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On-site performance assessment of buildings

IEA EBC Annex 71 and related activities

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IEA EBC Technical Day
Activities of IEA TCP on Energy in Buildings and Communities
June 11, 2019 - Brussels, Belgium

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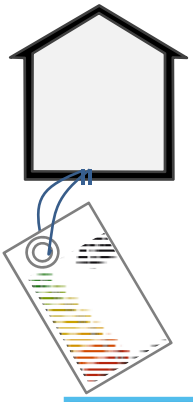
Today: theoretical approach

Energy performance of buildings estimated using simulation software, EPB and EPC

building plans and specifications

building delivery

energy labelling



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As-built thermal quality
Some global figures

design > < actual

Building envelope parts: +10% to + 400%
Whole building: +10% to +120%

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Lack of measurment-based verification and optimisation is **costly!**

single-family house

x0.000

office building, appartment building, ...

x00.000

business park

x.000.000

additional energy cost[3] of a 25% discrepancy

EU space heating load[1,2]

x0 billion EUR *... or about 5% of yearly energy imports*

1: spaces heated by building-own specific heating systems; does not include buildings heated by district heating or similar.
2: source: Average EU building heat load for HVAC equipment (http//ec.europa.eu/energy/sites/ener/files/documents/2014_final_report_eu_building_heat_demand.pdf)
3: These figure ignores the initial investment, e.g. in insulation works, that turns out ineffective.

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Today no real quality check 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?

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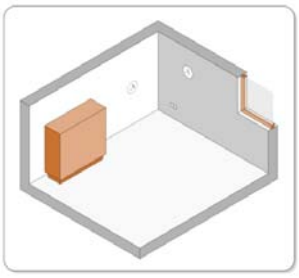
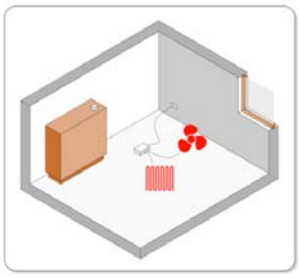
As-built thermal quality check

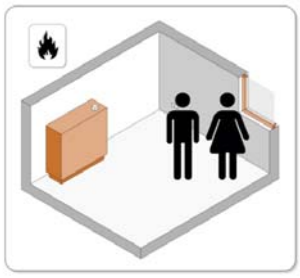
Three options



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

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Option 1. R-value / U-value test

Estimate local as-built thermal resistance of a building element, based on surface temperatures measured at either side and the heat flux measured at one side

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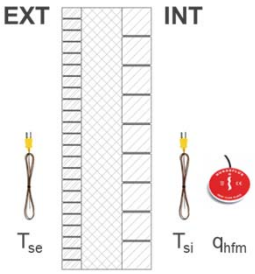
On-site characterisation of thermal resistance



THERMAL RESISTANCE

$$R = \frac{\Delta T_{si-se}}{q_{hfm}}$$

under stationary conditions

Semi-stationary methods

Average method (ISO 9869)

$$R = \frac{\sum_{j=1}^{n} \Delta T_{si/se,j}}{\sum_{j=1}^{n} q_{hfm,j}}$$

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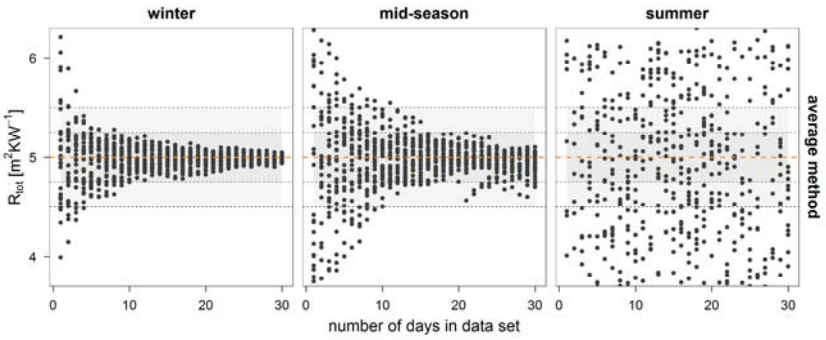
ISO 9869: Average method

Apply only in winter



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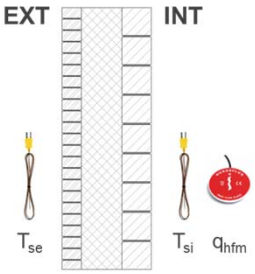
On-site characterisation of thermal resistance

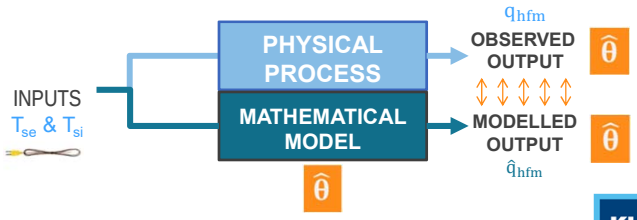


Semi-stationary methods

Average method (ISO 9869)

Dynamic methods

ARX-models
Anderlind's method
Grey box models



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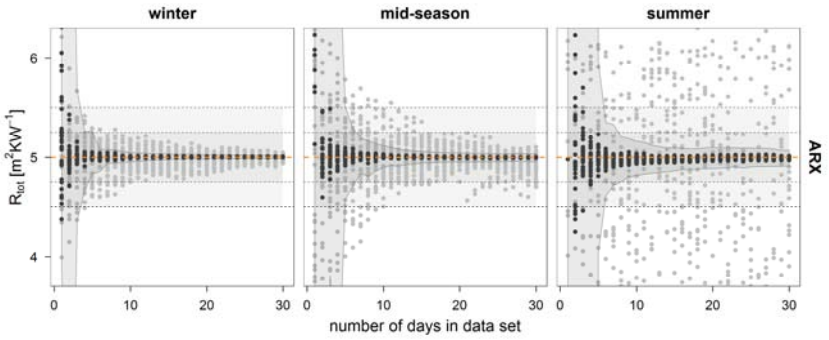
Dynamic models

Apply all year



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Option 2. Specific heating test

Estimate global as-built heat transfer coefficient H of a building envelope, based on measurements of indoor and outdoor climatic conditions and delivered heating power, during a specific stationary or dynamic heating experiment

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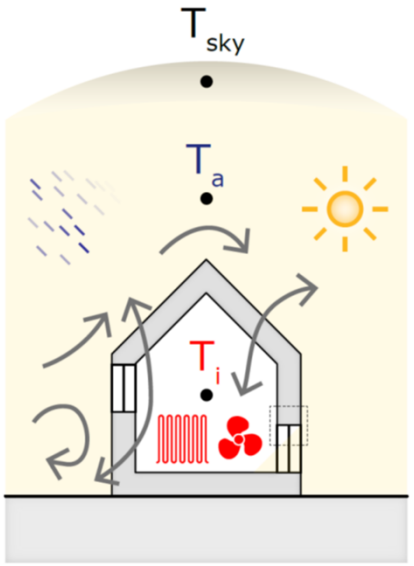
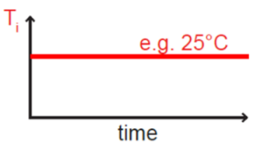
Co-heating test



Quasi-stationaire test:



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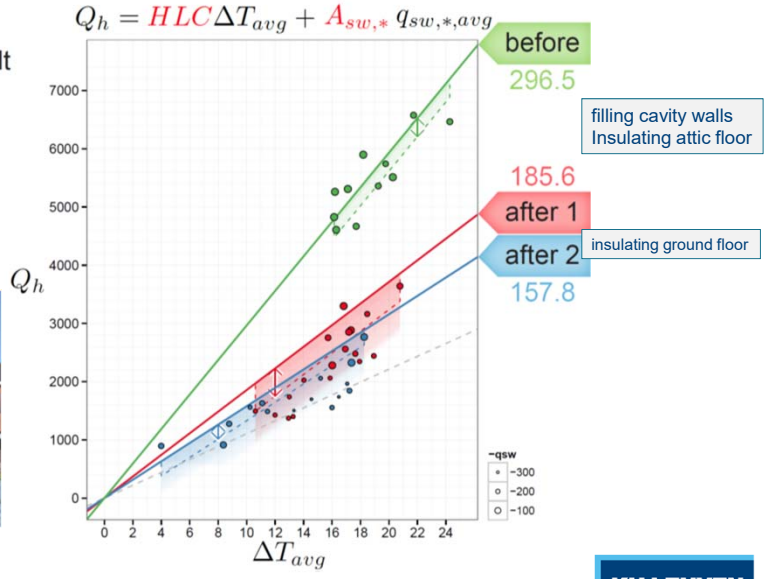
Analysis result

$$Q_h = HLC\Delta T_{avg} + A_{sw,*}\, q_{sw,*,avg}$$



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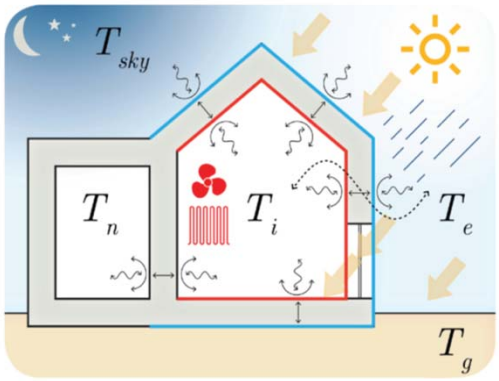
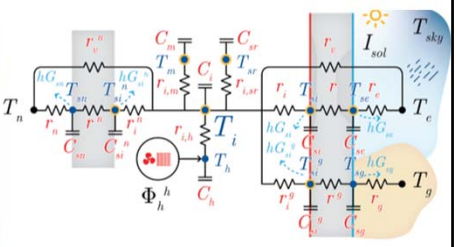
Modelling buildings as dynamic thermal systems





$$C_i \frac{dT_i}{dt} = \Phi_h + \Phi_{sol} + \Phi_l + \Phi_{tr} + \Phi_v + \Phi_m + \Phi_{sr}$$

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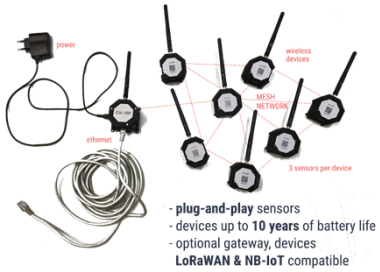
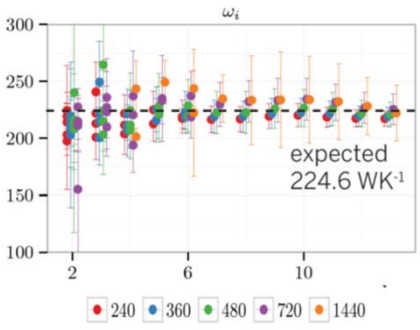
Detached house in Verlaine



- **plug-and-play** sensors
- devices up to **10 years** of battery life
- optional gateway, devices **LoRaWAN & NB-IoT** compatible

Measurement campaign of +7 days (sampling time of 6 hours) determines the overall HLC with +- 2.5% accuracy



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Option 3. On board test

Estimate global as-built heat transfer coefficient H of a building envelope, based on measurements of indoor and outdoor climatic conditions, building energy use and user behaviour, during normal operating conditions

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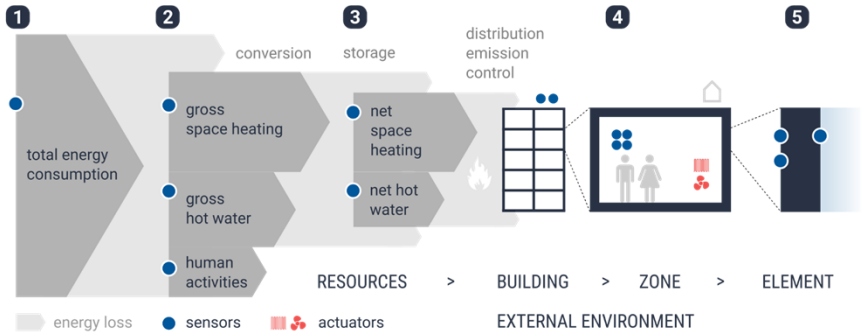
Great potential



Non-intrusive

Feedback on energy performance of **buildings in use**

Estimate expected energy savings

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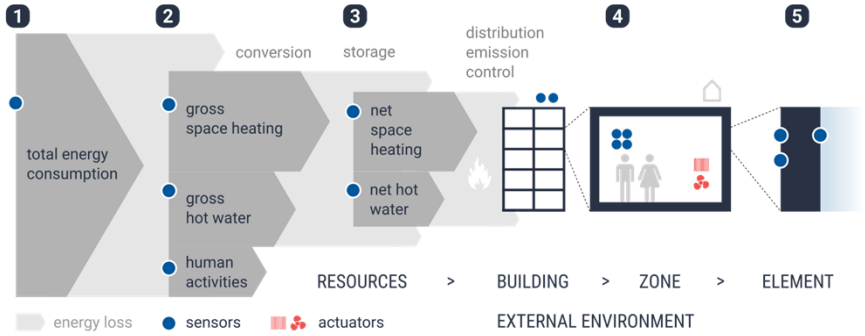
Great potential, but not easy…



No control on experiments
Comfort requirements of the users
Insulation quality, efficiency systems and **impact of users**

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Current IEA EBC project: Annex 71

HOME EBC STRATEGY PUBLICATIONS PROJECTS CONTACTS

HOME / PROJECTS / ANNEX

ONGOING PROJECTS
COMPLETED PROJECTS
PROJECT BY THEME
WORKING GROUPS

EBC ANNEX 71
Building Energy Performance Assessment Based on In-situ Measurements

Status: Ongoing (2016 - 2021)

Operating Agent
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Kasteelpark Arenberg 40
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BELGIUM
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Website: www.kuleuven.be/bwf/projects/annex71

Overview

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IEA EBC Annex 71-project
Different test cases



On-site measured data is used for:

- calculation of the actual overall heat loss coefficient
- development of fault detection diagnostics methods
- blind validation of BES-models

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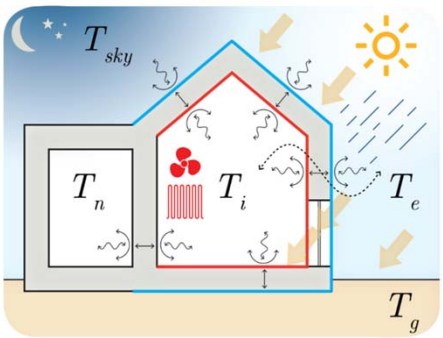
Determination of the overall HLC

Estimate global as-built heat loss coefficient HLC,
based on measured data during normal operating conditions

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



HLC ?

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

HLC

Exploration of different methods:

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

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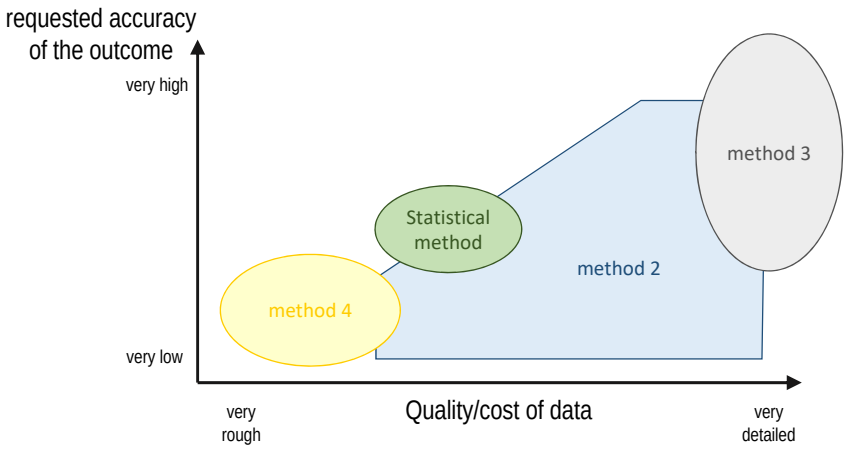
Looking for the sweet spot



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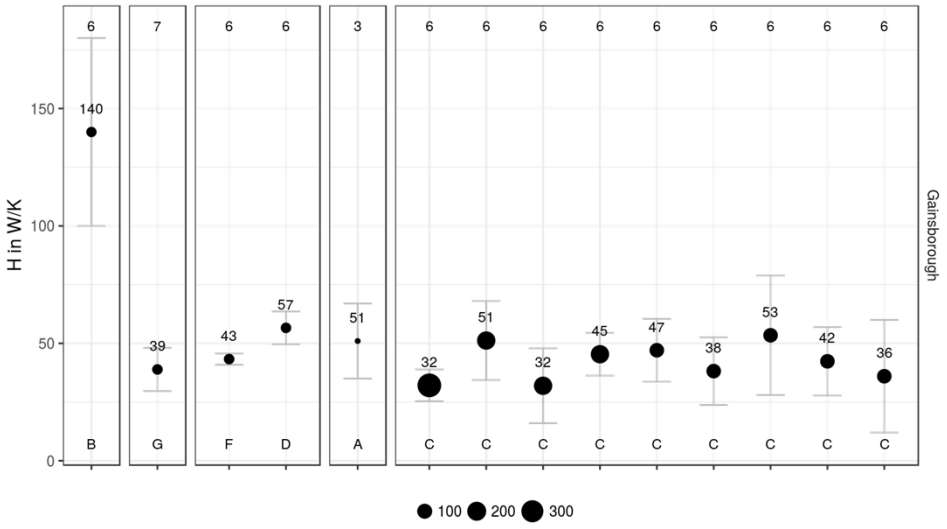
Gainsborough case



A: Bayesian - MCMC, B: BEECHAM, C: Linear regression, D: ARX, E: Average, F: RC (LORD), G: Grey-box (CTSM-R)

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Conclusions

- It is essential that the energy-efficient technologies used in buildings do more than simply satisfy regulations based on theory.
- Building owners, investors and governments need to know that the investments they make are actually delivering as expected.

Ensuring that real performances match design performances is crucial.
This requires reliable methods and procedures applicable on real life data.

- The as-built thermal quality can be fast and accurately estimated

  Locally with **option 1**: analysed using ARX models or grey-box

  Globally with **option 2**: co-heating test analysed with linear regression, dynamic test analysed with grey-box modeling or ARX models

  And hopefully soon globally with **option 3**!

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Thank you for your attention!

Acknowledgement to:
Geert Bauwens, An-Heleen Deconinck

CHARP

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