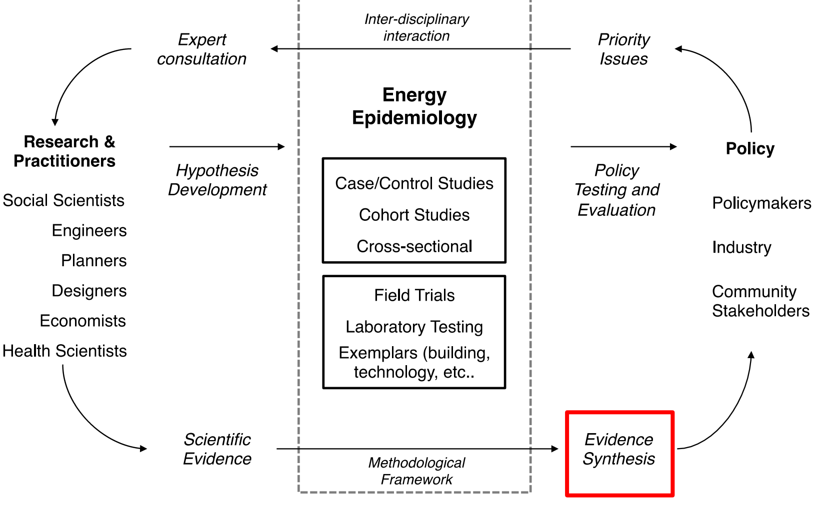
Central paradigm of energy epidemiology is:

That the **shift to a low-carbon society** along with the alleviation of energy-related social and environmental phenomena, such as fuel poverty and climate change, can be **improved through population-based methods** that analyse patterns and systems of energy demand services in order to better understand the practices, drivers, causes and differences of energy demand outcomes.



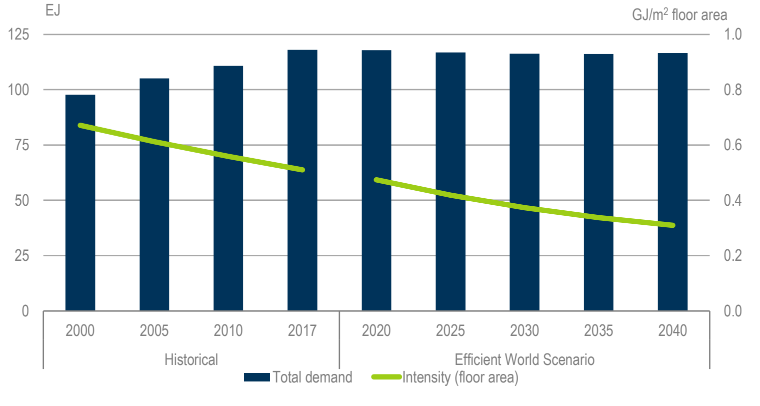
Model reporting guidelines

Buildings energy efficiency has been improving

Key policy actions

- Comprehensive efficiency policies, targeting both new and existing building stock and appliances.
- Incentives to encourage consumers to adopt high efficiency appliances and undertake deep energy retrofits.
- Improved quality and availability of energy performance information and tools.

Buildings energy use and energy intensity, 2000-40



Buildings energy use has been rising, but could stay flat to 2040, despite 60% more floor space.
Buildings energy intensity has been improving at 1.6% per year, but this could be 2.2% per year.

RCUK Centre for Energy Epidemiology

How can we better understand building stock models?

Building stock energy models (BSMs) offer a tool to assess the energy demand and environmental impact of building stocks, and can demonstrate and evaluate pathways for reducing their energy demand and respective GHG emissions.

The problem:
The heterogeneity of BSMs, together with a lack of consistency in the description and reporting of the models often hinders the understanding of the model, impeding an accurate interpretation 15 and/or comparison of the results.

The proposal:
Annex 70 have developed reporting guideline in order to improve reporting practices in the field of building stock energy modelling.

How can we better understand building stock models?

The aim of the reporting guideline is to **structure the information** for a given BSM in a consistent manner

The **reporting guidelines** will enable modellers to consistently structure the information about their models and **help reviewers and other interested parties find relevant information** about a model and thereby facilitate interpretation of model results.

The guidelines can be used to generate stand-alone reports describing a model (e.g., to be used as supplementary information to a publication using a model or as internal model documentation) or as a guidance on how to structure the information about a model in the main manuscript of a publication.

WILEY Blackwell equator network

Building Stock Model reporting guidelines

Topic	Subtopic	Guiding questions
Overview	Aim and scope	What is the overall aim and scope of the model? What are the main use cases addressed?
	Modelling ap- proach	What is the general modelling approach and how is it structured? What are the main model parts and compo- nents included in the model and how do they relate to each other? What are the key steps in the modelling workflow?
	System boundary	What are the system boundaries (temporal, geographical, building types, energy services, economic sectors, etc.) of the model?
	Spatio-temporal resolution	What is the spatio-temporal resolution of the model?

Model topics

Key model features

Detailed descriptions of the model

How can we better understand building stock models?

Topic	Subtopic
Overview	Aim and scope
	Modelling ap- proach
	System boundary
	Spatio-temporal resolution
Model Components	Building stock
	People Environment
	Energy
	Costs Dynamics
	Other aspects
Input and outputs	Data sources
	Data processing
	Key assumptions

Topic	Subtopic
Quality assurance	Calibration
	Validation
	Limitations
	Uncertainty
	Sensitivity
Additional information	Implementation Access
	Funding and contributors
	Areas of application
	Key references

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How to use the model reporting guidelines?

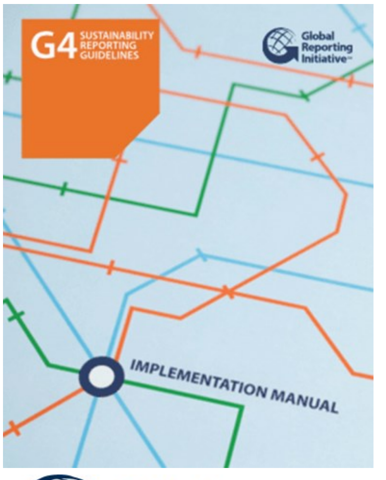
Used as a tool by authors, reviewers, and journal editors, in order to promote best practices in reporting building stock models and their results.

The application of the guidelines can improve the transparency and understanding of BSMs and their results and their reliability are better understood.

Guidelines offers benefits to modellers in terms of providing a clear framework for how they describe and report their models and easier to write and read model documentation through a consistent form.

Using the guideline as a checklist will ensure that important information is not omitted in the reporting.

Standardised format for model documentation will make reporting modelling results in future publications more straightforward.



Global Reporting Initiative™

RCUK Centre for Energy Epidemiology

Energy

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THANK YOU

Ian Hamilton
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Operating Agent for IEA EBC Annex 70

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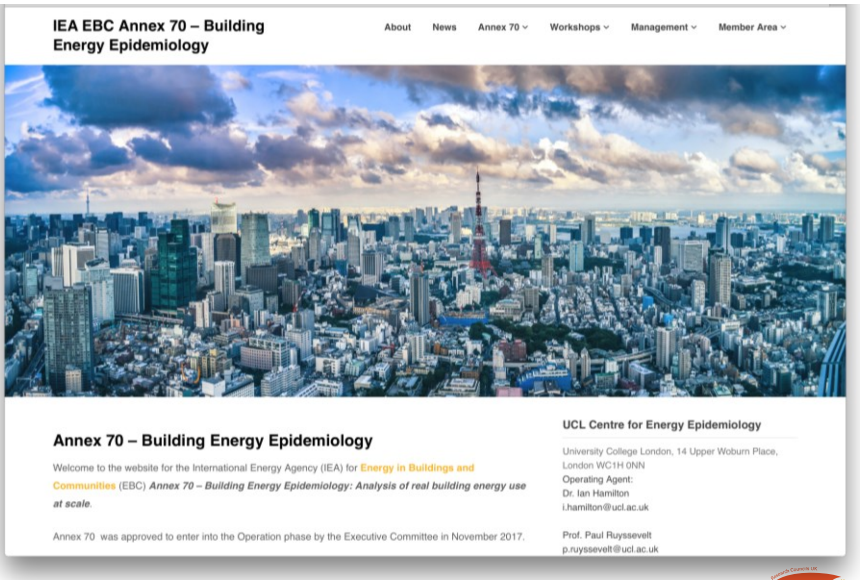


RCUK Centre for Energy Epidemiology

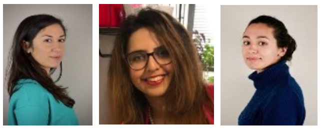
Energy

Annex 70: meaning for NL

Prof. Dr. Laure Itard
Chair Building Energy Epidemiology
14-6-2021

Participation

- 3 PhDs: Faidra Filippidou, Paula van den Brom, Shima Ebrahimigharehbaghi



- Chair Building Energy Epidemiology (BEE)

Why was it good for NL to participate ?

1. International Network

- Langevin, J., Reyna, J.L., Ebrahimigharehbaghi, S., Sandberg, N., Fennell, P., Nägeli, C., Laverge, J., Delghust, M., Mata, É., Van Hove, M. and Webster, J., 2020. Developing a common approach for classifying building stock energy models. *Renewable and Sustainable Energy Reviews*, *133*, p.110276.
- Fennell, P., Ebrahimigharehbaghi, S., Mata, É., Kokogiannakis G., Amrith, S., Ignatiadou, S., 2021. A review of the status of uncertainty and sensitivity analysis in building-stock energy models. Submitted to the Journal of Renewable and Sustainable Energy Reviews.

Why was it good for NL to participate?

2. Top Knowledge
   - Types and Scales of Building Stock Energy Models
   - Advanced data-driven Calibration methods
   - Advances methods for Uncertainty and Sensitivity Analysis (e.g. due to data scarcity for representative buildings or occupant-related)

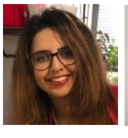
3. Awareness
   - NL is a small country with typical ways of registering data (e.g. energy use is registered at address level)
   - Other countries may use less privacy-sensitive methods, where models are calibrated at neighbourhood or regional level and use disaggregation models to infer properties of buildings
   - Coupling with GIS

Why was it good for NL to participate

4. Netherlands Enterprise
   - Essential knowledge for energy transition policy-making in Built Environment
   - Embedding in international developments
   - Knowledge used to contribute to national programs:
     - BTIC-IEBB (Integral Energy Transition in the Built Environment, TKI)
     - Guidance in validation core Dutch Building Stock Energy software (e.g. NTA8802, Vesta-Mais)
     - Analyses of national databases SHAERE for calibration software
   - Knowledge useful to contribute to setting up future programs

Thanks from NL!

- 3 PhDs: Faidra Filippidou, Paula van den Brom, Shima Ebrahimigharehbaghi


- Chair Building Energy Epidemiology (BEE)

EBC

Energy in Buildings and
Communities Programme

IEA EBC Annex 71

Quantifying the Thermal Performance of the Building Fabric based on Smart Meter Data

Staf Roels, Christian Struck and Twan Rovers

IEA Technical Collaboration Programme on Energy in Buildings and Communities Webinar
- Reducing the Performance Gap between Design Intent and Real Operation -

Today no operational rating and little measurement based optimisation of buildings

At the same time, we see following trends

Internet of Things

Home automation

Big Data

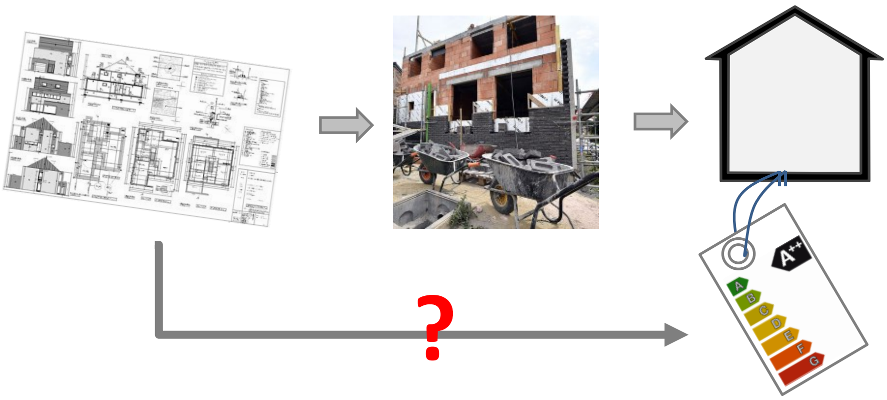
To what extent can we use on board monitored data
to assess the energy performance of our buildings?

Quantifying the thermal performance of the building fabric

Today's theoretical approach

Energy performance estimated using simulation software; EPB en EPC

building plans and specifications — building delivery — energy labelling

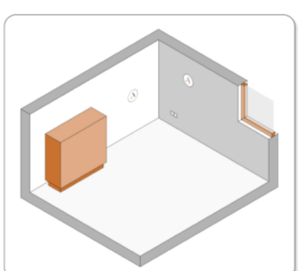


Actual quality/performance often tuns out worse than expected
Missed opportunities to optimise energy efficiency

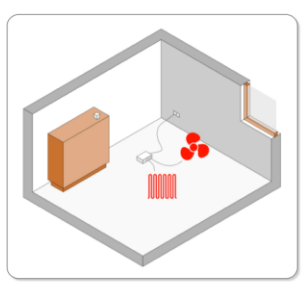
Quantifying the thermal performance of the building fabric

As-built thermal quality check

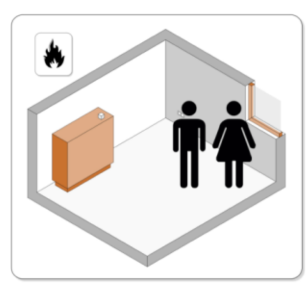
Three options



R-value/U-value test
Local thermal performance
of building elements



Specific heating test
Thermal performance
of whole building envelope



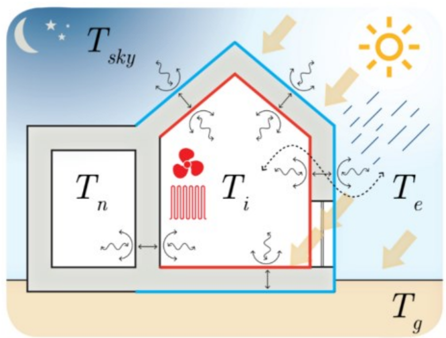
On-board test
Thermal performance
of whole building envelope

focus of IEA EBC Annex 58-project

focus of Annex 71-project

Estimate as-built thermal performance of the building fabric, based on measured data during normal operating conditions

$$C_i \frac{\partial \theta_i}{\partial t} = \Phi_h + \Phi_{int} + \Phi_{sol} + \Phi_l + \Phi_{tr} + \Phi_v + \Phi_m$$



HTC ?

$$C_i \frac{\partial \theta_i}{\partial t} = \Phi_h + \Phi_{int} + \Phi_{sol} + \Phi_l + \Phi_{tr} + \Phi_v + \Phi_m$$

$$\Phi_{tr} = \Phi_{tr}^{e} + \Phi_{tr}^{n} + \Phi_{tr}^{adj} + \Phi_{tr}^{g}$$

$$\Phi_{tr}^{e} + \Phi_{tr}^{n} + \Phi_{tr}^{g} \sim HTC$$

Exploration of different statistical methods:

- Averaging method
- Linear regression models
- Energy signature model
- AR(MA)X-models
- grey box models
- …

Investigating the impact of input data:

- solar gains
- heat input (SH vs. DHW)
- weather data
- indoor temperature
- infiltration and ventilation
- …

IEA EBC Annex 71: from extensive monitoring campaigns to smart meter data

extensive monitoring

smart meter data

artificial users

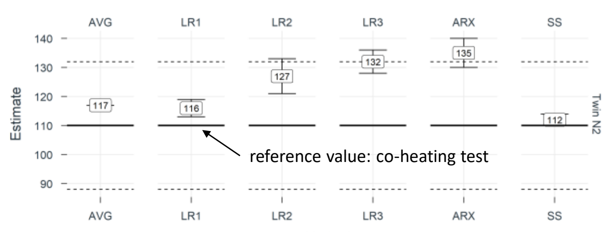
actual users

blind test

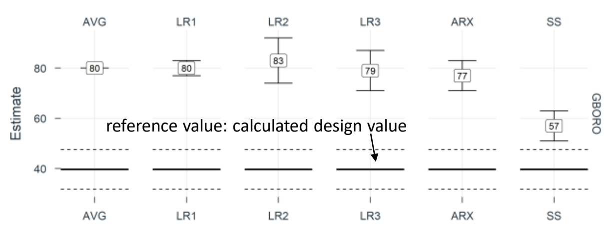
7

Some results

Twin test houses, Germany
artificial users



Social housing dwelling, UK
actual users



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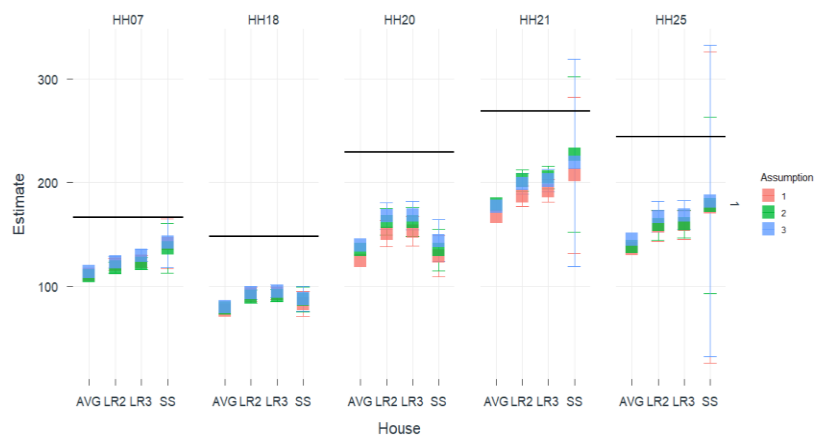
Blind test: SMETER-project, UK

Impact of the different assumptions applied on indoor temperature averaging



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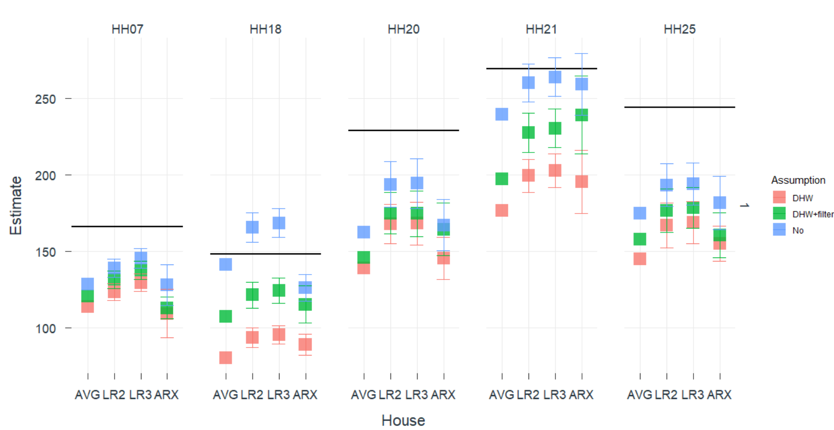
Blind test: SMETER-project, UK

Impact of the different assumptions applied in DHW and SH splitting



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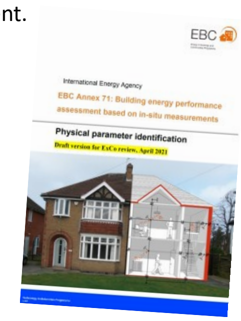
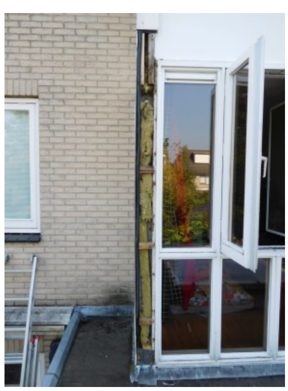
Conclusions

- Statistical tools show promise to determine the building's HTC based on limited on-site monitored data.
- Static methods showed to be more robust in application, but overall both static and dynamic measurements resulted in similar estimates
- Results often in close agreement with the target values (co-heating test results), but for some buildings deviations up to almost 50% were found.
- Assumptions on almost all parameters (measurement time and period, internal heat gains, temperature averaging,…) showed to significantly impact the outcome.
- A further in-depth analysis on more case studies is advisable to turn the methods into reliable tools to be used in actual performance assessment.
- Details can be found in the IEA EBC Annex 71-reports



Consequences for The Netherlands?

Characterization of as-built energy performance

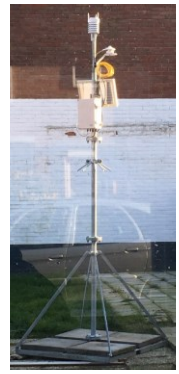


Source: https://www.bouwwereld.nl/categorie/bouwfouten

Consequences for The Netherlands?

Characterization of as-built energy performance

In-situ performance assessment of renovation measures, testing and standardization of methods (blowerdoortest, co-heating test, …)



Consequences for The Netherlands?

Characterization of as-built energy performance using on-board monitoring data.

- More cost-effective and less intrusive than traditional heating experiments
- Quality assurance
- Performance tracking
- Model calibration

Consequences for The Netherlands?

A number of methods have been developed and described to determine the as-built HLC and HTC.

Future work:

- Improving accuracy / reducing uncertainty
- Automation of methods for large-scale application

EBC

Energy in Buildings and Communities Programme

IEA EBC Annex 71

Quantifying the Thermal Performance of the Building Fabric based on Smart Meter Data

Staf Roels, Christian Struck and Twan Rovers

IEA Technical Collaboration Programme on Energy in Buildings and Communities Webinar
- Reducing the Performance Gap between Design Intent and Real Operation -

EBC Webinar
Reducing the Performance Gap between
Design Intent and Real Operation

IEA-EBC Annex 78:
Supplementing Ventilation with Gas-phase Air Cleaning

Professor Bjarne W. Olesen Ph.D.

- International Centre for Indoor Environment and Energy, ICIEE
- Technical University of Denmark
  - bwo@byg.dtu.dk

DTU

ICIEE

EBC
Energy in Buildings and Communities Programme

1

Outline/Agenda

1. INTRODUCTION
2. CONCEPT OF SUPPLEMENTING VENTILATION BY GAS PHASE AIR CLEANING.
   1. Measuring air cleaning efficiency for individual contaminants
   2. Measuring the Clean Air Delivery Rate and air cleaning efficiency based on Perceived Air Quality
3. TESTING OF GAS PHASE AIR CLEANERS
4. ENERGY IMPACTS OF USING GAS PHASE AIR CLEANING
5. USE OF CO_2 AS AIR QUALITY INDICATOR
6. DISCUSSION
7. CONCLUSIONS

2

EBC-IEA ANNEX 78: Operating Agents

- Dr. Bjarne W. Olesen, Technical University of Denmark.
- Dr. Pawel Wargocki, Technical University of Denmark.

- PREPARATION PHASE 01-07-2018 TO 30-06-2019
- WORKING PHASE 01-07-2019 TO 30-06-2023
- REPORTING PHASE 01-07-2023 TO 30-06-2024

ANNEX STRUCTURE

- Subtask A: Energy benefits using gas phase air cleaning
  - Subtask leader: Alireza Afshari, Denmark
  - Co-leader: *Sasan Sadrizadeh* , Sweden
- Subtask B: How to partly substitute ventilation by air cleaning
  - Subtask leader: Pawel Wargocki, Denmark
  - Co-leader: Shin-Ichi Tanabe , Japan
- Subtask C: Selection and testing standards for air cleaners
  - Subtask leader: Paolo Tronville, Italy
  - Co-leader: Jinhan Mo, China
- Subtask D: Performance modelling and long-term field validation of gas phase air cleaning technologies
  - Subtask leader: Karel Kabele, Czech
  - Co-leader: Jensen Chang , USA

Concept for calculation of design ventilation rate ISO CEN ASHRAE

People Component

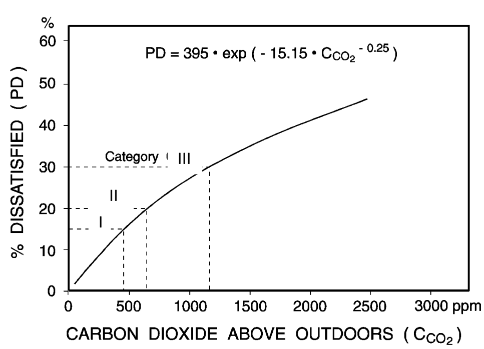
Building Component

Breathing Zone Outdoor Airflow

$$V_{bz} = R_p P_z + R_a A_z$$

- R_p: Minimum l/s/Person
- P_z: Number of People
- A_z: Building Area
- R_a: Minimum l/s/m²

CO_2 as reference



$$Q_h = \frac{G_h}{C_{h,i} - C_{h,o}} \cdot \frac{1}{\varepsilon v}$$

where

Q_h is the ventilation rate required for dilution, in m³ per second;

G_h is the generation rate of the substance, in micrograms per second;

$C_{h,i}$ is the guideline value of the substance, in micrograms per m³;

$C_{h,o}$ is the concentration of the substance of the supply air, in micrograms per m³;

ε_v is the ventilation effectiveness.

CONCEPT OF SUPPLEMENTING VENTILATION BY GAS PHASE AIR CLEANING.

- **Clean Air Delivery Rate (CADR)**
  - **CADR = $\varepsilon_{PAQ} \cdot Q_{AP} \cdot (3,6/V)$**
  - where:
  - ε_{clean} or ε_{PAQ}, is the air cleaning efficiency
  - Q_{AP} is the air flow through the air cleaner, l/s;
  - V is the volume of the room, m^3.
- **Air Cleaning Efficiency**
  - $\varepsilon_{clean} = 100(C_U - C_D)/C_D$

  where:
  - ε_{clean} is the air cleaning efficiency
  - C_U is the gas concentration before air cleaner
  - C_D is the gas concentration after air cleaner.
- **Higher Air Quality Category**

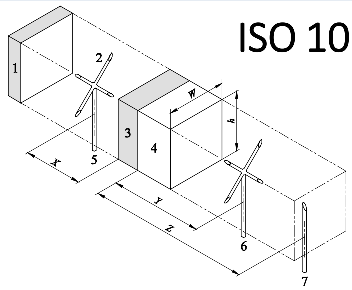
$$\varepsilon_{PAQ} = Q_o / Q_{AP} \cdot (PAQ / PAQ_{AP} - 1) \cdot 100$$

- where:
- ε_{PAQ} is the air cleaning efficiency for perceived air quality;
- Q_o is the ventilation rate without air cleaner, l/s;
- Q_{AP} is the ventilation rate with air cleaner, l/s;
- PAQ is the perceived air quality without the air cleaner, decipol;
- PAQ_{AP} is the perceived air quality without the air cleaner, decipol

Testing Gas Phase Air Cleaners Standards

- ISO 10121-2:2013 "Test methods for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 2: Gas-phase air cleaning devices (GPACD)"
- • ISO 10121-1:2014 "Test method for assessing the performance of gas-phase air cleaning media and devices for general ventilation - Part 1: Gas-phase air cleaning media"
- • ANSI/ASHRAE Standard 145.2-2016 "Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Air-Cleaning Devices" (first edition in 2011)
- • ANSI/ASHRAE Standard 145.1-2015 "Laboratory Test Method for Assessing the Performance of Gas-Phase Air-Cleaning Systems: Loose Granular Media" (first edition in 2008)

TESTING OF GAS PHASE AIR CLEANERS



Key

1 diffusor and Δp device
2 sampling points – should be of "fork" type or similar with multiple inlet points to make a compounded sample over the whole cross section
3 GPACD under test
4 GPACD section of test duct
5 upstream sampling point for T_U, RH_U, p_U and C_U at X mm before the GPACD
6 Downstream sampling point for T_D, RH_D, p_D and C_D at Y mm after the GPACD
7 Q, air flow rate sampling point at Z mm after the GPACD
W internal width of the test duct along the GPACD section, 3+4
h internal height of the test duct along the GPACD section, 3+4

Figure 1 — Normative section of test stand showing ducting, measurement parameters and sampling points

ISO 10121-2:2014

Air Cleaning Efficiency

$$\varepsilon_{clean} = 100(C_U - C_D)/C_D$$

where:

E_{clean} is the air cleaning efficiency
C_U is the gas concentration before air cleaner
C_D is the gas concentration after air cleaner.

PERCEIVED AIR QUALITY

INTERNATIONAL STANDARD **ISO 16000-28**

First edition
2012-03-15

Indoor air —

Part 28:
Determination of odour emissions from building products using test chambers

Air intérieur —

Partie 28: Détermination des émissions d'odeurs des produits de construction au moyen de chambres d'essai

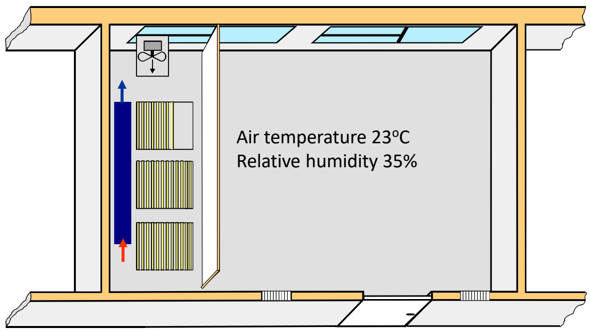
Test Panel
- Trained
- Untrained

Odour
- Acceptance
- Intensity
- Hedonic tone

Examples of diffuser and mask used for odour evaluatio

Figure C.1 — Diffuser

Experimental setup



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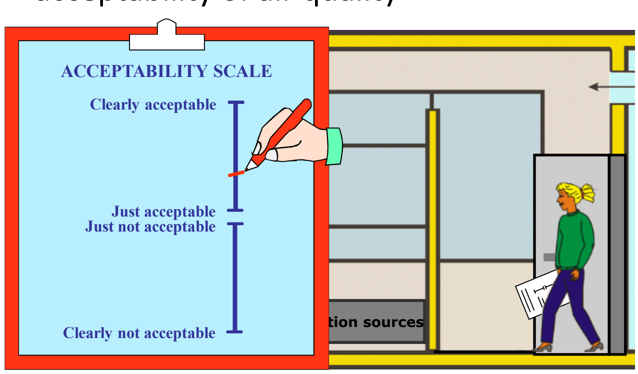
Sensory measurements

- Panel of 50 untrained subjects assessed acceptability of air quality



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12

PERCEIVED AIR QUALITY

$$ACC = \frac{\sum_{i=1}^{N}(ACC)_i}{N} \qquad [1]$$

where:
ACC = mean vote of acceptability of air quality;
ACC_i = acceptability vote by the observer.
N = number of observers.

The accuracy of evaluations is expressed by a standard error of the measured acceptability [2]:

$$SE = \frac{SD}{\sqrt{N}} \qquad [2]$$

where:
SE = standard error;
SD = standard deviation of mean vote of acceptability;
N = number of observers.

Using mean acceptability ratings, the percentage dissatisfied with the air quality can be calculated (Gunnarsen and Fanger, 1992) [3]:

$$PD = \frac{\exp(-0.18 - 5.28 \cdot ACC)}{1 + \exp(-0.18 - 5.28 \cdot ACC)} \cdot 100 \qquad [3]$$

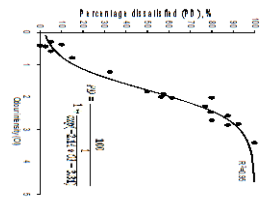
where:
PD = percentage dissatisfied with the air quality, %;
ACC = mean vote of acceptability.

Using the percentage dissatisfied, the perceived air quality expressed in decipol, as defined by Fanger (1988), can be calculated [4]:

$$PAQ = 112 \cdot [\ln(PD) - 5.98]^{-4} \qquad [4]$$

where:
PAQ = perceived air quality, decipol;
PD = percentage dissatisfied with the air quality, %.

Both the percentage dissatisfied with the air quality [3] and the perceived air quality in decipol [4] are used to set requirements regarding air quality and ventilation of spaces (e.g., ASHRAE, 2004; CEN, 1998).



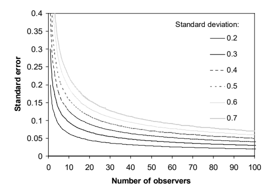
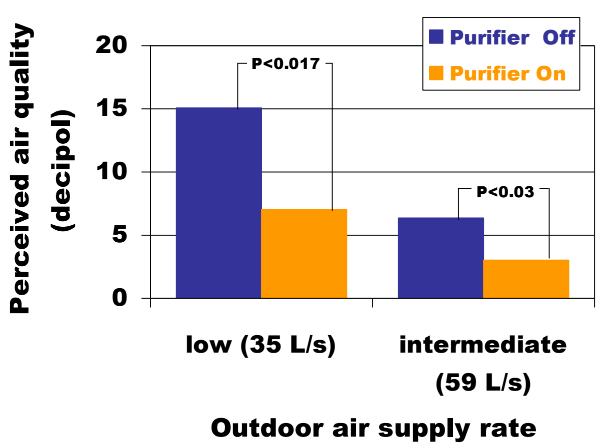
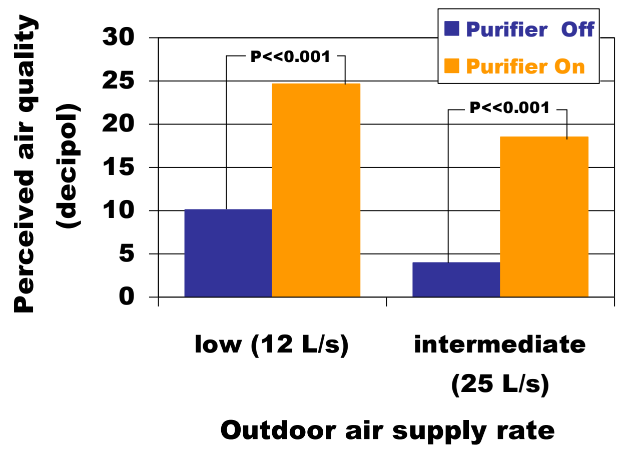


Figure 3. Standard error of the acceptability rating as a function of number of observers and standard deviation of the rating of acceptability

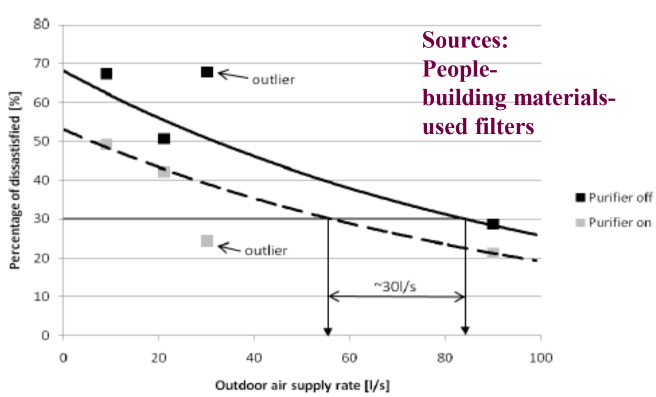
Results: Bldg mat, PCs, filters



Results: Human bioeffluents

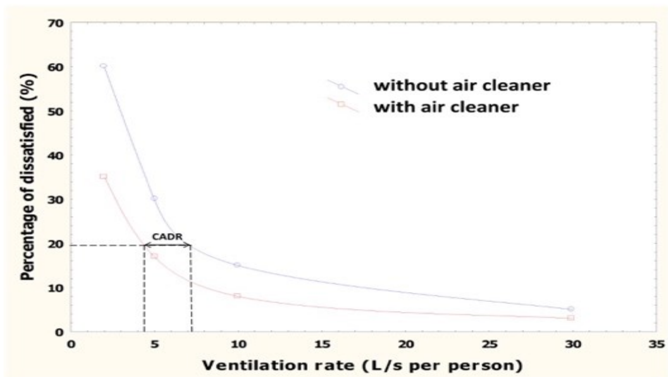


Effect of air cleaning on perceived Air Quality



Sources:
People-
building materials-
used filters

Clean Air Delivery rate per person



Issues

- International Standards for Ventilation (Indoor Air Quality) like EN16798-1, ISO17772-1 and ASHRAE 62.1 are mainly based on criteria for the Perceived Air Quality (PAQ), sometimes expressed as levels of CO_2 as a tracer for emission from occupants.
- If air cleaning is used, an equivalent level of air quality will be reached at higher CO_2 concentrations.
- It is also assumed that when ventilation is used for PAQ, the required ventilation will also dilute other substances like Radon, VOCs.
- The decreased ventilation rate when using gas phase air cleaning may not be sufficient.

ΔCO_2 levels considering a 30 % reduced ventilation rate due to air cleaners

Space type Single office	*Occupancy [m^2 per person]*	*Category*	*Derived from qtot*	
			Very low-polluting building	*Low-polluting building*
			Indoor CO_2 level above outdoor level ΔCO_2 *[ppm]*	
Without air cleaner	10	IEQI	370	278
		IEQII	**529**	**397**
		IEQIII	926	694
		IEQIV	**1389** (1010)	**1010** (794)
With air cleaner	10	IEQI	529	397
		IEQII	**756**	**567**
		IEQIII	**1323** (1029)	**992** (817)
		IEQIV	**1984** (1100)	**1443** (911)

Issues

- Today, gas phase air cleaners are tested based on a chemical measurement, which do not account for the influence on PAQ and human bio effluents as a source of pollution.
- Studies have shown that some gas phase air cleaning technologies will not work when humans are the source, and the evaluation is done by PAQ.
- There is a need for new test standards
- Testing with PAQ requires a measurement of subjective reactions
- Testing with human bio effluents as a source requires the use of humans as a source

Testing Issues

- If only a test with chemical measurements is done, should it be allowed to reduce the building component?
- How to standardise the building source?
- How to standardise the human bio effluent source?
- What if human source is Chinese persons and testing panel is Danish persons?
- It is a relative measurement, which makes some of the issues less important

ENERGY USE-INDOOR ENVIRONMENT

- Reduced Energy Use
  - Heating/Cooling of Supply Air
  - Reduced energy for humidification and/or De-humidification
  - Fan Energy
  - Energy Use of Air Cleaner
  - Heat Recovery or not
- Noise level
  - Reduced air flow in AHU
  - Noise from air cleaner
- Draught level
  - Reduced air flow in occupied space
  - Draught from portable air cleaner

Conclusion

- A concept for substituting part of the required ventilation with gas phase air cleaning technology has been presented
- There is a need for new testing standards that considers perceived air quality and human emissions as a source.
- The energy impact of using gas phase air cleaning must be studied further. By reducing the ventilation rate energy use can be reduced for:
  - pre-heating or pre-cooling of outside supply air
  - humidifying or de-humidifying
  - fan energy for air transport
- Energy use may be increased due to:
  - Additional fan energy for stand-alone air cleaners
  - Additional fan energy due to increased pressure drop over the device
  - Reduced potential for cooling by outside air
- It must be verified that the reduced ventilation rate is still high enough to dilute individual contaminants.
- Adjusted CO_2 criteria must be used to express the indoor air quality and to use for demand-controlled ventilation.

Questions?

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Energy in Buildings and Communities Programme

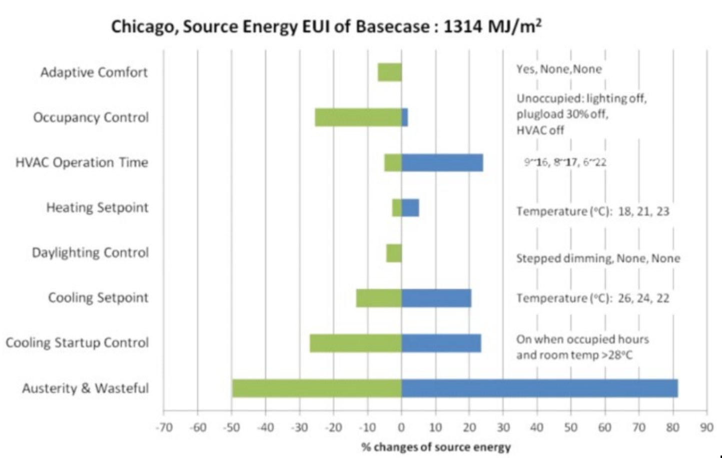
Do Occupants Matter?

Comfort and Occupant Behavior as Relevant Drivers for Building Energy Performance

Andreas Wagner
Karlsruhe Institute of Technology (KIT)
Germany

EBC Webinar 'Reducing the Performance Gap between Design Intent and Real Operation', June 11, 2021

Potential Influence of Comfort Conditions and Occupancy on Building Energy Performance



Hong and Lin, 2013

Role of Occupants in Building Energy Performance Gap

Study by A. Mahdavi, Ch. Berger et al. in Subtask 1 of Annex 79:

144 articles reviewed in search of evidence for the alleged role of occupants as the cause of the performance gap

Central finding:
Existing studies do not provide a convincing evidence for the purported significant contribution of occupants to energy performance gap

Only 40% of studies meet the minimum credibility criteria
Only 14% entail actual monitored data on occupant behavior

Publication link: https://doi.org/10.3390/su13063146

Occupants' Interventions and Building Energy Performance

Reasons for occupants' interventions:
- dissatisfaction with building automation
- interfaces are not designed/equipped for intended purpose
- planners do not consider occupants' needs in building design (same is true for building operation)
- intended interventions in buildings with occupant-centric design concept


Source:Schakib


Source: Gilani and O'Brien

→ **Occupants have to be included into overall building concept and into control strategy**
→ **Better understanding of occupant behaviour is essential**

Lessons Learned in Annex 66 and Open Questions

EBC
Energy in Buildings and Communities Programme

IEA EBC Annex 66 provided sound framework for:

- experimentally studying and modeling different behavioral actions
- implementation of occupant behavior models into simulation platforms

But: discrepancy with design and building operation practice and open questions:

- What is impact of multiple indoor environmental parameters on human perception and resulting behavioral reactions?
- How do building controls' interfaces and their underlying logic affect behavior?
- How can building automation systems and other readily-available data sources be better leveraged for improving occupant-centric building concepts?
- What kind of information has to be provided to better inform designers and building managers on how to apply occupant behavior knowledge and models in practice?

Objectives of Annex 79

EBC
Energy in Buildings and Communities Programme

- **Improvement of knowledge about occupants' interactions with building technologies**. Specific focus on:
  - comfort-driven actions caused by **multiple and interdependent environmental influences** which are not yet covered by current models
  - **building technologies' interfaces** in terms of their suitability for taking advantage of adaptive opportunities, and their effect on building energy consumption
- **Deployment of 'big data'** (data mining and machine learning) for the building sector based on various sources of building and occupant data as well as sensing technologies
- Sustainable **implementation of occupant behaviour models** in building practice
  - guidelines / recommendations for **standards for applying occupant behaviour models and new knowledge on occupants during building design and operation**
  - focused **case studies** to **implement and test the new models** in different design and operation phases in order to get valuable feedback

Participating Countries

EBC
Energy in Buildings and Communities Programme

1	Australia
2	Austria
3	Belgium
4	Brazil
5	Canada
6	China
7	Denmark
8	France
9	Germany
10	Italy
11	Netherlands
12	Norway
13	Singapore
14	Sweden
15	Turkey
16	UK
17	USA
18	Switzerland

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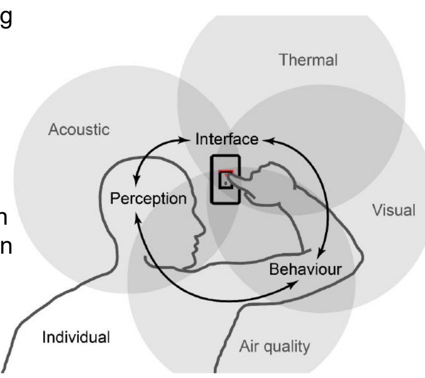
Ongoing Activities

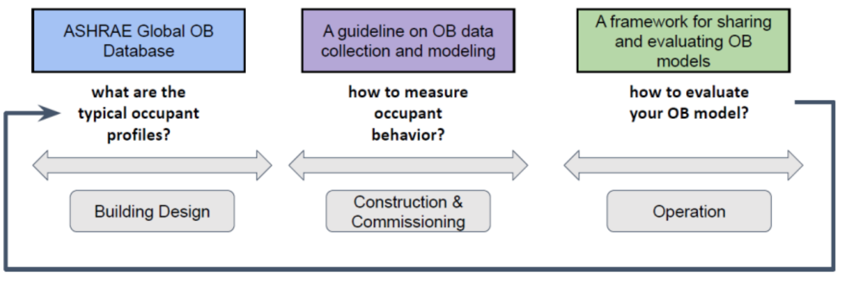
- Collecting information on human-building interaction in multi-domain studies
- Defining necessary conditions for multi-domain indoor environmental quality standards
- Indoor environmental factors and human responses: a framework for multi-domain studies
- A COVID-19 pandemic-driven review of multi-domain IEQ studies in residential buildings and work-from-home settings



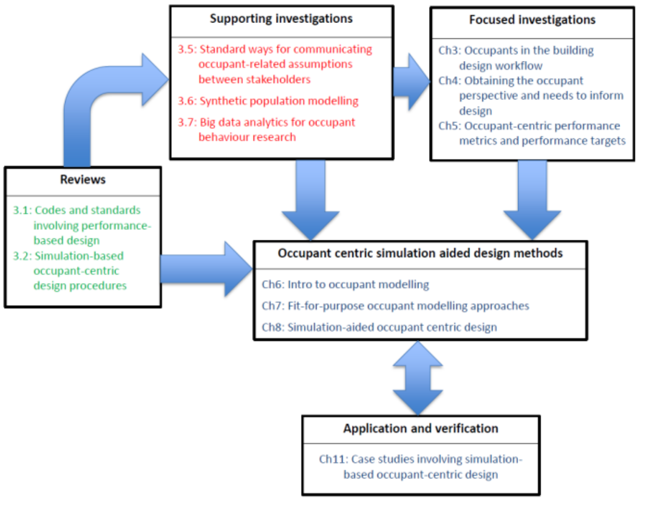
Marcel Schweiker

Ongoing Activities

Goal: Advance methodologies and tools for data-driven Occupant Presence and Action (OPA) modelling and implementation



Ongoing Activities

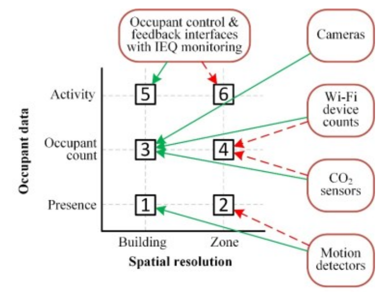


Ongoing Activities

- Literature reviews on OCC
- Operator interviews

- OCC case study descriptors survey
- OCC taxonomy
- OCC in simulation
- *Demand response & OCC*
- *COVID-19 & OCC*

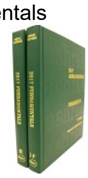
- Synthesis of OCC case study findings

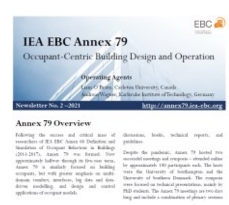


Important Outputs so far

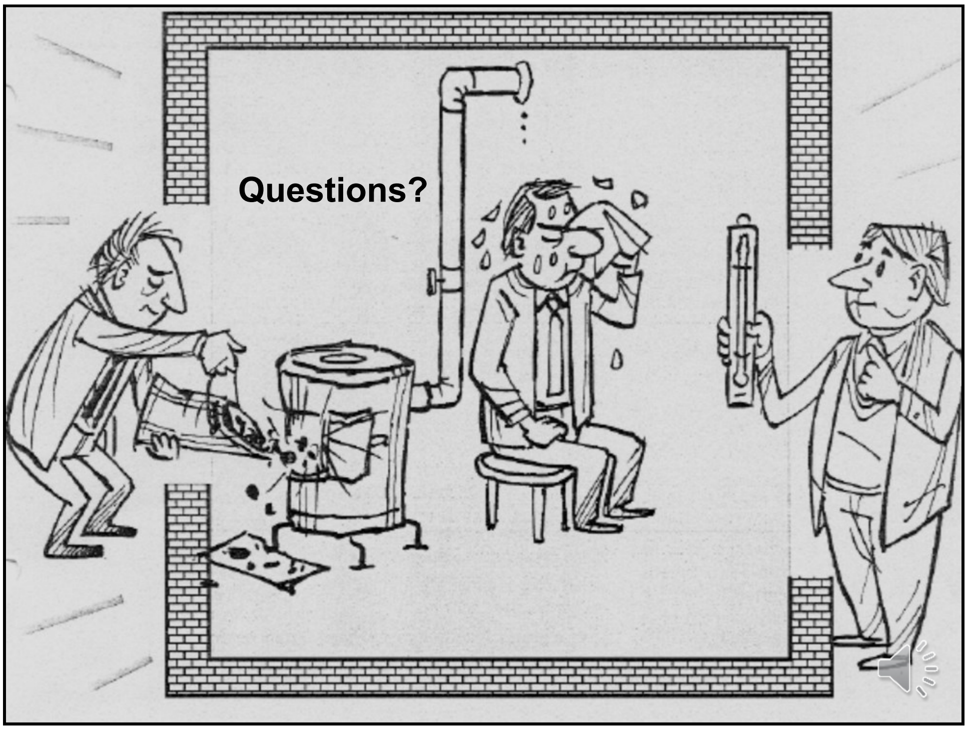
- Special issue on review papers in Journal Building and Environment complete

- On-going special issue on occupant-centric controls in the Journal of Building Performance Simulation
- Contribution to ASHRAE handbooks (2021 Fundamentals new section on occupant modeling in Chapter 19)





- REHVA Guidebook planned
- 29 journal papers in total 2020 and 2021
- Annex 79 Newsletter for 2020 published (https://www.dropbox.com/s/4fyp0yz4jkjcams/Annex%2079%20newsletter%202021.pdf?dl=0)
- **More information on IEA EBC Annex 79: https://annex79.iea-ebc.org/**


Questions?

IEA Technology Collaboration Programme on Energy in Buildings and Communities Webinar
Friday 11th June 2021

Reducing the Performance Gap between Design Intent and Real Operation

IEA EBC Annex 79

Significance for the Netherlands

Peter Op 't Veld
Huygen Engineers and Consultants
Senior consultant / H2020 coordinator

1

Reducing the Performance Gap between Design Intent and Real Operation ……a long history within IEA - EBC

ANNEX 53 2008 - 2013
Total Energy Use in Buildings: Analysis & Evaluation Methods

Annex 53 has identified the strong influence of occupants on building performance

→

ANNEX 66 2013 - 2018
Definition and Simulation of Occupant Behavior in Buildings

Annex 66 provides a framework for experimentally studying and modelling different behavioural actions, including implementation of these models into simulation platforms

→

ANNEX 79 2018 - 2023
Occupant-Centric Building Design and Operation

Annex 79 provide new insights into comfort-related occupant behaviour in buildings and its impact on building energy performance. An open collaboration platform for data and software is being created to support the use of 'big data' methods and advanced occupant behaviour models.

2008 > …from making models and simulations more accurate towards understanding the factors that have an impact on the performance gap < 2023

as buildings do not use energy but occupants, occupancy behavior is key

determining the role of OB → **understanding the role of OB** → **OB centered design and operation**

2

The significance of IEA Annex 79 (and 53 – 66) for the Netherlands:

input for National and EU H2020 research projects

EBC
Energy in Buildings and Communities Programme

	ANNEX 53 2008 - 2013 Total Energy Use in Buildings: Analysis & Evaluation Methods	ANNEX 66 2013 - 2018 Definition and Simulation of Occupant Behavior in Buildings	ANNEX 79 2018 - 2023 Occupant-Centric Building Design and Operation
National: TKI program	TRECO - home 2014 - 2018 TRECO – office 2015 - 2019 Towards Real Energy performance and Control in Homes and Offices	DYNKA 2018 - 2022 Dynamic Light and Indoor Environment for offices PERDYNKA 2019 -2022 Personalized Dynamic Light and Indoor Environment for offices	SMART OFFICE 2020 – 2023 Smart & Grid Interactive Office Buildings WORKROOM Exploring an indoor climate that fits you
EU: H2020		MOBISTYLE 2016 - 2020 Motivating end-users Behavioral change by combined ICT based modular Information on energy use, indoor environment, health and lifestyle www.mobistyle-project.eu	

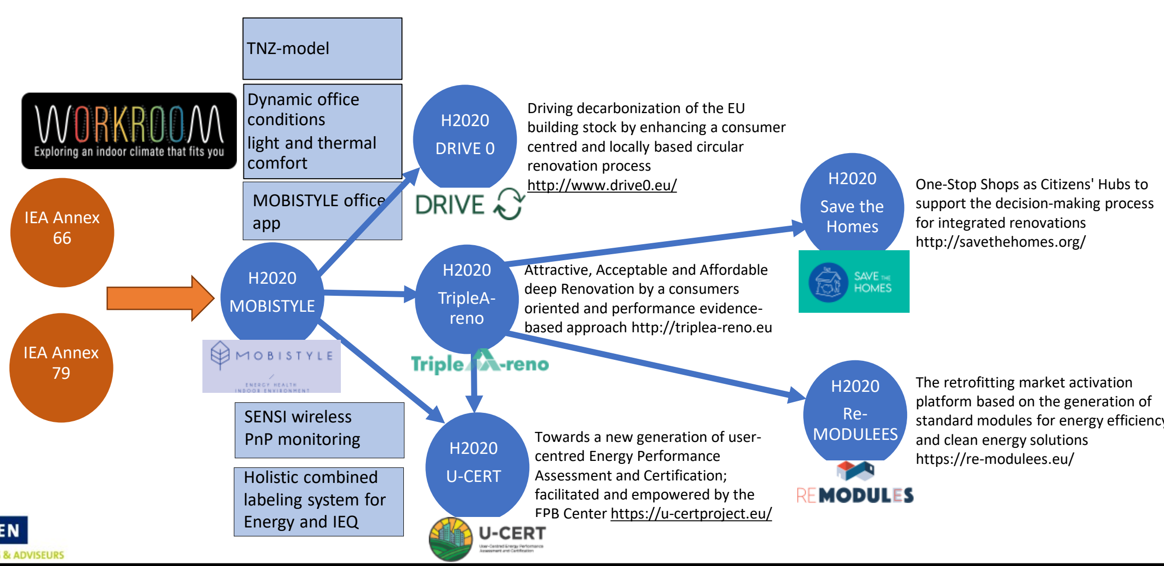
HUYGEN INGENIEURS & ADVISEURS

3

IEA Annex 66 and 79:

The inspiration and start of several of our H2020 projects with anthropology-based people centered approach

EBC
Energy in Buildings and Communities Programme

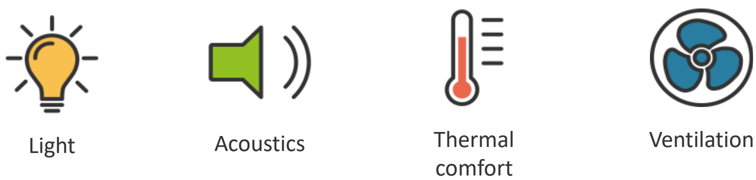


HUYGEN INGENIEURS & ADVISEURS

4

The significance of IEA Annex 79: input for our consultancy (Huygen IA) - WorkRoom

- Users of a clients future building will come over to the Huygen office
- They will be educated on the four main topics of building physics & services:

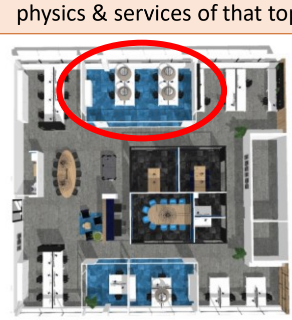


- Every module will end with experiments to give insight in their personal preferences on those topics
- After a WorkRoom day the participants understand their choices within the program of requirements for the different functions of their new office building and can discuss these choices with the decision makers

The significance of IEA Annex 79 input for our consultancy (Huygen IA)

WHAT?

- One room in the Huygen office
- 8 working places
- Every module starts with 15-30 minutes of interactive background explanation/lecture on the building physics & services of that topic.



HOW?

After that, the room is technically altered to let the people experience:

Acoustics
- Different reverberation times for different functions.
- Different sound levels of installation noise.
- Different insulation levels of partition walls.

Ventilation
- Different levels of CO_2 concentration.
- Different ventilation rates.

Light
- Different light levels.
- Different color temperatures of light.

Temperature
- Different temperature setpoints.

THANK YOU FOR YOUR ATTENTION!

IEA EBC Annex 75

Cost-Effective Building Renovation at District Level Combining Energy Efficiency & Renewables

13 countries are involved in the project:
AT, BE, CH, CN, CZ, DK, ES, GE, IT, NL, NO, PT, SE

January 2018 – June 2022

Manuela Almeida (Operating Agent)
University of Minho
Portugal

Technical webinar
11th June, 2021

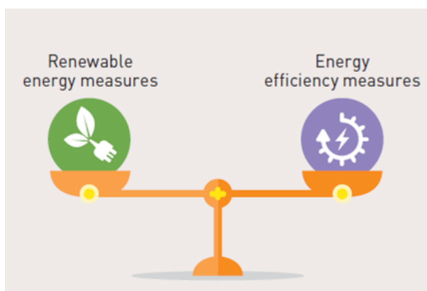
1. Project Goal

Project Goal: reach cost-effective energy and carbon emission optimization in building renovation at an <u>urban district scale</u> combining both energy efficiency measures and renewable energy measures

Key issue: find the balance point between energy efficiency measures and measures that promote the use of renewable energy

Annex 56: At the building level

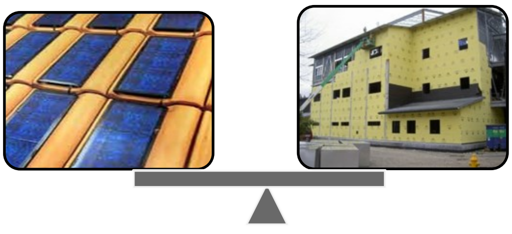
Annex 75: At the level of groups of buildings / urban districts



2. Project Idea

EBC
Energy in Buildings and Communities Programme

- At district level there are specific opportunities as well as specific challenges when compared to the building level
- Finding the balance between renewable energy supplies and energy efficiency measures for the renovation of the existing stock is more complex at district level than for individual buildings, but may also bring larger benefits



2. Project Idea

EBC
Energy in Buildings and Communities Programme

There are several options available that need to be explored:

Examples:

- There is an opportunity to benefit from district based renewable energy approaches
- The availability of heat storage facilities are wider at district level as in a single-building intervention the options are limited to the building floor space
- We can benefit from significant economies of scale for energy efficiency measures due to aggregated demands and synergies in construction procurement, processes and planning
- The provision of district heating systems to groups of buildings may benefit from synergies when combined with energy efficiency measures applied to the buildings envelopes

2. Project Idea

EBC
Energy in Buildings and Communities Programme

However, there are also some challenges:

- At the level of individual buildings, synergies between energy efficiency measures and installation of renewable energy systems can be easily achieved but, at district level such synergies are not necessarily available as they depend on the existing heating systems and on the synchronization of the buildings´ renovation cycles

In this context, it is important to explore the potential of cost-effective renovation interventions at district level to accelerate the necessary transition towards low-emissions and low-energy districts

Annex 75 project aims to make a comprehensive analysis that covers not only the energy, economic and environmental issues, but also identify opportunities and barriers in the relations between different stakeholders and in policies and incentives for boosting energy renovations

Technology Collaboration Programme
by iea

3. Research Questions

EBC
Energy in Buildings and Communities Programme

Questions investigated:

- What are the most cost-effective combinations of RES measures and EE measures
- Which factors determine the cost-effectiveness of the balance between EE and RES measures
- What is the most cost-effective approach between a centralized or a decentralized approach
- Which technologies are seen as most relevant
- How do energy efficiency measures relate to technology choices
- To what extent are EE measures beyond anyway renovations cost-effective
- Is the cost effectiveness of EE measures the same for different RES options
- Which approaches allow achieving districts fully supplied with renewable energy at the lowest cost
- …

Technology Collaboration Programme
by iea

4. Annex 75 Objectives

EBC
Energy in Buildings and Communities Programme

The objectives of Annex 75 are:

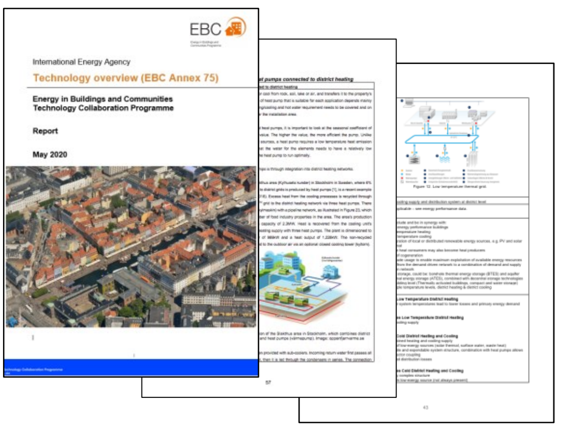
- To give an overview on various technology options, taking into account existing and emerging efficient technologies with potential to be successfully applied
- To define a flexible methodology, supported by efficient tools, to identify cost-effective strategies for renovating urban districts to significantly reduce carbon emissions and energy use
- To identify and document good practice examples showing strategies for transforming existing urban districts into low-energy and low-emissions districts
- To prepare Guidelines for policy makers and energy-related companies on how to encourage the market uptake of cost-effective strategies combining energy efficiency measures and renewable energy measures
- To prepare Guidelines for building owners and investors about cost-effective district-level solutions

http://annex75.iea-ebc.org/

5. Outputs

EBC
Energy in Buildings and Communities Programme

Technology Overview Report



The report presents an overview of the available technologies for energy renovation and renewable energy supply at the district level, showing:

- Technical and economic characteristics of the technology options, taking into account economies of scale
- Interdependencies, obstacles and success factors for combining the technology options
- Available potentials, and expected future developments

https://annex75.iea-ebc.org/publications

5. Outputs

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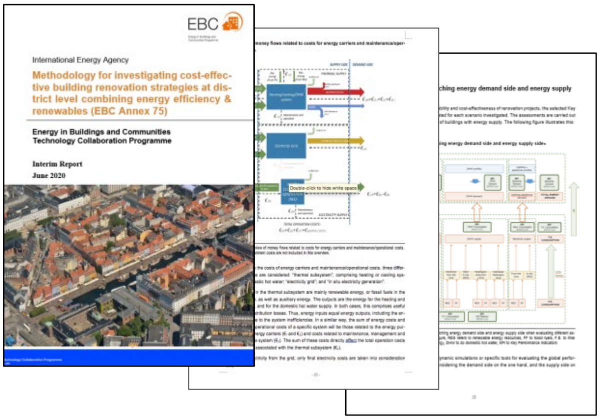
Methodology Report



The report describes the methodology for identification and assessment of cost-effective strategies for renovating urban districts:

- Defines the boundary conditions for the assessments
- Presents the recommended approach for the assessments
- Presents the main research questions to be investigated
- Defines the outputs to be generated in the analyses

This document intends to support decision makers in the evaluation of the efficiency, impacts and cost-effectiveness of different strategies for renovating urban districts

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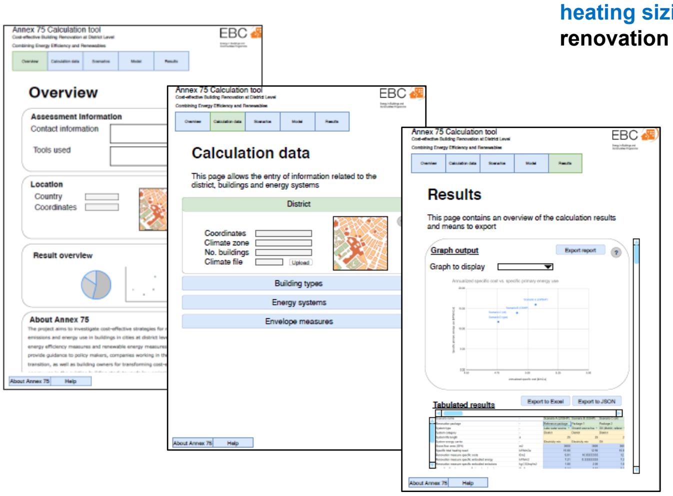
Annex 75 District Calculation Tool

Online calculation tool for district heating sizing and cost-effectiveness of renovation strategies



- characteristics of the district
- characteristics of the buildings
- renovation scenarios
- cost curves
- …

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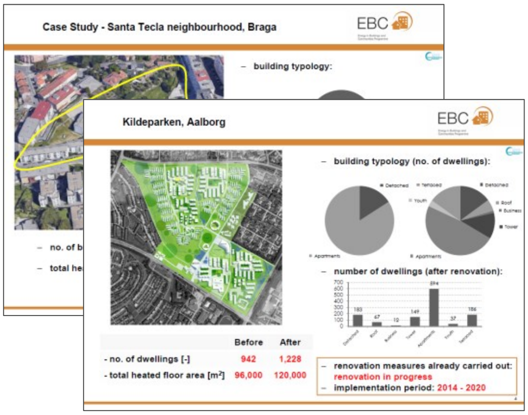
Identification of Success Stories and Case Studies



Success Stories – already finished district-based renovation projects

where economic, technical and social factors that enable or hinder successful renovations were identified and analysed

Case Studies – open renovation projects used to apply and test the Annex 75 Methodology

There is still the possibility to provide guidance in choosing the most appropriate renovation strategies especially in finding synergies and trade-offs for combining energy efficiency measures and renewable energy measures

Results obtained and lessons learned are used to prepare a good practice guidance for low-energy and low-emission districts

5. Outputs

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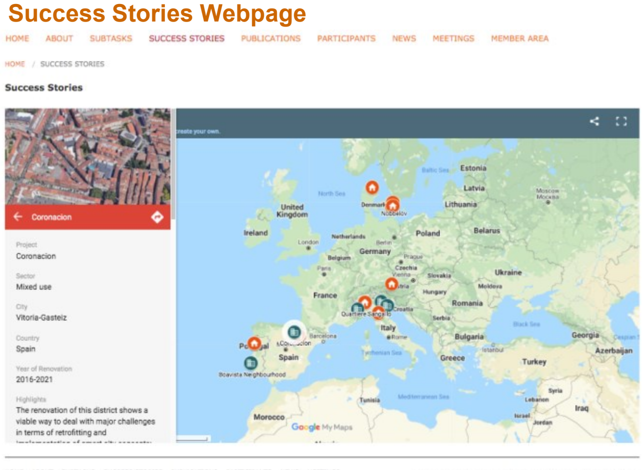
Success Stories Webpage



Interactive map integrated in the Annex 75 website.

https://annex75.iea-ebc.org/success-stories

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Renovation at district scale is a cost effective key strategy to boost the reduction of CO2 emissions

by optimising the implementation of renewable energy sources and taking advantage of economies of scale and higher levels of efficiency regarding the use of resources and waste minimization

Table 2 (*continued*)

Coronación district, Spain (320 dwellings + 5 tertiary buildings) ***ES1***

Areas [m²]	Energy use [kWh/m²y]	before	after
District	Heating	151	70
89 100	DHW	Included in heating	
Heated floor	Cooling	0	0
49 187	Renewable energy (m²)	0	0

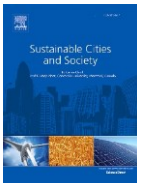
This project is part of SmartEnCity, a project funded under the European Union's Horizon 2020 in which Vitoria-Gasteiz is one of the three lighthouse demonstrator cities. The intervention consisted of the thermal renovation of 320 dwellings and the installation of a new district heating system based on biomass boilers (wood chips). An integrated energy management system will optimise efficiency at dwelling, building and district level. The project was partly financed (up to 54%) by different public institutions; in some cases (households with low incomes), the regional government cover up to 100% of the cost.

Lourdes Neighbourhood, Spain (486 dwellings) ***ES2***

Areas [m²]	Energy use [kWh/m²y]	before	after
District	Heating	90	46*/24**
22 500	DHW	Included in heating	
Heated floor	Cooling	0	0
40 448	Renewable energy (m²)	0	0

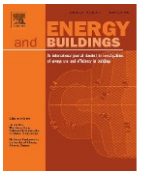
* Non-renovated buildings
** Renovated buildings

This project responds to the need to promote the integral renovation of this deprived social housing area and the upgrade of the inefficient district heating system (80% renewables with biomass) as well as the improvement of thermal envelopes of only three blocks. The project was framed within a CONCERTO Programme and subsidies and the favourable financing opportunities played an important role in the successful implementation of the intervention. This success is moving other neighbours into action and a second redevelopment project in the district is currently under development, promoting the renovation of thermal envelopes of the rest of the blocks.



Building renovation at district level – Lessons learned from international case studies
May 2021

https://doi.org/10.1016/j.scs.2021.103037



Cost-effective building renovation at district level combining energy efficiency & renewables - Methodology assessment proposed in IEA EBC Annex 75 and a demonstration case study
October 2020

https://doi.org/10.1016/j.enbuild.2020.110280

Drives, Barriers and Lessons Learned were identified

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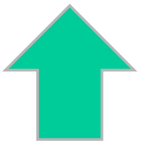
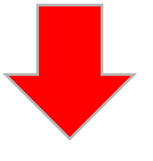
Cost-Effective Building Renovation at District Level

Drivers



- **Energy savings and emission reductions**
- **Improving the overall building quality, including indoor climate**
- **Improving the image and the economic value of the district**
- **Financial models that can alleviate split-incentive problems between investors and resident organizations**

Barriers



- **Need to comply with the increasingly demanding energy regulations**
- **Restrictions in the renovation scope to avoid a clear increase in the rent**
- **The resettling of tenants during the renovation**

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Preliminary Lessons Learned regarding key factors for district scale renovations

- **Available funding** is a decisive factor in carrying out district scale renovations
- **Good communication** amongst the different stakeholders, especially with residents
- **Strong leadership** to coordinate activities due to the great number of stakeholders
- **Citizen engagement**
- **Existence of pilot projects** to demonstrate the possibilities
- **Availability** of not only **technical solutions** but also **business and financing models**
- **Availability of local policy instruments** to assist local uptake and co-creation in municipalities, cities and regions

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Workshops on Policy Instruments, Stakeholder Dialogue and Business models for upscaling District energy renovation


Workshop at Bilbao – March 2019


Workshop at Delft – October 2019

With insights from the **workshops** and **interviews**, a **report** is being prepared:

- To **give an overview** on various **policy instruments** and **business models** at the district level
- To **evaluate stakeholder's acceptance** of the proposed policy instruments
- To **illustrate the development** and **assessment** of **innovative local policy instruments** in selected cases
- To **give recommendations** to **policy makers** and their **key partners** on how they can **influence the uptake** of cost-effective low carbon renovation strategies

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Thank you for your attention!

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IEA EBC Annex 75 Subtask D: Policy Instruments, Business Models & Stakeholder Dialogue

Dr. Erwin Mlecnik
Subtask D leader, TU Delft, The Netherlands

11th June 2021

Objective

- Give recommendations to policy makers and building owners about how they can influence the uptake of cost-effective combinations of energy efficiency measures and renewable energy measures in building renovation at district level.
- Research approach:
  - Innovative local policy instruments (catalogue)
  - Emerging business models (catalogue)
  - Stakeholder research (in-depth interviews)
  - Guidelines

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Stakeholders

- ➢ Different starting conditions in various countries/ regions/ municipalities
- ➢ Different roles, influence, power and interest levels per stakeholder/ project

P. Policy actor	C. Client or beneficiary/ demand actor	F. Financing intermediary	E. Energy solution provider	R. Renovation solution provider	I. Other intermediaries
o Municipality or city o County council o Provincial/ regional government o Federal/ national government body o Other, namely:.. o Public agency or institute: Innovation agency, Energy agency, Public service, Educational institute, Research institute, Other:..	o Private owner or assembly thereof: Private owner, homeowner assembly, housing cooperative or co-housing, other:.. o Housing association or company: Private housing actor or real estate company, public or social housing actor, semi-public or mixed, other:..	o Bank o Investment fund operator o Real estate development company o Project development company o Building portfolio manager o ESCO o Other:…	o Distribution system operator (DSO) o Transmission system operator (TSO) o Energy supply company o Energy service provider o Renewable energy company o Heat grid	o Planning and construction party, o Urban planner o Architect o Design team o General contractor o Subcontractor o Supplier of products or technologies o Supplier of concepts or systems o Facility manager o Installer o One-stop-shop o Other:…	o Federation of local authorities, suppliers, contractors, architects, homeowners, renters, building owners, other:… o Trade organization o Not-for-profit organization o Neighborhood interest association o Private actor contracted as intermediary process actor: Neighborhood communication agent, business model developer, consultant, other:… o Other:…

- District action requires a collaboration of multiple types of stakeholders
- Municipalities can lead or facilitate development of common understanding and stakeholder dialogue

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Business models

- ➢ Various archetypes of business models (atomised, market intermediary, one-stop-shop or service contract) depending on the business model owner
- ➢ Business approaches for energy renovation don't mix (yet) with those for energy supply
- ➢ Growing complexity of business model when targeting geographical areas

- Complementary innovative business models & stakeholder collaboration are key to achieving district level action
- Growing support for service intermediaries and motivated cooperatives (sometimes excluded for funding options)

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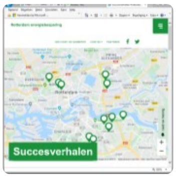
Policy instruments

- ➢ Similarities and differences in perceived use, difficulty & easiness
- ➢ Different starting conditions in various countries/ regions/ municipalities

- Sticks: adapted permits, control of living conditions, carbon pricing schemes, requirements for sale and rent of municipal land,..
- Carrots: tax incentives, support for group purchases and cooperatives, coaching and unburdening of multiple homeowners at the same time,..
- Organizational instruments: strategy development, tactical plans, online and offline services and communication,..



Source figures: Interreg 2 Seas Triple-A project

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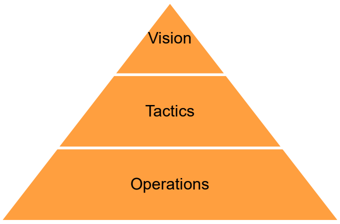
Recommendations



- Combine (developing) heat plans, (still largely missing) building stock renovation plans, and (emerging) climate management plans
- Create or use integrated supply, intermediaries and local networks; support combinations of innovative business models
- Staff a consulting infrastructure and stakeholder dialogue in promising districts

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Thank you for your attention!

Contact

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Interreg
2 Seas Mers Zeeën
Triple-A