Seminar

Real building energy performance assessment

Wednesday 16 April 2014 - 14:00-18:00 – Gent, Belgium

Presentations

The seminar is organised by the DYNASTEE platform (www.dynastee.info) which is facilitated by INIVE (www.inive.org), in the framework of the IEA Annex 58 6th international expert meeting in Geent. The practical organisation is in the hands of University Ghent and BBRI, under the auspices of the Technical Committee Hygrothermics.

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Energy in Buildings and Communities Programme

The energy performance of a building is essentially determined by the (1) thermal characteristics of the building envelope, (2) installed services and (3) building usage. As the latter is not easily predicted nor controlled, the first two are decisive in achieving the envisaged building energy performance, both for new buildings and renovations.

The theoretical energy use calculated on the basis of building plans and specifications, in order to meet building regulations or specifications by the builder, determines the anticipated performance.
It may differ, however, from the actual 'as-built' performance in a significant way.
The IEA EBC Annex 58-project on ' Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements' is working on this gap between actual and calculated performance of the building. A consortium of researchers and industries from 15 countries are developing knowledge, tools and networks to achieve reliable in-situ dynamic testing and data analysis methods that can be used to characterise the actual thermal performance and energy efficiency of building components and whole buildings.

This seminar gives an overview of the current knowledge in the field of energy performance assessment. It aims also at looking into the future of new applications and answers how to close the gap between calculated and real performance.

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The seminar is open to all professionals interested in the real performance characterization of buildings.

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About Dynastee

Dynastee is a platform of information exchange on dynamic analysis, simulation and testing of the energy performance of buildings. Dynastee is closely linked to the activities of the IEA ECB Annex 58 project; it is responsible for the subtask on dissemination and the Network of Excellence. This is done through activities such as training of researchers on dynamic methods (Summer School), bringing its expertise from earlier projects (PASSYS-PASLINK) into the Annex 58 project, publication of a newsletter and a website, and organising workshops and webinars.

About INIVE

INIVE EEIG (International Network for Information on Ventilation and Energy Performance) a European Economic Interest Grouping has 11 member organisations (BBRI, CETIAT, CIMNE, CSTB, ERG, ENTPE, IBP-Fraunhofer, SINTEF, NKUA, TMT US and TNO) (www.inive.org).

INIVE is coordinating and/or facilitating various international projects, e.g. the AIVC (www.aivc.org), the European portal on Energy Efficiency (www.buildup.eu), TightVent Europe (www.tightvent.eu), Venticool (www.venticool.eu) and Dynastee (www.dynastee.info)

Programme

Wednesday 16 April 2014 - 14:00-18:00

1. **The IEA EBC Annex 58-project on 'Reliable Building Energy Performance Characterisation Based on Full Scale Dynamic Measurements'**
   Staf Roels, KULeuven, Operating Agent Annex 58
   The Annex 58-project tries to develop the necessary knowledge, tools and networks to achieve reliable in-situ dynamic testing and data analysis methods that can be used to characterise the actual thermal performance and energy efficiency of building components and whole buildings.

2. **The gap between calculated and real performances: Experiences from the laboratory and field and the measures to address the difference**
   Chris Gorse, Leeds Sustainability Institute, UK
   The co-heating test has become the accepted method of acquiring thermal building performance data in the field. Much has been gained from the research exploring heat loss and the factors that have contributed to the performance gap provide a body of knowledge that inform element, junction and whole building design. The different tests will reveal different characteristics of performance and behaviour that will continue to build on the knowledge already amassed. The situation has changed from one that denies the performance gap, to one that now has the tools to address the change required.

3. **State of the art on test facilities and data analysis methods**
   Arnold Janssens, UGent
   The presentation gives an overview and evaluation of previous and ongoing in situ test activities to characterize energy performance of building components and whole buildings. Examples of full scale test facilities available at different institutes all over the world are presented. An overview is given of common methods to analyse dynamic data, with their advantages and drawbacks.

4. **Standardisation of methods for in-situ performance assessment**
   Gilles Flamant, BBRI
   Since 2010, working group 13 of CEN TC89 is working on the elaboration of new standardized procedures for deriving in-situ test data that will complement the thermal performance characteristics of construction products, building elements and structures established by conventional steady state methods. This presentation gives the objectives, the work progress, the difficulties encountered, the issues and possible solutions considered.

5. **Co-heating test: a state-of-the-art**
   Geert Bauwens, KULeuven
   An overview of the current state of the art of the co-heating test, as it is applied to assess the thermal characteristics of the building envelope. Focus lies more on data analysis methodology, not so much on the experimental equipment and setup and subsequent data collection.

Coffee break

6. **Experiences with in situ measurements**
Frédéric Delcuve, Knauf Insulation, Belgium
Knauf Insulation recently launched a co-heating test initiative to investigate the real-world performance of a thermal renovation process. One of the tests was conducted using a terraced house located near Liège, Belgium. Co-heating testing not only provides a consistent and repeatable means to test the real-world effects of a given type of insulating product, it also helps to identify and understand the discrepancy between real and expected performance.

7. **Reliability of characterisation models and methods: A Round Robin Experiment on a test box**
Staf Roels, KULeuven and Maria José Jimenez, CIEMAT, Spain
The research within the IEA EBC Annex 58 project is driven by case studies. As a first simple case, an experiment on testing and data analysis is performed on a round robin test box. This test box can be seen as a scale model of a building, built by one of the participants, with fabric properties unknown to all other participants. Full scale measurements have been performed on the test box in different countries under real climatic conditions. The obtained dynamic data are distributed to all participants who tried to characterise the thermal performance of the test box's fabric based on the provided data. It is shown how different techniques can be used to characterise the thermal performance of the test box, ranging from a simple stationary analysis to advanced dynamic data analysis methods.

8. **Dynamic building envelopes: testing, analysis and simulation**
Hans Bloem, JRC, Italy
The energy performance assessment of dynamic building envelope elements has to be based on declared and designed performance values and importantly be verified by in-situ measurements.
A common approach for testing, analysis and simulation of dynamic building envelopes is required.

9. **A view on the future, characterization based on smart metering data**
Henrik Madsen, P. Bacher, H. Aalborg Nielsen, S.B Mortensen, DTU, Denmark
In the near future frequent readings of the energy consumption will be generally available given the use of smart meters. This talk describes statistical methods for use of such time series data, jointly with meteorological time series data, to obtain valuable information about the thermal performance of buildings. Specifically smart meter data can be used in automated systems for a continuous screening of the city for identifying the buildings with the most critical energy efficiency. Subsequently the methods can be used for identifying the potential problematic aspect of the critical buildings. Hence these methods provide a systematic approach for maximizing the performance gains obtained given a certain investment allocated for an upgrade of the energy efficiency.

10. **Final discussion and conclusions**

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IEA EBC Annex 58

Reliable building energy performance characterisation based on full scale dynamic measurements

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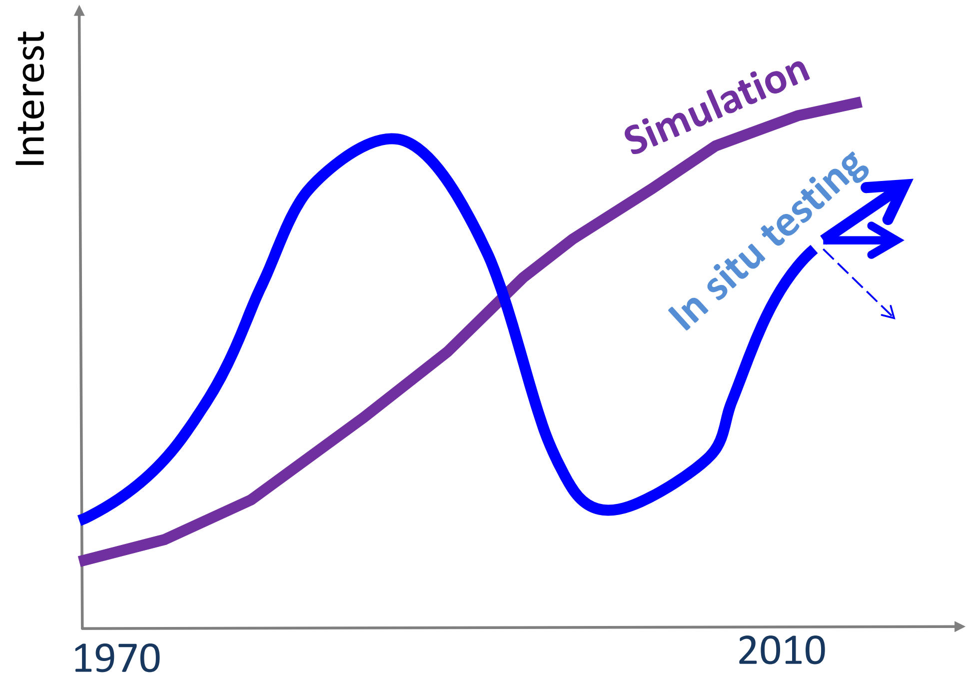
Real building energy performance assessment

Workshop@UGent __ April 18th , 2014

EBC Annex 58

6th expertmeeting at UGent:

Background: Renewed interest in full scale testing



Possible explanations for renewed interest:

- Full scale dynamic testing can help to **validate our calculation tools** (building energy simulation models). This becomes more important when moving towards nZEB

- Full scale testing allows to investigate the **performances in reality** (including workmanship)

- Full scale testing can be used to assess the **representativity of laboratory** testing (e.g. thin reflective foils)

- Full scale testing is a necessary tool to **characterise** advanced components and systems and to **evaluate** nearly zero energy buildings

EBC Annex 58

Background

Measurements of thermal performance of newly erected dwellings in UK:
measured vs. predicted overall heat losses (W/K)

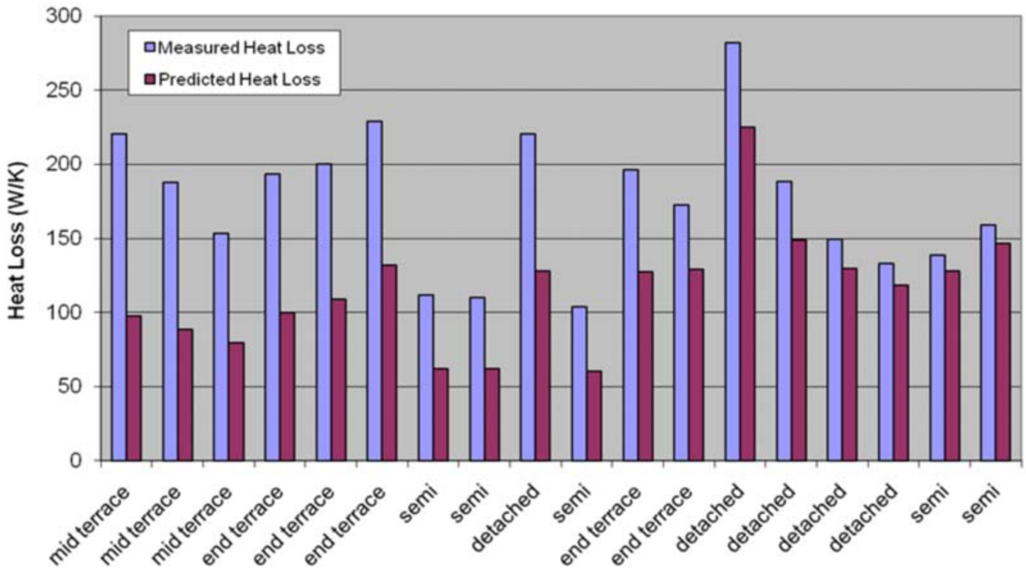


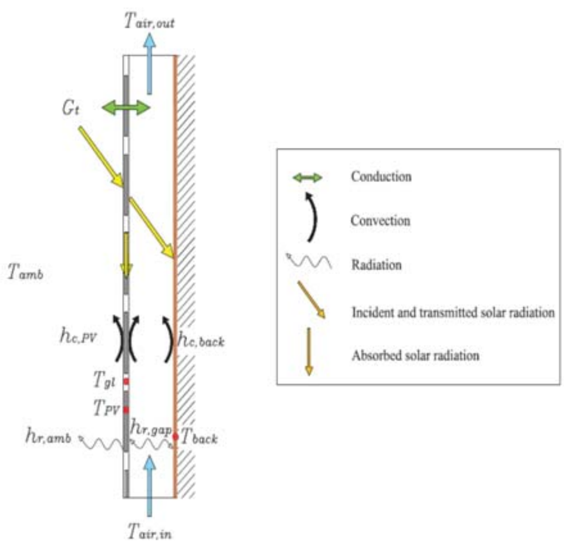
Figure from [Wingfield et al., 2011]

Full scale testing is essential to characterise the real thermal performance of buildings

EBC Annex 58

Background

Measurements at CIMNE (Lleida, Spain):
analysis of dynamic thermal response of ventilated photovoltaic double skin facade

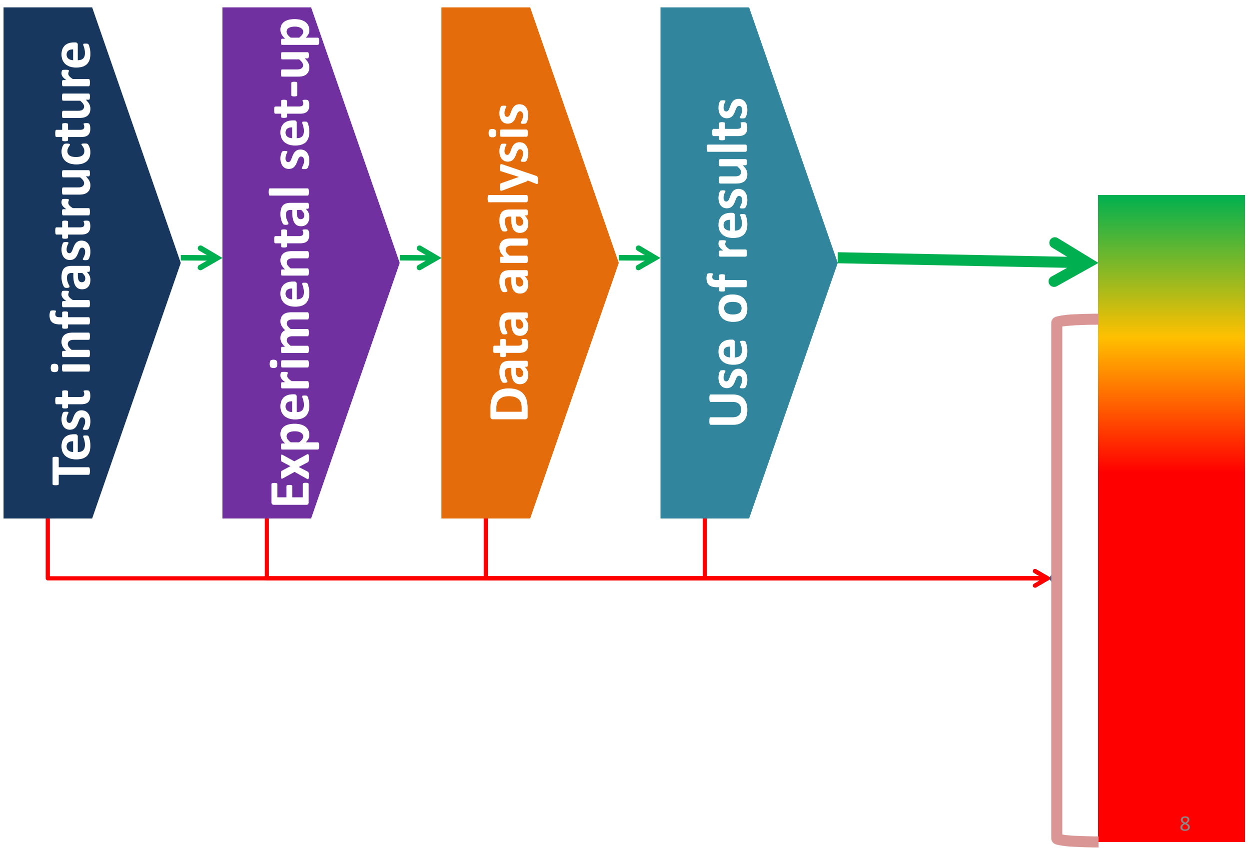


Full scale testing is essential to integrate the behaviour of new advanced building components in a correct way in BES-models

Measurements at IBP (Fraunhofer, Germany):
Common exercise within IEA EBC Annex 58: dynamic response of buildings

Full scale testing is essential to verify our current BES-models

Full scale testing requires quality!



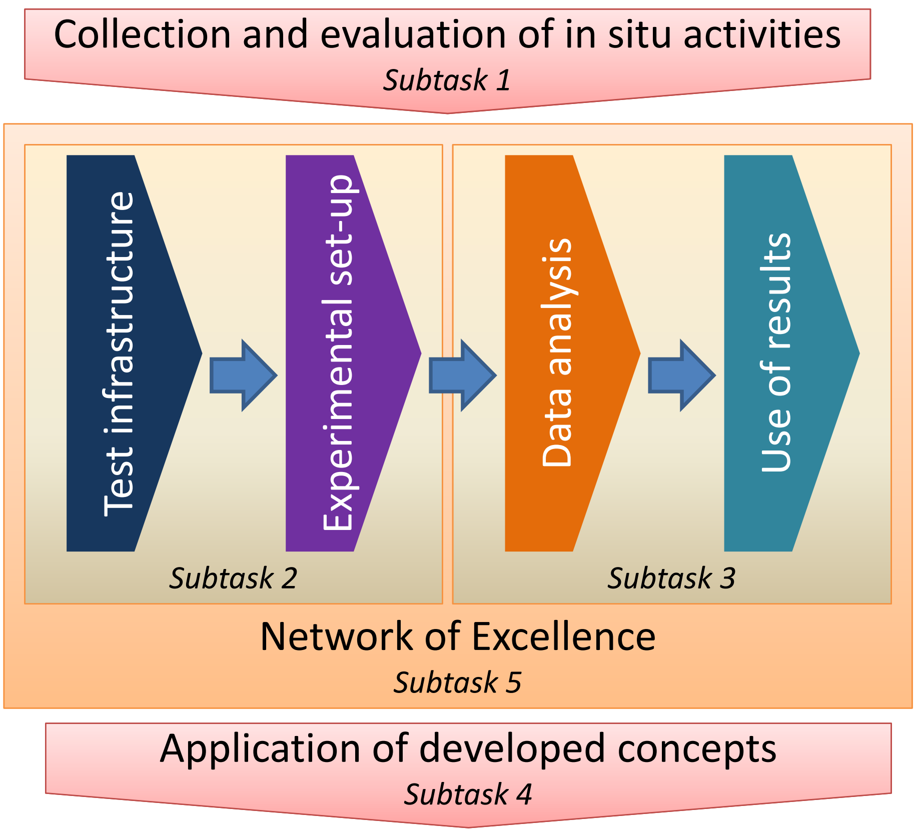
Objectives

IEA EBC Annex 58

Reliable building energy performance characterisation based on full scale dynamic measurements

- Determine the actual energy performance of buildings
- Characterise the dynamic behaviour of buildings (grey box models)
- Validate our numerical BES-models
- Guarantee quality of measurements / data analysis / use of the results

Structure of Annex 58



The Gap Between Calculated and Real Performance

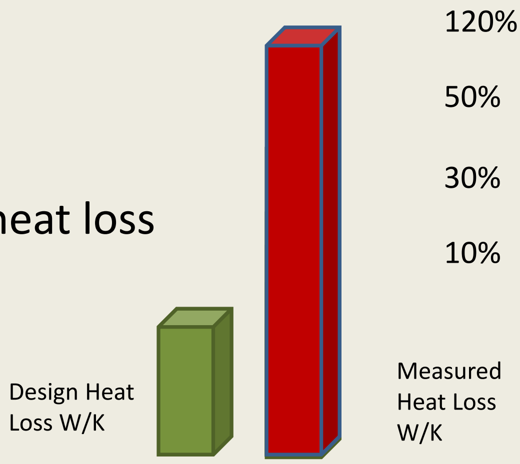
Professor Chris Gorse

Leeds Sustainability Institute

Leeds Metropolitan University

Solving the Performance Gap

- The difference between
  - Design prediction
  - Measured values
- Measured whole building heat loss
- Solutions exist



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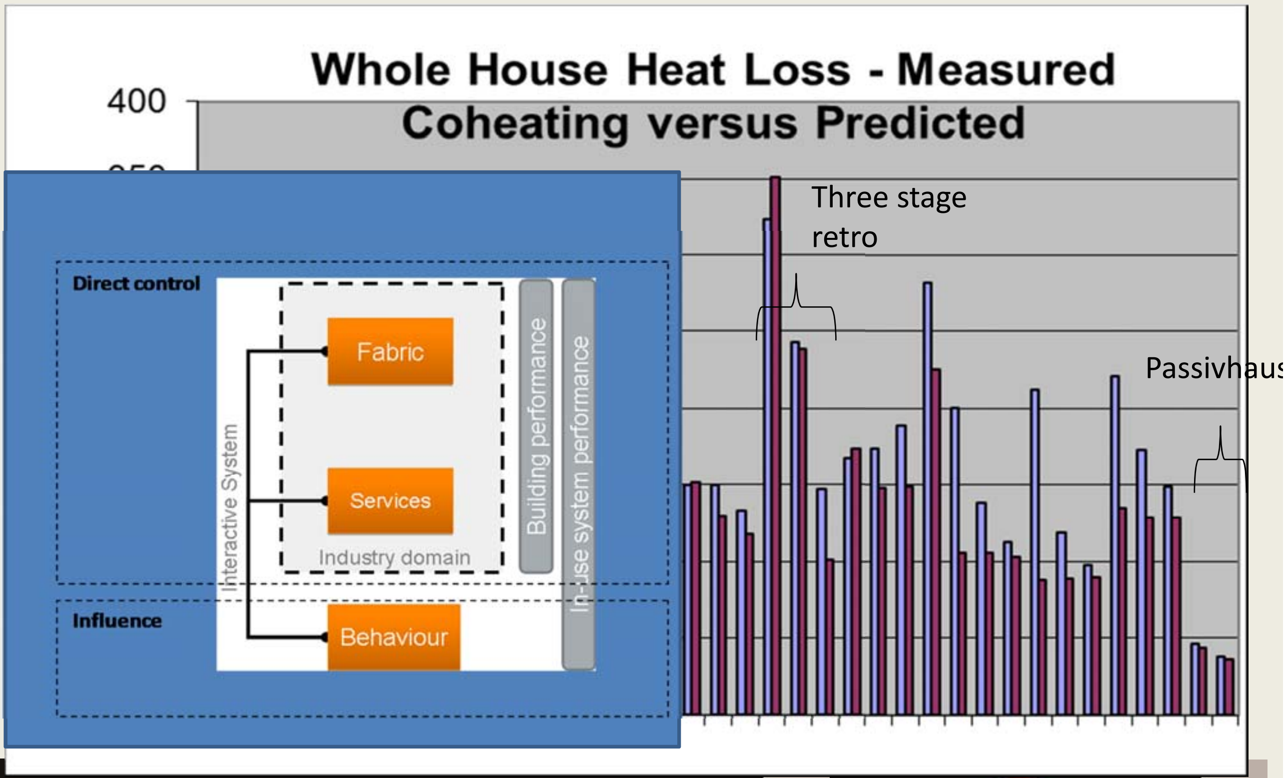

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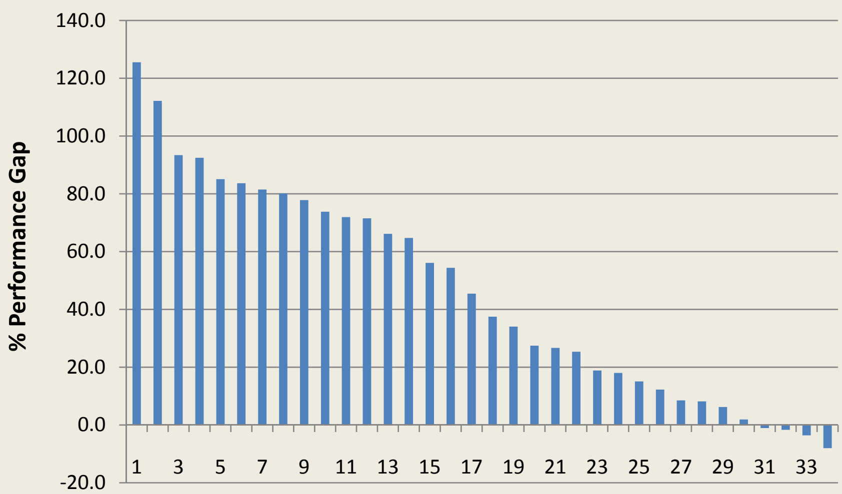
Reducing Tolerance & Improving confidence



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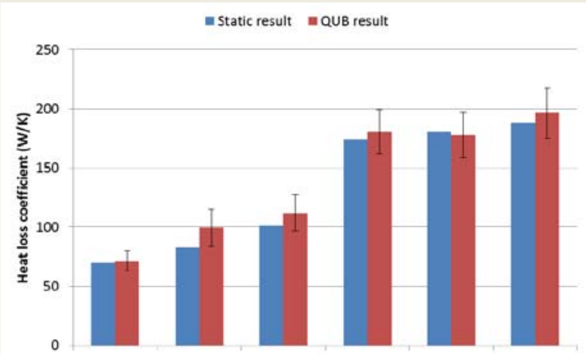
Reliability and Validity:

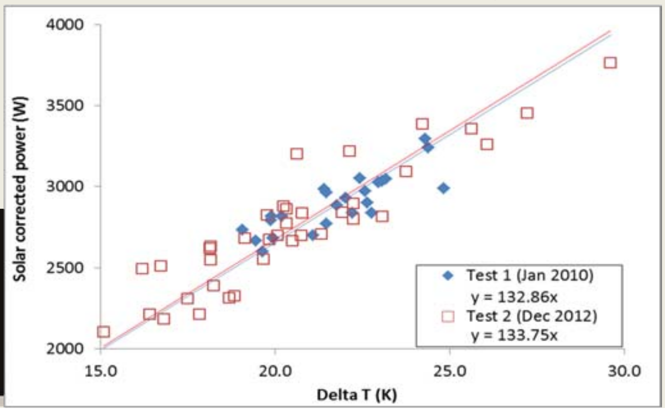
Unique opportunity to cross check methods

- Initial test on field house 132.9 (± 1.5) W/K
- Repeat test after 35 months 133.8 (± 1.9) W/K

  <1% difference, independent sample T test of 24 hour solar corrected HLC no significant difference (P=0.432)
- Leedsmet Steady state and Saint Gobain QuB

  <2% difference



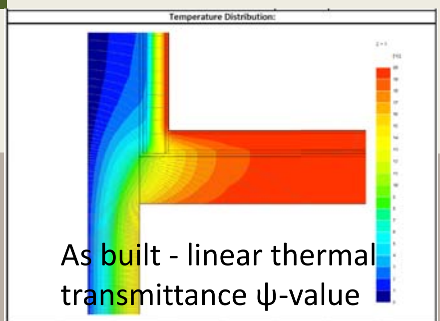


Closing the loop

Full retrofit	Retrofit original floor	Solid wall insulation	Replacement glazing	Loft insulation	Min thermal upgrade
69.7 W/K	82.7 W/K	101.2 W/K	174.2 W/K	180.5 W/K	187.5 W/K

63% Heat loss reduction
£348

If there is a gap which building elements and junctions are responsible



As built - linear thermal transmittance ψ-value

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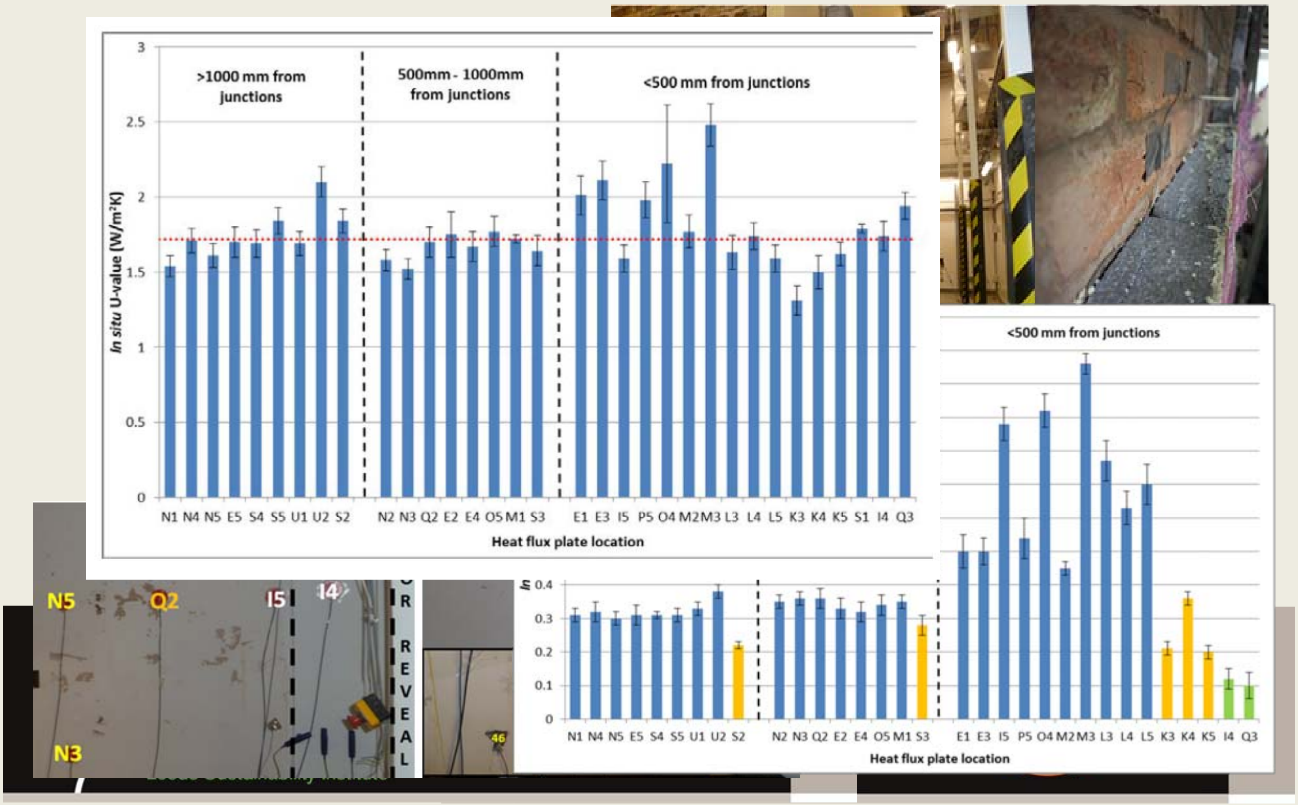
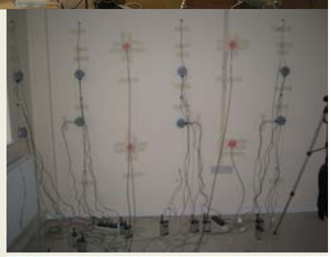
Proximity to junctions and plane elements



Building Forensics

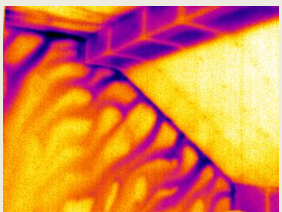
Pressurisation testing

Surface/cavity temperature measurement

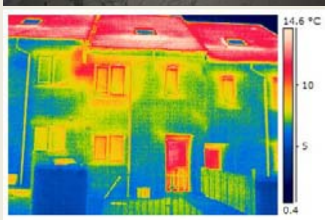


Tracer gas measurement

Heat flux measurement



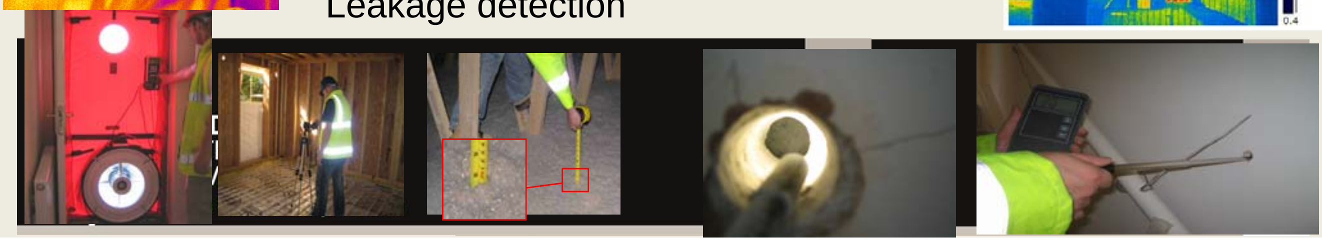
Construction observations



Thermal imaging

Air flow measurements
Leakage detection

deconstruction



Coheating is not always appropriate

Table 1 Pressurisation Test Results: poor results post intervention

Test no.	Date	Depressurisation Only			Pressurisation Only			Mean	
		Air Permeability	Air Change Rate	r^2	Air Permeability	Air Change Rate	r^2	Air Permeability	Air Change Rate
		m³/(h.m²) @ 50 Pa	h^{-1} @ 50 Pa		m³/(h.m²) @ 50 Pa	h^{-1} @ 50 Pa		m³/(h.m²) @ 50 Pa	h^{-1} @ 50 Pa
01	30-Sep-13	22.87	28.39	0.999	25.27	31.37	0.997	24.07	29.88
02	21-Oct-13	23.78	29.53	0.999	25.34	31.45	0.998	24.56	30.49
03	02-Apr-14	19.45	24.15	0.999	20.97	26.03	0.998	20.21	25.09

Notes: Test 01 and 02 were performed at the start and end of the pre-refurbishment coheating test, test 03 conducted during the heat-up stage of the post-refurbishment coheating test.

Workmanship and design ?

Table 2 Pressurisation Test Results: reasonable and good results post intervention

Property	Date	Depressurisation Only			Pressurisation Only			Mean	
		Air Permeability	Air Change Rate	r^2	Air Permeability	Air Change Rate	r^2	Air Permeability	Air Change Rate
		m³/(h.m²) @ 50Pa	h^{-1} @ 50Pa		m³/(h.m²) @ 50Pa	h^{-1} @ 50Pa		m³/(h.m²) @ 50Pa	h^{-1} @ 50Pa
16 HV (contractor retrofit)	11-Mar-13	19.14	22.82	0.992	19.27	22.96	0.994	19.21	22.89
	14-May-13†	12.96	15.45	0.998	13.60	16.21	0.999	13.28	15.83
	21-Nov-13	11.48	13.69	0.999	12.70	15.13	0.998	12.09	14.41
18 HV (system retrofit)	11-Mar-13	Unable to completed test due to incomplete air barrier, leakage detection only.							
	21-Nov-13	7.31	8.71	0.991	7.47	8.90	0.997	7.39	8.80
	28-Nov-13	4.70	5.61	1.000	4.76	5.68	1.000	4.73	5.64

†Additional temporary sealing applied around the cellar door.

Dwellings tested in original state, at initial air barrier completion, at finished state.

Same design different levels of workmanship?

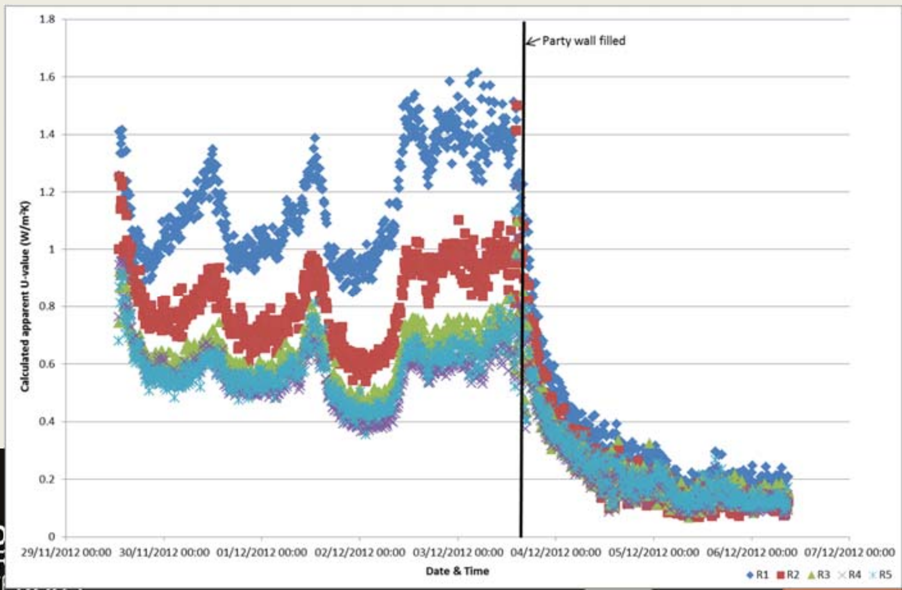
Table 3 Pressurisation Test Results: good results post intervention

Property	Date	Depressurisation Only			Pressurisation Only			Mean	
		Air Permeability	Air Change Rate	r^2	Air Permeability	Air Change Rate	r^2	Air Permeability	Air Change Rate
		m³/(h.m²) @ 50Pa	h^{-1} @ 50Pa		m³/(h.m²) @ 50Pa	h^{-1} @ 50Pa		m³/(h.m²) @ 50Pa	h^{-1} @ 50Pa
11 ST (system retrofit)	26-Feb-13	15.34	19.07	0.998	18.2	22.63	0.995	16.77	20.85
	20-Jan-14	6.25	7.78	1.000	6.60	8.21	1.00	6.43	7.99

Tests performed at end of coheating tests prior to and post-refurbishment

Exemplar projects

- Examples of good practice: Knauf



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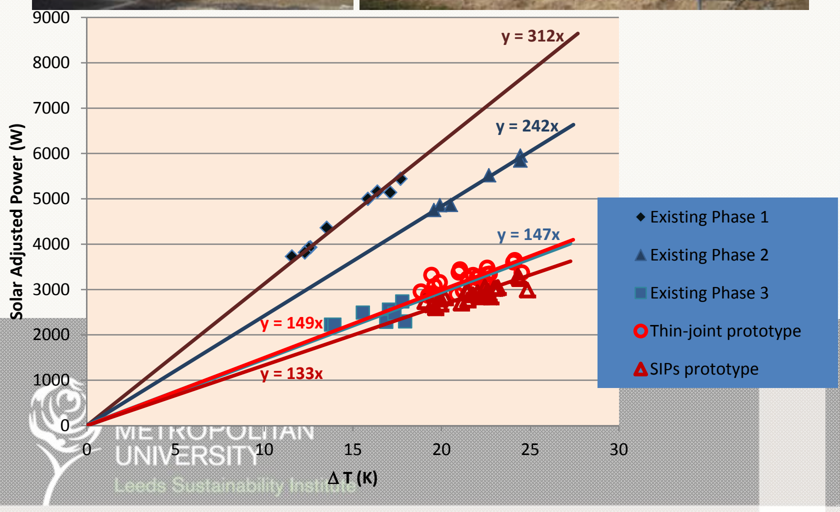
Retrofits and New Build at Scale

A retrofit that meets new enhanced prototype standards

Derwenthorpe Prototypes:

Refurb (1930s 3 bed semi -112 m²) 323 W/K to 147W/K
SIPs 133W/K (4 bed 153 m²) prototype
Panel 150 W/K (4 bed152 m²) prototype



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Departure from guessing: Seminal

- Full scale test facility and comparable field data
- Data for payback model
  - Steady state measurement - Coheating
  - Dynamic measurement – QuB whole building
- Saint Gobain

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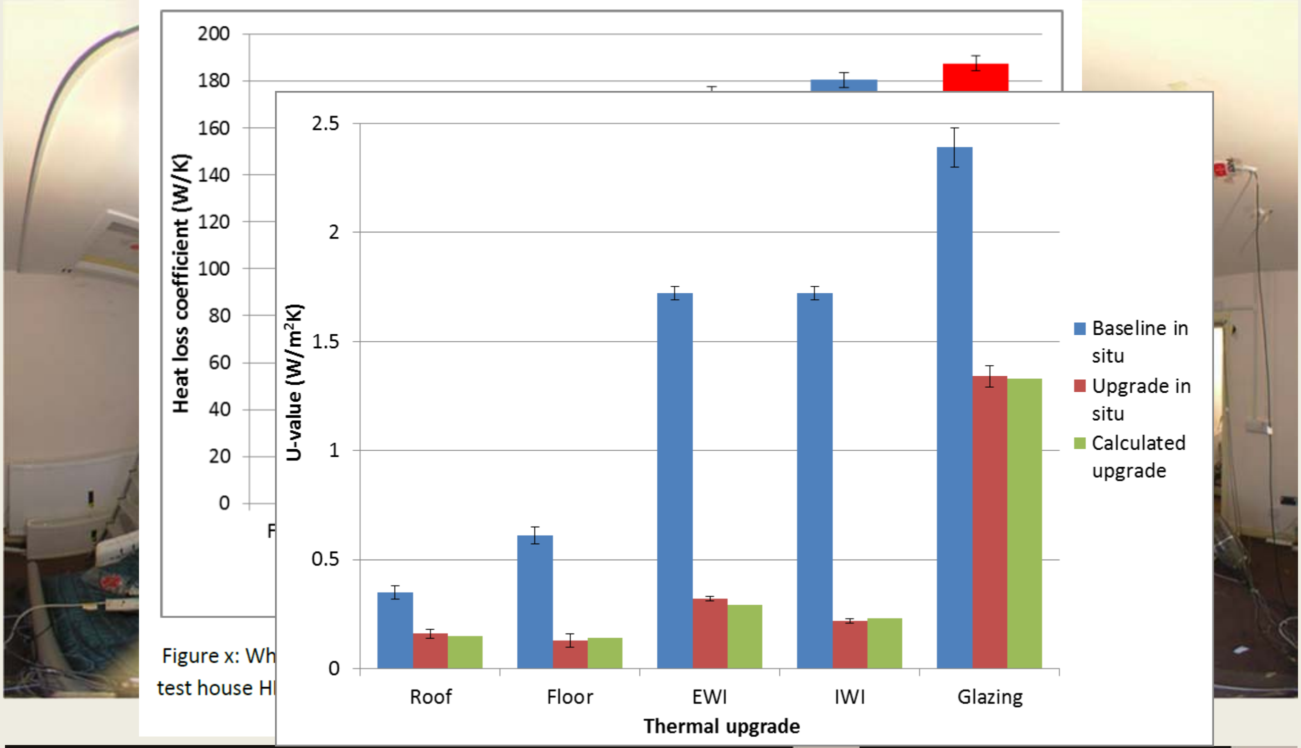

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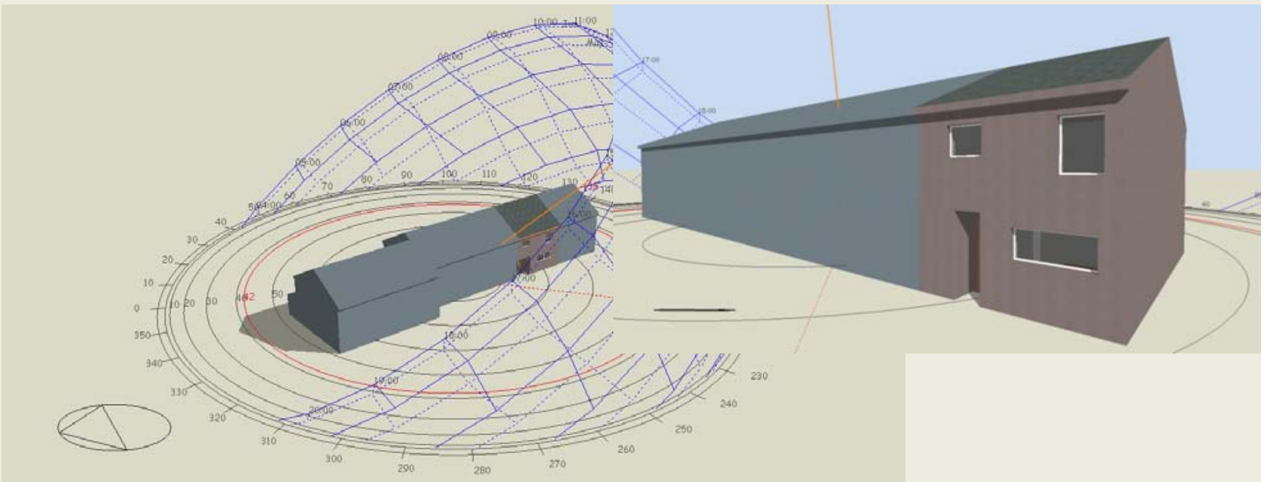
Scaling up: Calibrated models



Dynamic Thermal Simulations using DesignBuilder and IES Virtual Environment: Working on a calibration methodology to validate the fabric performance of domestic dynamic thermal simulations (DTS)

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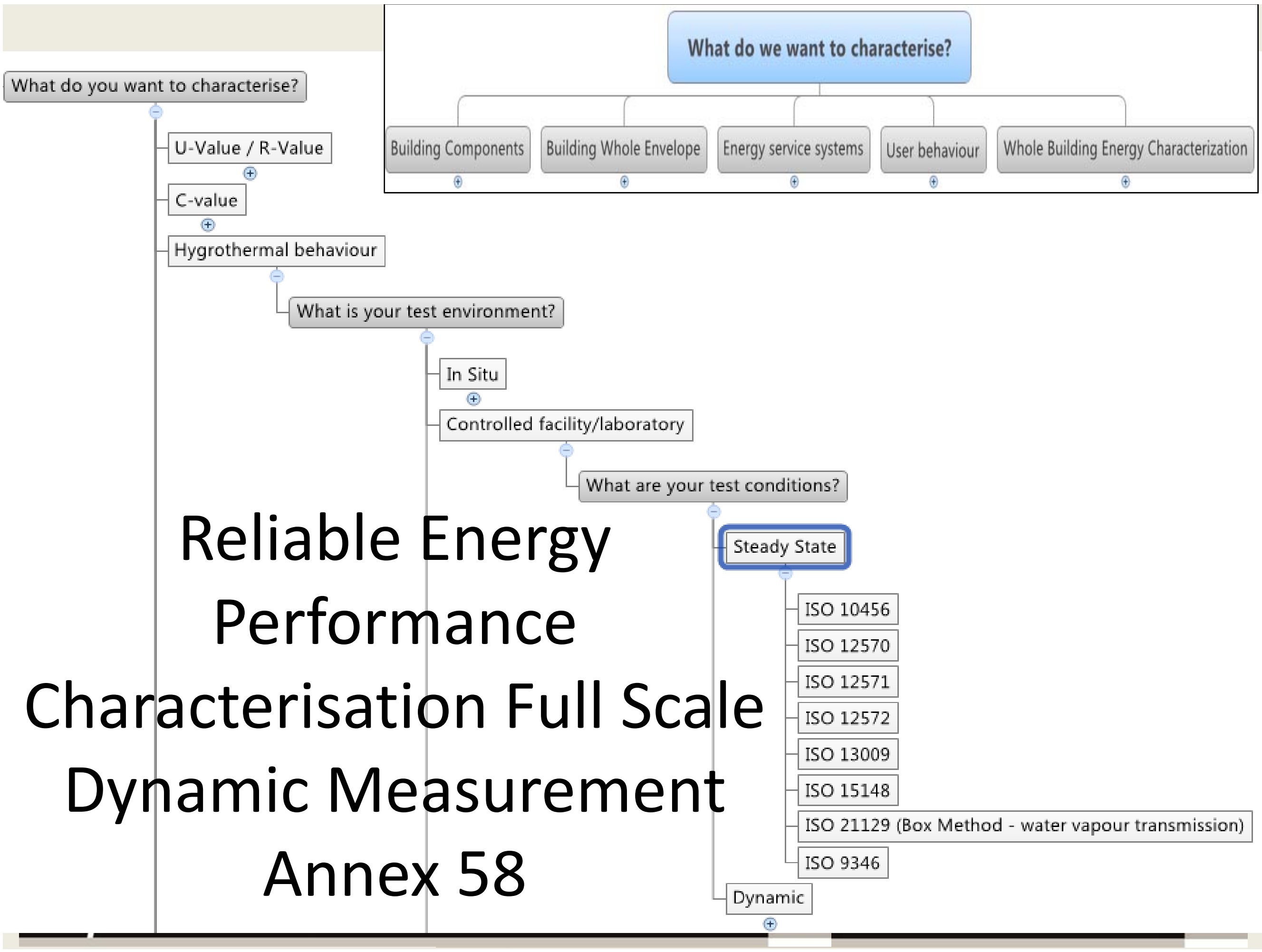

Reliable Energy Performance Characterisation Full Scale Dynamic Measurement Annex 58

Real Performance

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Energy in Buildings and Communities Programme

Seminar

Real building energy performance assessment

State of the art on test facilities and data analysis methods

UNIVERSITEIT GENT

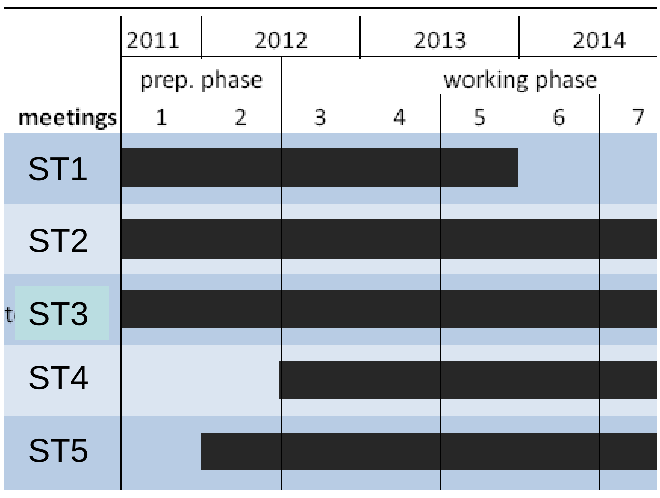
Arnold Janssens

Ghent University UGent

G. Alcamo (UNIFI), P. Bacher (DTU),
A. Erkoreka (UPV), G. Flamant (BBRI),
E. Himpe (UGent)

IEA Annex 58 Subtask 1: State of the art on full scale testing and dynamic data analysis

- Overview and evaluation of previous and ongoing in situ test activities.
- Inventory of full scale test facilities at different institutes
  - Report with 27 test facilities
- Description of common methods to analyse dynamic data
  - Report on analysis methods related to 4 main test procedures



Subtask 1 completed,
Reports in editing and review stage

Introduction

- Actual energy performance of building components
  - High quality test facilities
    - Testing in full scale under realistic conditions
    - Accurate measurements
  - Methods to analyse dynamic measuring data
  - Characterisation of energy performance
    - Uncertainty estimation
- Actual energy performance of whole buildings
  - Continuous on-site data gathering
    - Smart meters, weather data,…
  - Build upon data analysis experience from full scale test facilities
  - Applications in ‘as built’ compliance testing, commissioning, user feedback, etc…

Scope and scale of full scale test facilities

- Scope:
  - Thermal performance
  - Moisture/ durability
  - Air tightness
  - Energy performance
- Scale
  - Components
    - Envelope
    - Facade systems
    - Building services systems
  - Whole building





Full scale test facilities (1)

- Facilities for evaluation of (hygro)thermal building envelope performances
  - VLIET, K.U.Leuven, Belgium
  - BSRTU, Carinthia University, Austria
  - Field exposure of walls facility, NRC, Canada
  - IBP outdoor testing site, Germany
  - Building physical research equipment, TUT, Finland
  - Minibat, CETHIL, France
  - ZEB test cell, SINTEF, Norway

Full scale test facilities (2)

- Facilities for characterisation of building component energy performances
  - LECE, CIEMAT, Spain
  - Paslink test cells, LCCE, Spain
  - Test site UIBK, Austria
  - INCAS Platform, INES, France
  - Calorimetric test facility, IBP, Germany
  - Test cell, TAD Firenze, Italy
  - The Cube, Aalborg university, Denmark
  - LOT, CIMNE, Spain
  - LWF, Rosenheim, Germany

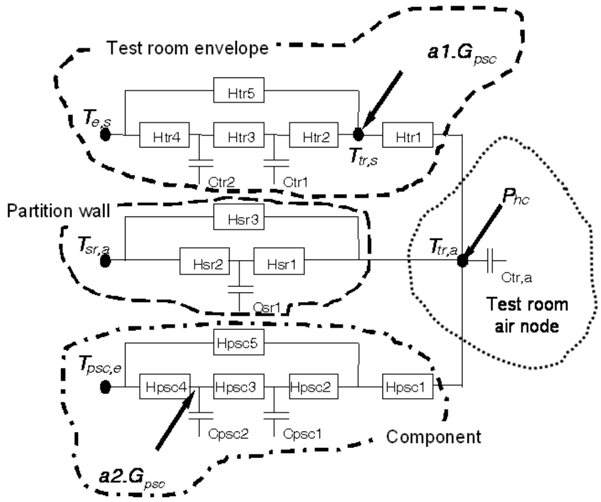
Full scale test facilities (3)

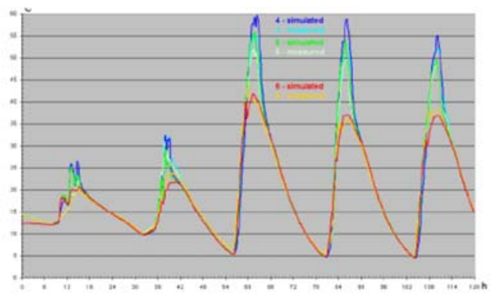
- Facilities for energy performance testing of building integrated components and systems
  - Twin houses, IBP, Germany
  - EnergyFlexHouse, DTI, Denmark
  - Flexlab, LBNL, USA
  - VERU, IBP, Holzkirchen
  - Kubik, Tecnalia, Spain
  - Salford energy house, University of Salford, UK
  - Arfrisol-buildings, CIEMAT, Spain
  - J. Geelen laboratory, Ulg Arlon campus, Belgium
  - Zero energy certified passive house, PoliMi, Italy
  - DEFI, ENTPE, Morocco
  - Lecture rooms facility, KAHO, Belgium

Reliable Building Energy Performance Characterisation
Based on Full Scale Dynamic Measurements

Common points of attention

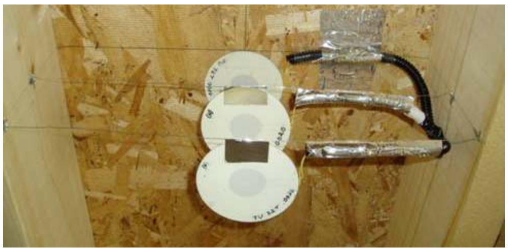
- Complement to other test methods
  - Material testing
  - Steady-state testing
  - Accelerated tests
- Link with models
  - Experimental design
  - Analysis
  - Validation
  - Extrapolation

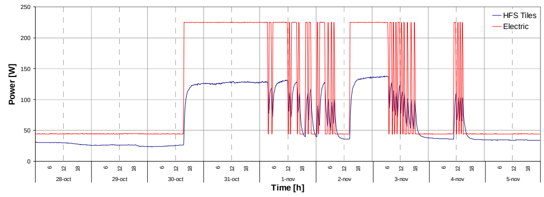


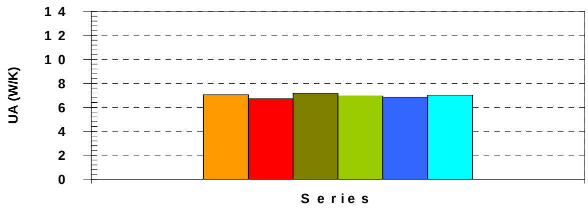


Common challenges in quantifying performances

- Technical
  - Measuring accuracy
  - Calibration
  - Controls
  - Data management
- Data analysis
  - Methodology
  - Error estimation







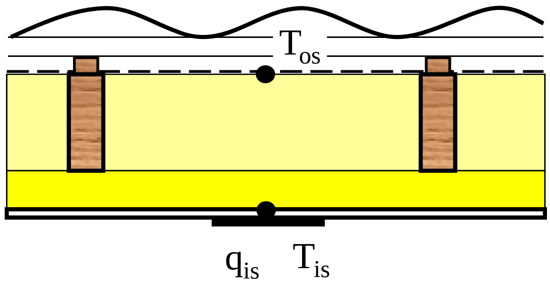
Methods to analyse dynamic data for energy performance characterisation

- Related to application in in-situ measurement methods
- Methods related to performance quantification of building components based on in-situ measurements:
  - measurement of thermal transmittance of building components based on heat flux meters (R);
  - measurement of thermal and solar transmittance of building components tested in outdoor calorimetric test cells (UA & gA);
- Methods related to performance quantification of whole buildings based on in-situ measurements:
  - measurement of heat loss coefficient and solar aperture of whole buildings based on co-heating or transient heating (H & A_{sol});
  - energy performance characterisation of whole buildings based on monitored dynamic energy and climatic data.

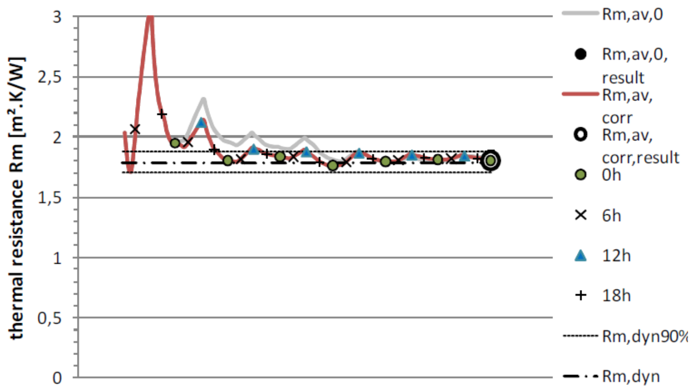
Heat flow meter method

- ISO 9869 method
- Steady-state analysis

$$R_{N,s-to-s} = \frac{\sum_{k=1}^{N}\left(T_{i,s,k} - T_{o,s,k}\right)}{\sum_{k=1}^{N} q_{i,s,k}}$$

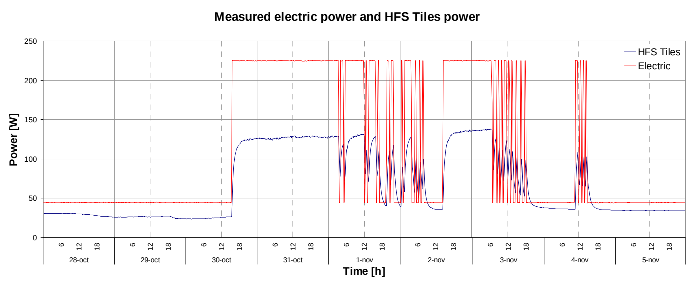


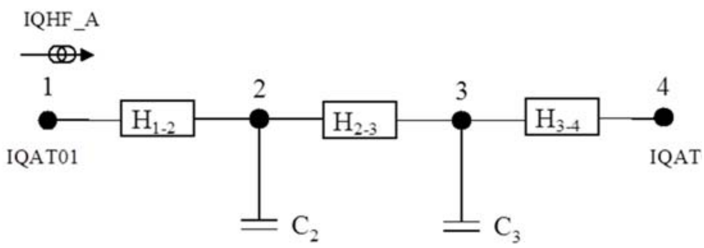
- Advantage:
  - Straightforward
- Disadvantages:
  - Long test duration
  - No information on dynamic performance
  - Large uncertainties in some cases



Heat flow meter method

- Dynamic analysis
  - Dynamic test conditions (ROLBS)
  - System identification
    - RC-models
    - FDE or SDE
    - Software tools
- Advantages
  - Shorter test duration
  - Dynamic performance
  - Error estimation
- Concerns
  - Advanced methods
  - Physical meaning of parameters





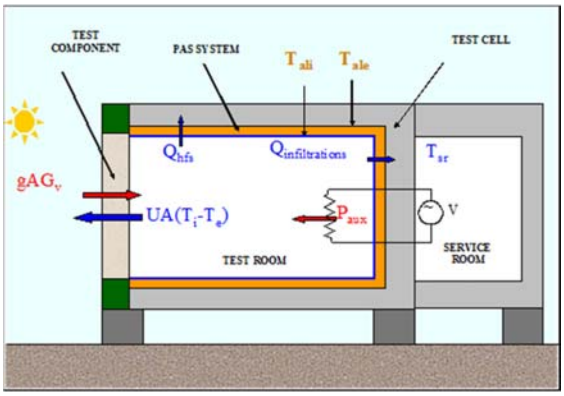
$$C_2 \cdot \frac{dT_2}{dt} = \left(T_1 - T_2\right)H_{1-2} + \left(T_3 - T_2\right)H_{2-3}$$

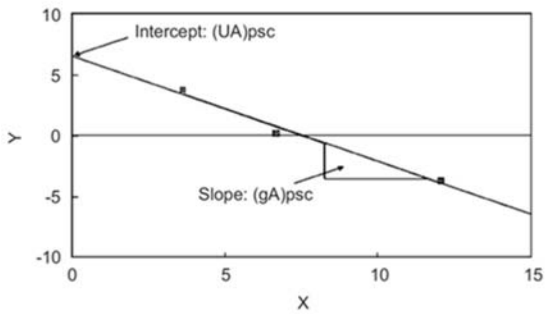
Outdoor calorimetric test cell method

- Measurement of net heat flow through component
- Steady state analysis

$$\Phi_{H,nd} = (UA)_c \cdot \Delta T - (gA)_c \cdot I_{sol,v}$$

- Dynamic analysis
  - Tools developed in PASLINK platform
    - LORD: FDE
    - CTSM: SDE, grey-box



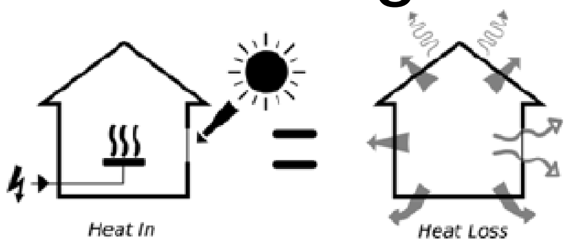


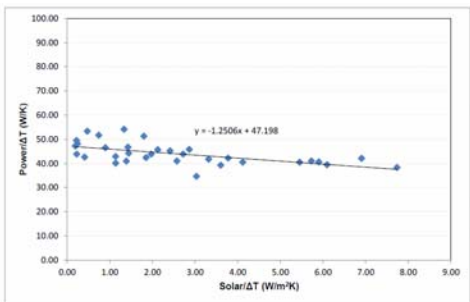
Measurement of heat loss coefficient of whole buildings

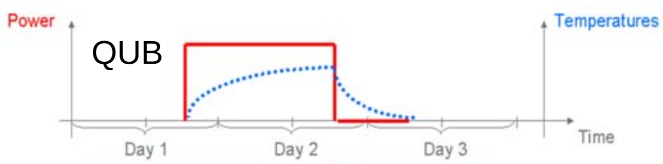
- Co-heating test
  - Measurement of heat input during thermostatic heating
  - Steady state regression analysis

$$\Phi_H = (H_{tr} + H_{ve})\Delta T - \sum A_{sol} I_{sol}$$

- Transient heating test
  - Measurement of thermal response during stepwise heating and cooling

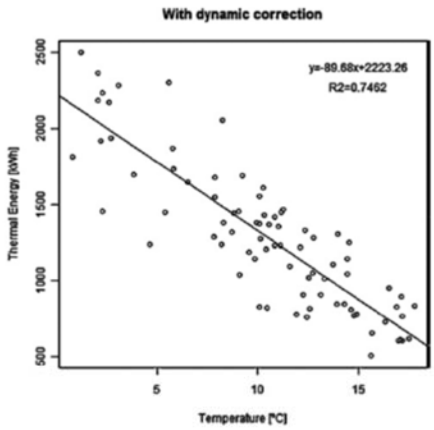






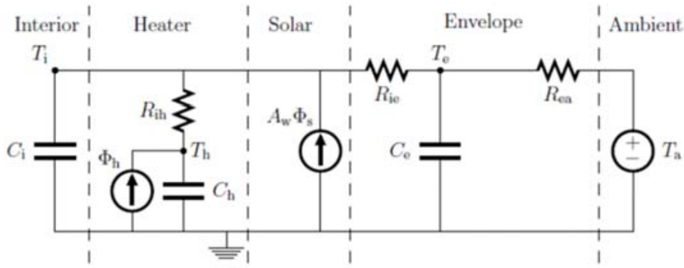
Energy performance characterisation of buildings

- Measurement of total energy consumption and climatic data
- Steady state analysis
  - ‘Energy signature’



$$(H_{tr} + H_{ve})(T_i - T_e) = \Phi_H + \Phi_{int} + \Phi_{sol} - \Phi_{dyn}$$

- Dynamic analysis
  - Modelling building heat dynamics
  - SDE, grey box (CTSM-R)



Overview of ‘in-situ’ methods

\ How long? \ What ? \	Quick (direct or transient)	< 1 week (dynamic data)	> 2 weeks (daily average)
U-value [W/m²K]	Direct (IR or 3T°)	Heatflux Meter (ISO 9869-1)	Heatflux Meter (ISO 9869-1)
Heat Loss Coefficient (HLC) [W/K]	Transient (QUB, STEM/PSTAR)	**Dynamic Co-heating & Tracer Gas + Dynamic Identification**	Co-heating
Dynamic envelope parameters [MJ/K, etc.]	?		Adapted Co-heating
Air change [h^{-1}]	Blower Door		Tracer Gas, …
Solar aperture [m²]	?		Statistical average

Conclusions

- State of the art of full scale dynamic testing
  - 27 facility descriptions in IEA Annex 58 ST1 Report
  - Test and data analysis methods developed for facilities basis for application on whole building energy performance characterissation
  - Applications in 'as built' compliance testing, commissioning, user feedback, etc…
- Data analysis methods
  - Focus on dynamic analysis methods
    - Shorter test duration
    - More complete characterisation of energy performance
    - Error estimation
  - Large potential, subject to further research

Standardisation of methods for in-situ performance assessment

Gilles Flamant
Belgian Building Research Institute

Seminar
Real building energy performance assessment
Ghent, Belgium, 16 April 2014

Full scale dynamic testing …

- allows to investigate the **performances in reality** (including workmanship)
- can be used to assess the **representativity of laboratory testing** (e.g. thin reflective foils)
- is a necessary tool to **characterise advanced/complex components** and systems and to evaluate nearly zero energy buildings
- can help to **validate** our calculation tools (building energy simulation models). This becomes more important when moving towards nZEB.

CEN TC89 WG13

- WG13 : In-situ thermal performance of construction products, building elements and structures

  Scope : to elaborate a procedure, or procedures, to derive in-situ test data that will complement the declared or design thermal performance value of construction products, building elements and structures established by conventional steady state methods, e.g. in accordance with EN 10456 and EN 6946
- Start in 2010
- 13 countries – more than 40 participants (Convenor J. Deneyer)

CEN TC89 WG13

- Task groups

Tasks	Title
1	General principles
2	Testing of products
3	Testing of building elements
4	Testing of structures
5	Testing of completed buildings

Review of existing standards

TC's	Standards
ISO TC163	ISO 9869-1 : Thermal insulation — Building elements — In-situ measurement of thermal resistance and thermal transmittance — Part 1 : Heat flowmeter method
CEN TC89	prEN12494 : Building components and elements — In-situ measurement of the surface-to-surface thermal resistance (1997)
CEN TC89	EN 13187 : Thermal performance of buildings - Qualitative detection of thermal irregularities in building envelopes - Infrared method (ISO 6781:1983 modified)
CEN TC89	EN 13829 : Thermal performance of buildings - Determination of air permeability of buildings – Fan pressurization method (ISO 9972:1996, modified)
CEN TC89	EN 15217 : Energy performance of buildings - Methods for expressing energy performance and for energy certification of buildings
CEN TC89 & ISO TC 163	EN ISO 12569 : Thermal insulation in buildings - Determination of air change in buildings - Tracer gas dilution method (ISO 12569:2000)
CEN TC89 & ISO TC 163 SC2	EN ISO 15927-1 : Hygrothermal performance of buildings - Calculation and presentation of climatic data - Part 1: Monthly means of single meteorological elements (ISO 15927-1:2003)
CEN TC89 & ISO TC 163	EN ISO 13786 Performance thermique des composants de bâtiment - Caractéristiques thermiques dynamiques - Méthodes de calcul (ISO 13786:2007)
CEN/TC 156	EN15251 : Indoor environmental input parameters for design and assessment of energy performance of buildings addressing indoor air quality, thermal environment, lighting and acoustics (2007) CEN/TC 156 "Ventilation for buildings"
CEN TC 156	EN 15242 : Ventilation for buildings - Calculation methods for the determination of air flow rates in buildings including infiltration
CEN/TC BT 173	EN 15603 : Energy performance of buildings - Overall energy use and definition of energy ratings
…	…

Review of existing standards

ISO 9869:1994

Thermal insulation -- Building elements -- In-situ measurement of thermal resistance and thermal transmittance

Under revision


FINAL DRAFT

INTERNATIONAL STANDARD

ISO/FDIS 9869-1

ISO/TC 163/SC 1

Secretariat: DIN

Voting begins on: 2014-03-25

Voting terminates on: 2014-05-25

Thermal insulation — Building elements — In-situ measurement of thermal resistance and thermal transmittance —

Part 1:

Heat flow meter method

Isolation thermique — Éléments de construction — Mesurage in situ de la résistance thermique et du coefficient de transmission thermique —

Partie 1: Méthode du fluxmètre

Reference number
ISO/FDIS 9869-1:2014(E)

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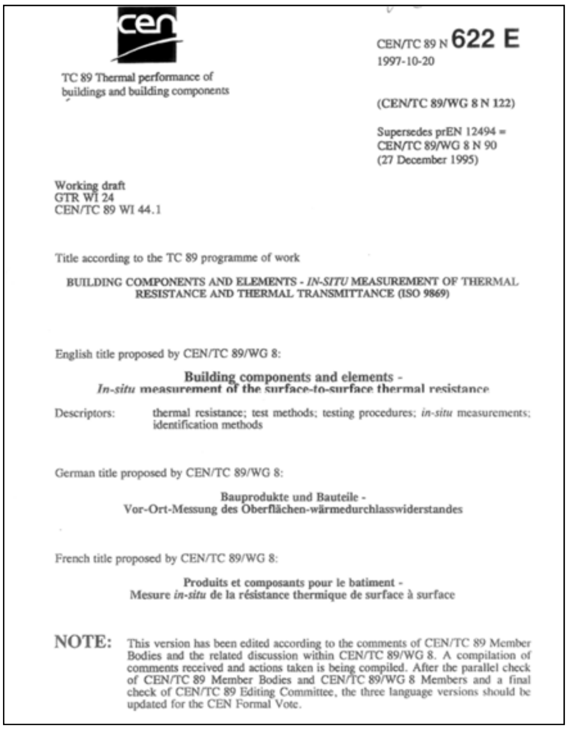
Review of existing standards

prEN 12494
(1997)

abandoned



cen

CEN/TC 89 N 622 E
1997-10-20

TC 89 Thermal performance of buildings and building components

(CEN/TC 89/WG 8 N 122)

Supersedes prEN 12494 =
CEN/TC 89/WG 8 N 90
(27 December 1995)

Working draft
GTR WI 24
CEN/TC 89 WI 44.1

Title according to the TC 89 programme of work

BUILDING COMPONENTS AND ELEMENTS - *IN-SITU* MEASUREMENT OF THERMAL RESISTANCE AND THERMAL TRANSMITTANCE (ISO 9869)

English title proposed by CEN/TC 89/WG 8:

Building components and elements -
***In-situ* measurement of the surface-to-surface thermal resistance**

Descriptors: thermal resistance; test methods; testing procedures; *in-situ* measurements; identification methods

German title proposed by CEN/TC 89/WG 8:

Bauprodukte und Bauteile -
Vor-Ort-Messung des Oberflächen-wärmedurchlasswiderstandes

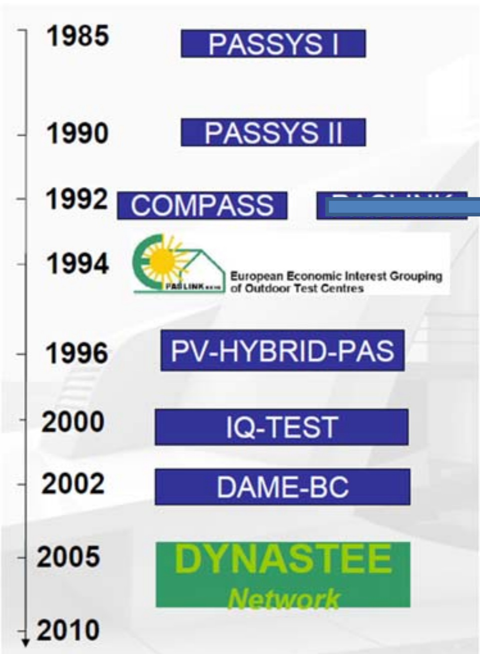
French title proposed by CEN/TC 89/WG 8:

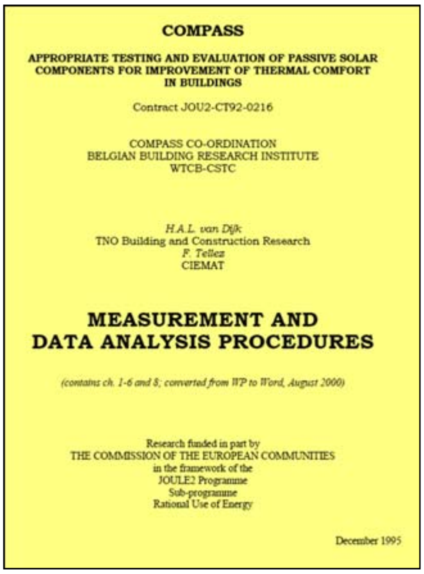
Produits et composants pour le batiment -
Mesure *in-situ* de la résistance thermique de surface à surface

NOTE: This version has been edited according to the comments of CEN/TC 89 Member Bodies and the related discussion within CEN/TC 89/WG 8. A compilation of comments received and actions taken is being compiled. After the parallel check of CEN/TC 89 Member Bodies and CEN/TC 89/WG 8 Members and a final check of CEN/TC 89 Editing Committee, the three language versions should be updated for the CEN Formal Vote.

From PASSYS to DYNASTEE

History





COMPASS

APPROPRIATE TESTING AND EVALUATION OF PASSIVE SOLAR COMPONENTS FOR IMPROVEMENT OF THERMAL COMFORT IN BUILDINGS

Contract JOU2-CT92-0216

COMPASS CO-ORDINATION
BELGIAN BUILDING RESEARCH INSTITUTE
WTCB-CSTC

H.A.L. van Dijk
TNO Building and Construction Research
F. Tellez
CIEMAT

MEASUREMENT AND DATA ANALYSIS PROCEDURES

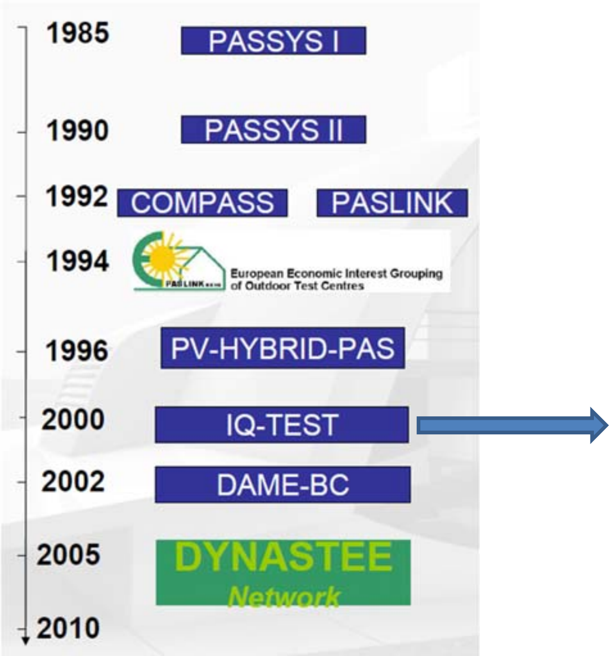
(contains ch. 1-6 and 8; converted from WP to Word, August 2000)

Research funded in part by
THE COMMISSION OF THE EUROPEAN COMMUNITIES
in the framework of the
JOULE2 Programme
Sub-programme
Rational Use of Energy

December 1995

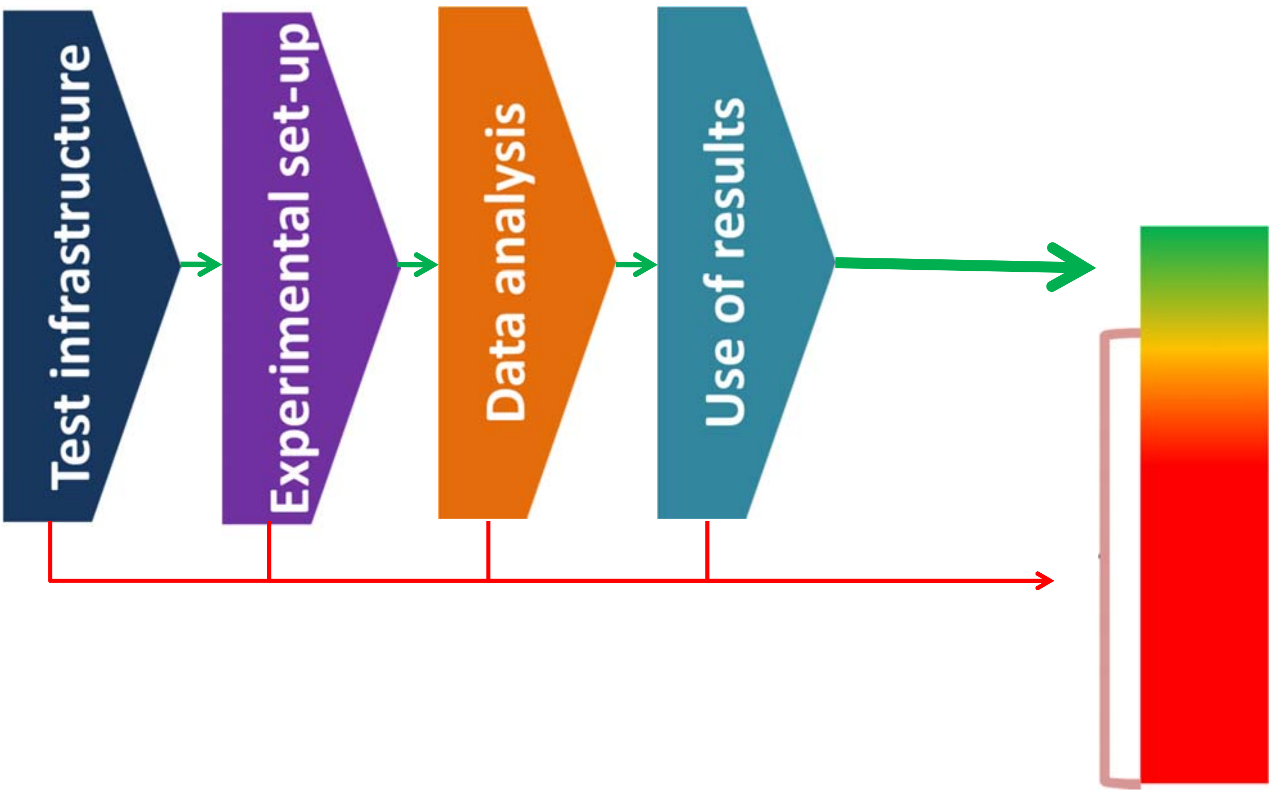
From PASSYS to DYNASTEE

History



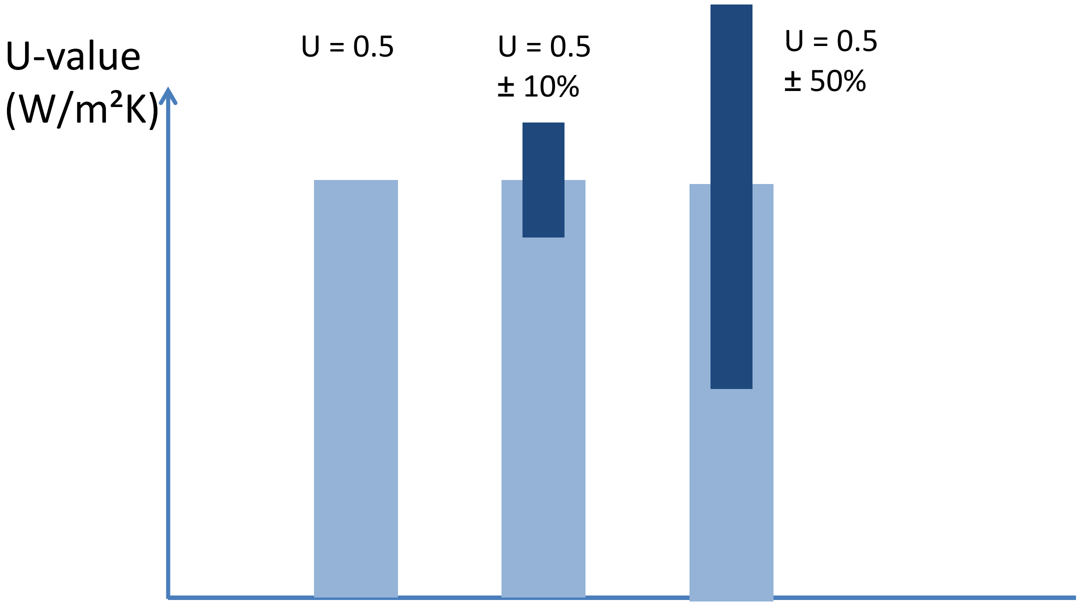
IQ-TEST - Improving quality in testing and evaluation of solar and thermal characteristics of building components

Full scale testing requires quality !



Uncertainty

… must be determined

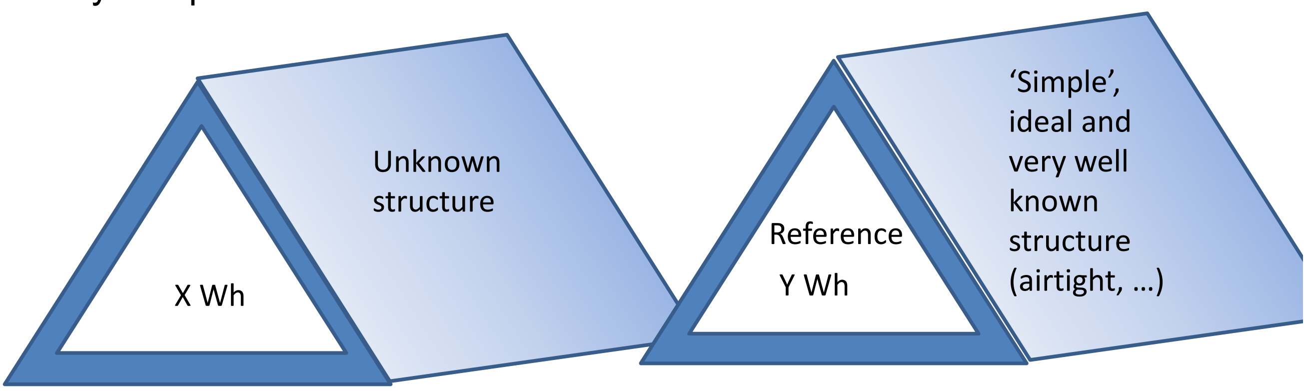


Issue # 1

Which properties are we measuring ?

Measurement of the “Dynamic thermal performance” under real outdoor (and indoor) conditions

1. By comparison with a reference structure



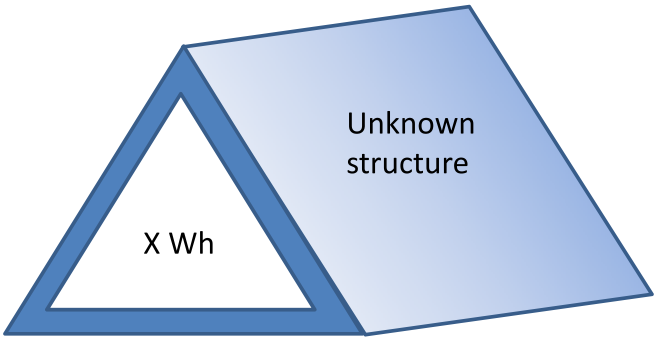
Wh/24hrs - for climatic conditions during period 1
Wh/48hrs - for climatic conditions during period 2

Issue # 1

Which properties are we measuring ?

Measurement of the “Dynamic thermal performance” under real outdoor (and indoor) conditions

2. By normalising the energy used to the standard outdoor climatic condition



Weather set	‘in-situ’ U-value
1	U1 = 0.51
2	U2 = 0.45
3	U2 = 0.60

- Which indicator ? ‘(in-situ) U-value’ [W/m²K] ?
- Defined for different weather sets ? how to characterise the external climate ? How to define a standard set of external climate conditions in a simple way ?
- Extrapolation of results ?

Issue # 1

Which properties are we measuring ?

Measurement of the “Dynamic thermal performance” under real outdoor (and indoor) conditions

3. New dynamic thermal performance indicator ?

Issue # 2

What are the determined properties for ?

- Existing buildings – on field

  Energy performances in reality of a specific building

  HLC / U-value

1. Show compliance with legal requirements ?
2. Scientifically interesting to understand where and why deviation occurs between measured and predicted values:
   - → how to improve the building design (due to poor workmanship and/or poor installation and/or poor design) ?
   - → how to improve the calculation method ?

Issue # 2

What are the determined properties for ?

- Testing facilities (calorimeter, test house, …)

Energy performances of (advanced/complex) building component or structure under real outdoor conditions (in a controlled environment)

HLC / U-value

1. = U design ? May be used in a legal context ?

Scope WG13 : to elaborate a procedure, or procedures, to derive in-situ test data that will complement the declared or design thermal performance value of construction products, building elements and structures established by conventional steady state methods, e.g. in accordance with EN 10456 and EN 6946

Issue # 2

What are the determined properties for ?

- Testing facilities (calorimeter, test house, …)

Energy performances of (advanced/complex) building component or structure under real outdoor conditions (in a controlled environment)

HLC / U-value

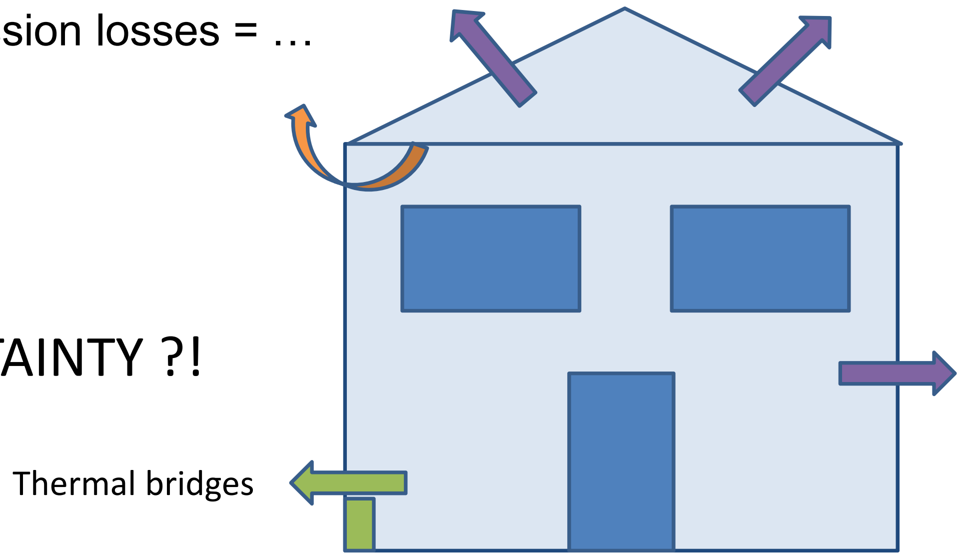
1. = U design ? May be used in a legal context ?
2. Research context → Need to understand where and why deviation occur :
   - → how to improve the design of the component / structure
   - → how to improve the calculation method ?

Issue # 3

Principle of the "Deconstruction"

- Energy in cell = heat losses – solar heat gains
- Heat losses = transmission + air infiltration (no ventilation)
- Transmission losses = …

UNCERTAINTY ?!

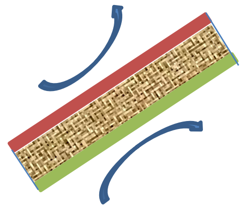


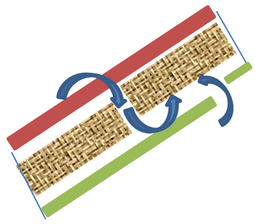
Issue # 4

If and how to extract an effective 'product' R-value ?

- Scope :

  to elaborate a procedure, or procedures, to derive in-situ test data that will **complement** the declared or design **thermal performance value of construction products**, building elements and structures established by conventional steady state methods, e.g. in accordance with EN 10456 and EN 6946
- Scientifically correct ?
- Result only valid for the tested structure ?

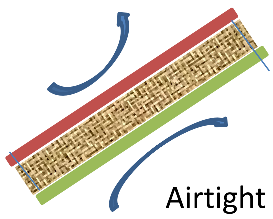


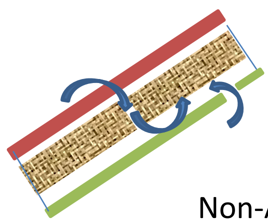


Issue # 5

When and how to use heat flow meters ?

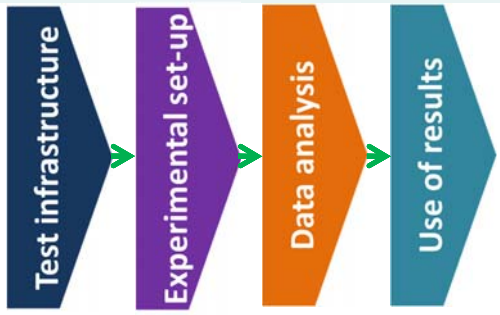
- Use strictly within ISO 9869 ?
- ISO 9869 is too limiting ? Allowing (much) wider use ?
- Effect on the measurement uncertainty ?





Issue # 6

Data analysis



- How to standardize ?
- Which models ?

  Grey & Black box models (non physical models)
- Highly dependent on the knowledge, level of skill, experiences of the person who applies the method
- Restrict standard only to testing parts ?
- Benchmark/Validation cases ? Analogy with EN ISO 10077-2 ?

Conclusions

Some issues :

1. Which properties are we measuring ?
2. What are the determined properties for ?
3. Principle of “Deconstruction”
4. If and how to extract an effective ‘product’ R-value ?
5. When and how to use heat flow meters ?
6. Standardization of “Data analysis” part ?

Full scale testing requires quality at different levels

Need to know the uncertainty on the final result

Annex 58 Seminar
Real building energy performance assessment
Wednesday 16 April 2014

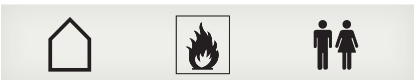
Co-heating test: a state-of-the-art

Geert Bauwens, Staf Roels
Building Physics Section, Department of Civil Engineering, KU Leuven

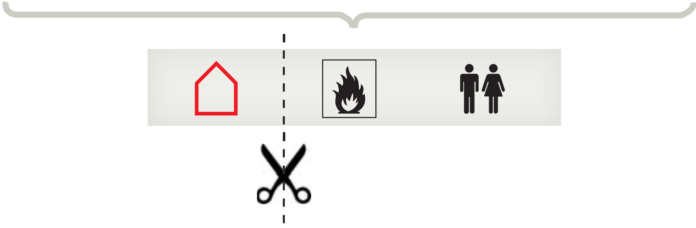
1 Introduction

Energy performance of buildings: predicted vs actual

Energy performance of buildings: predicted vs actual

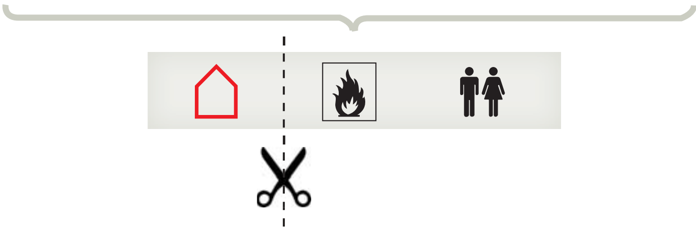


Energy performance of buildings: predicted vs actual



thermal performance characterisation building fabric

Energy performance of buildings: predicted vs actual



thermal performance characterisation building fabric

co-heating test

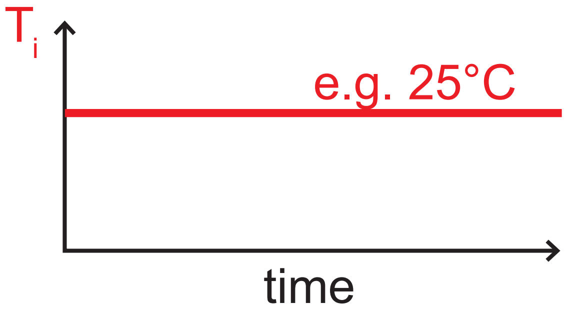

heaters
thermostat
heaters


ventilators
thermostat
heaters
heaters
ventilators


sensors
ventilators
thermostat
heaters
heaters
ventilators
sensors

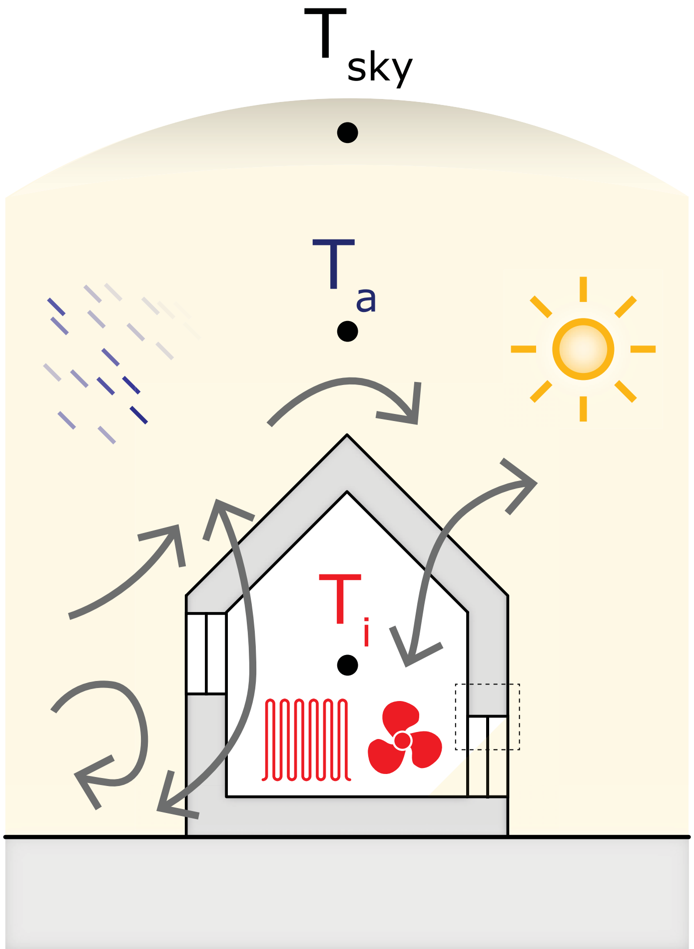
Co-heating test

quasi-stationary test



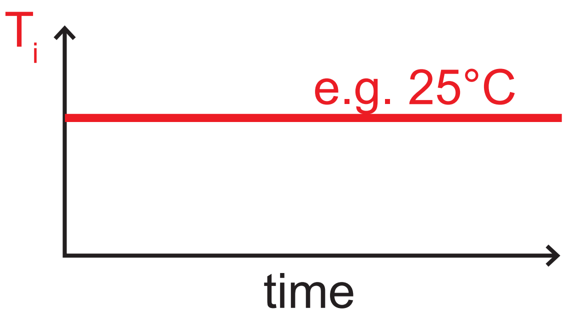
monitored throughout test:

aggregated data (e.g. daily)



Co-heating test

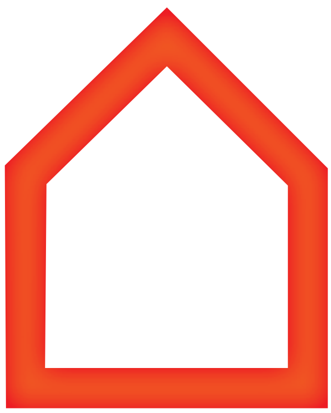
quasi-stationary test



monitored throughout test:

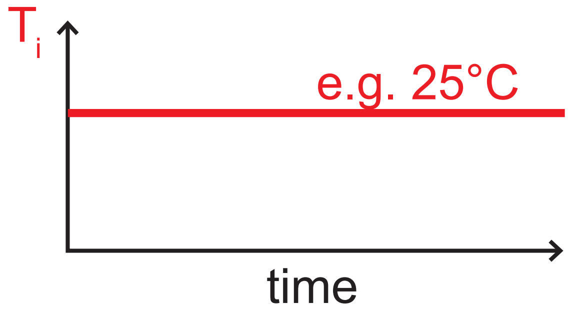
aggregated data (e.g. daily)

HLC



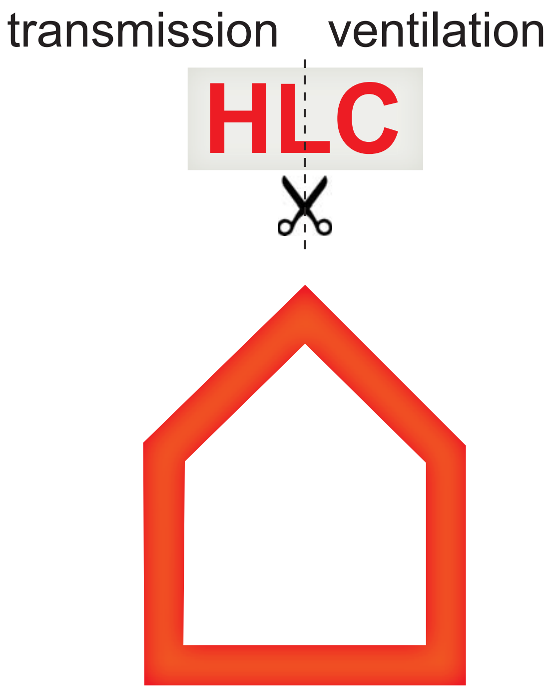
Co-heating test

quasi-stationary test



monitored throughout test:

aggregated data (e.g. daily)



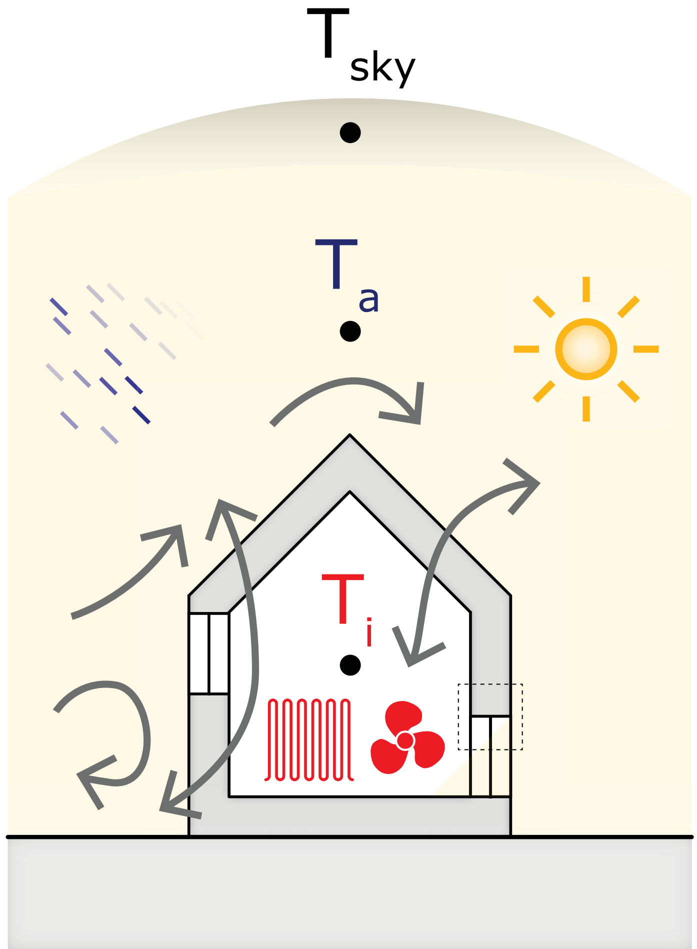
2

State-of-the-art

Simplified heat balance

T_i - T_a

$$Q_h = HLC\Delta T - A_{sw,*} q_{sw,*} + c$$

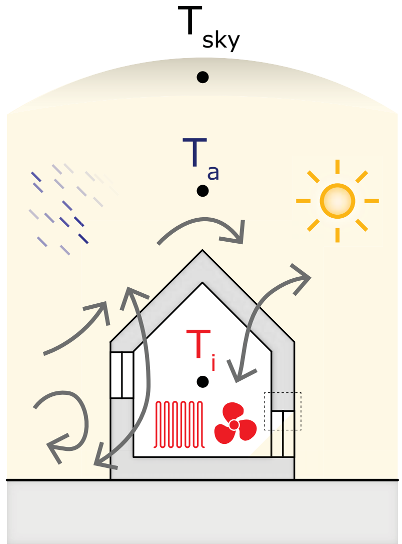


2.1

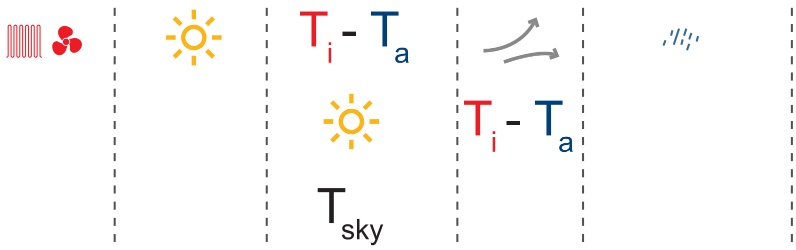
Basic heat balance

Stationary heat balance towards T_i

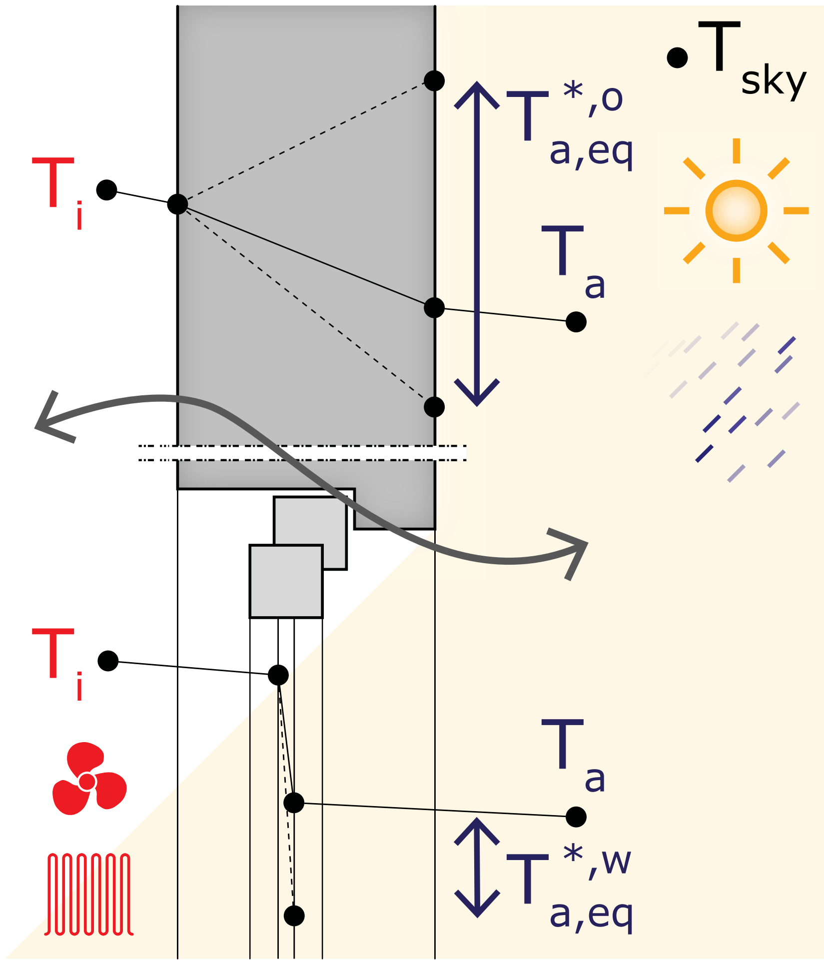
$$\sum Q_i + c = 0$$



$$Q_h + Q_{sw} - Q_{tr,eq} - Q_v - Q_{latent} + c = 0$$

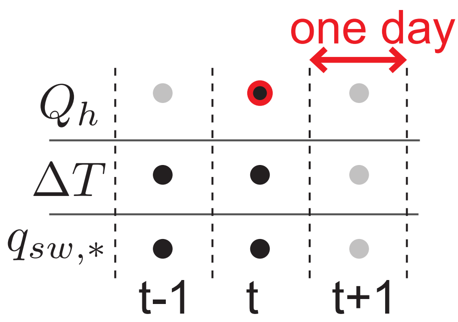


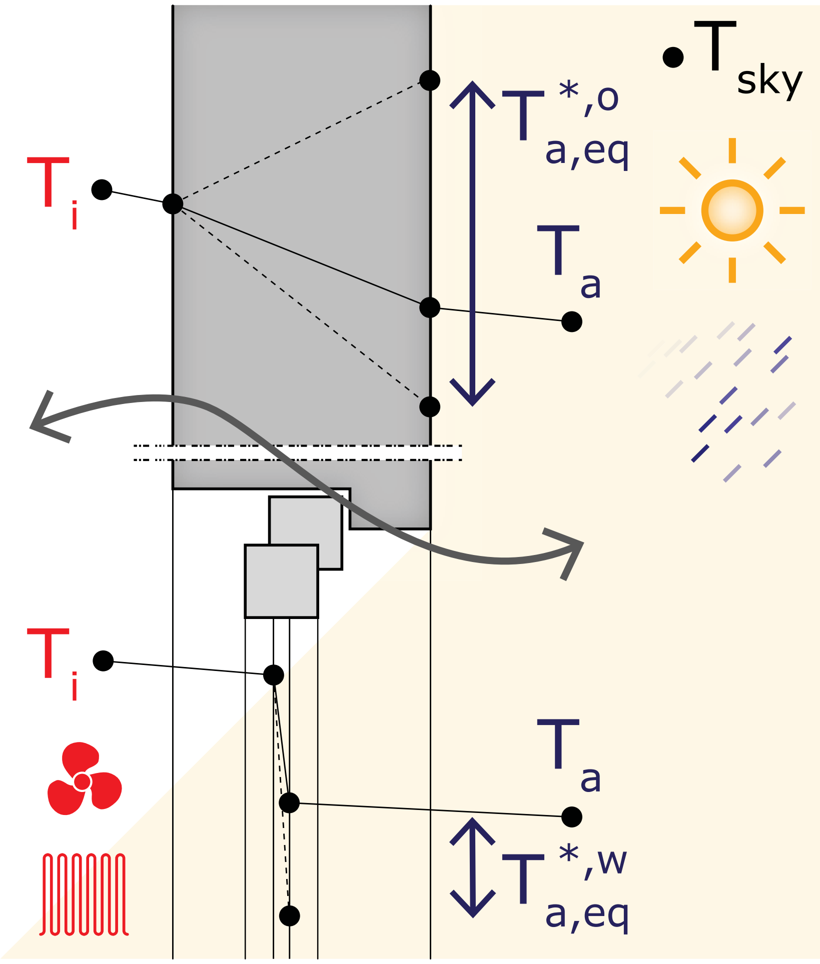
- equivalent outdoor temperature



- equivalent outdoor temperature

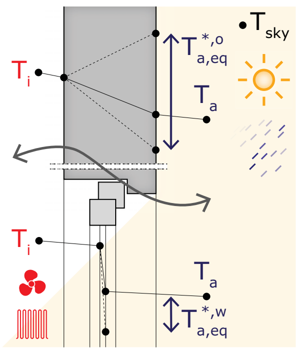
- thermal lags

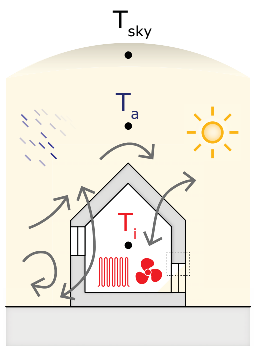




Stationary heat balance T_i

$$\sum Q_i + c = 0$$





$$Q_h + \sum_{*,w} A_{sw,*,w} q_{sw,*,avg} + \sum_{*,o} U_o A_{*,o} \alpha_{sw,*,o} q_{sw,*,avg}$$

$$= \sum_{*,o} U_o A_{*,o} \Delta T_{avg} + \sum_{*,w} U_w A_{*,w} \Delta T$$ T_i - T_a

$$+ \sum_{*,o} U_o A_{*,o} c_{lw,*,o} + \sum_{*,w} U_w A_{*,w} c_{lw,*,w} + c_a G_a \Delta T + c_{vP} + c$$

T_{sky} T_{sky}

2.2 Linear regression

Simplified heat balance

$T_i - T_a$

$$Q_h = HLC\Delta T - A_{sw,*}q_{sw,*} + c$$

- stationary heat balance
- aggregated performance data

Simplified heat balance

T_i - T_a

$$Q_h = HLC\Delta T - A_{sw,*}q_{sw,*} + c$$

Linear regression analysis:

- simple linear regression (solar corrected Q_h)
- simple linear regression (transformed equation)
- multiple linear regression

Simplified heat balance

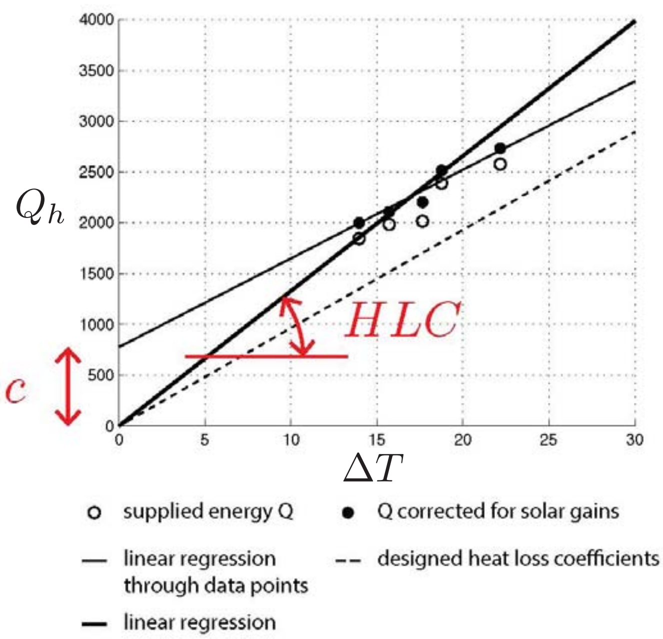
T_i - T_a

$$Q_h = HLC\Delta T - A_{sw,*}q_{sw,*} + c$$

Linear regression analysis:

- simple linear regression (solar corrected Q_h)
- simple linear regression (transformed equation)
- multiple linear regression

$$Q_h + A_{sw,*}\,q_{sw,*} = HLC\Delta T + c$$



Simplified heat balance

T_i - T_a

$$Q_h = HLC\Delta T - A_{sw,*} q_{sw,*} + c$$

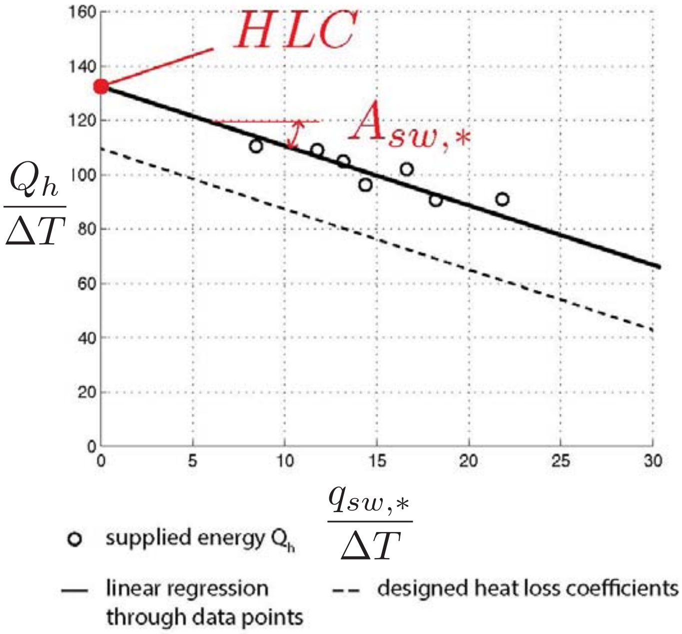
$$\frac{Q_h}{\Delta T} = HLC - A_{sw,*}\frac{q_{sw,*}}{\Delta T}$$

Linear regression analysis:

- simple linear regression (solar corrected Q_h)

- simple linear regression (transformed equation)

- multiple linear regression



Simplified heat balance

T_i - T_a

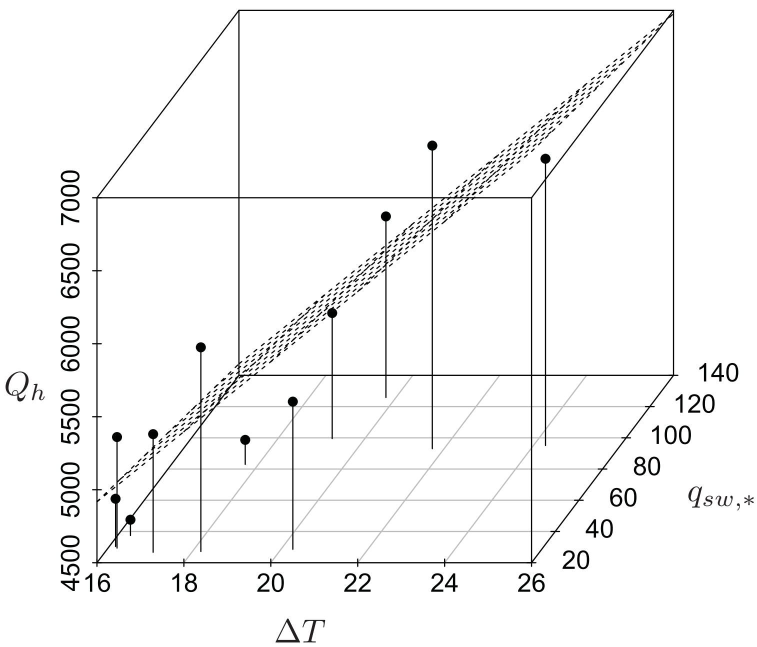
$$Q_h = HLC\Delta T - A_{sw,*} q_{sw,*} + c$$

Linear regression analysis:

- simple linear regression (solar corrected Q_h)

- simple linear regression (transformed equation)

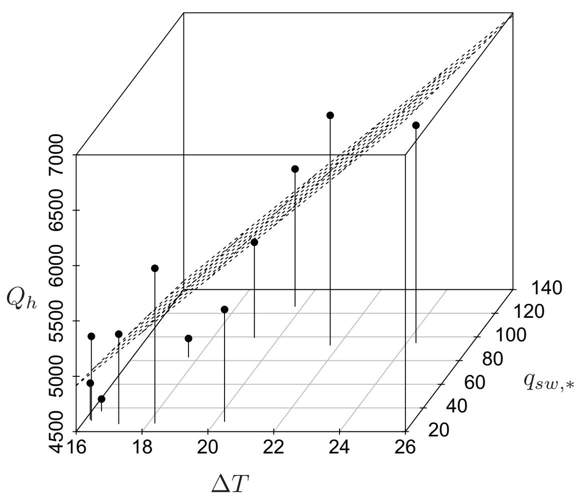
- multiple linear regression

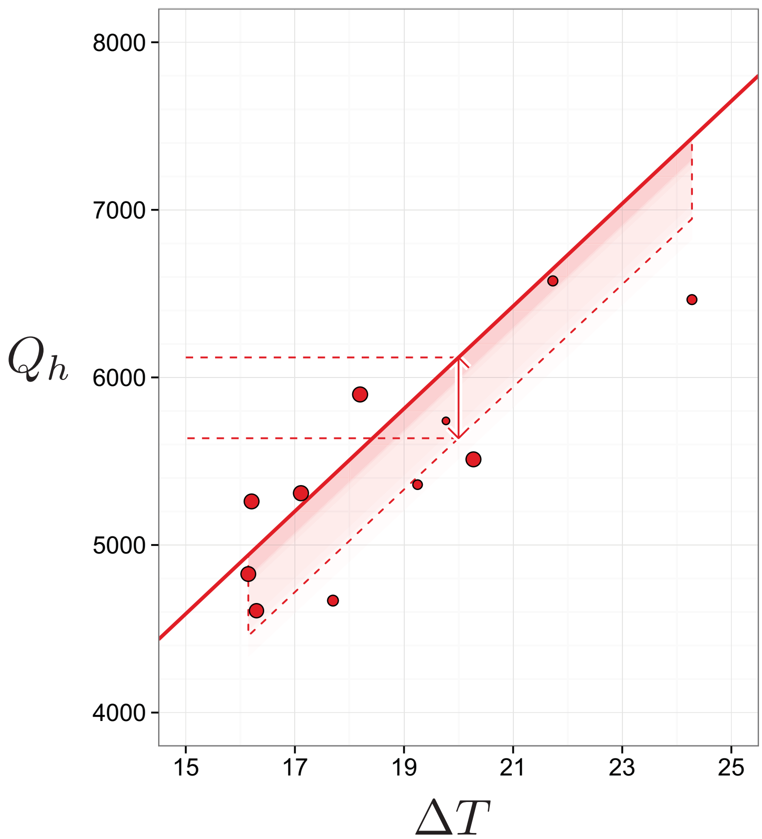


2.3 Visualisation

Multiple linear regression

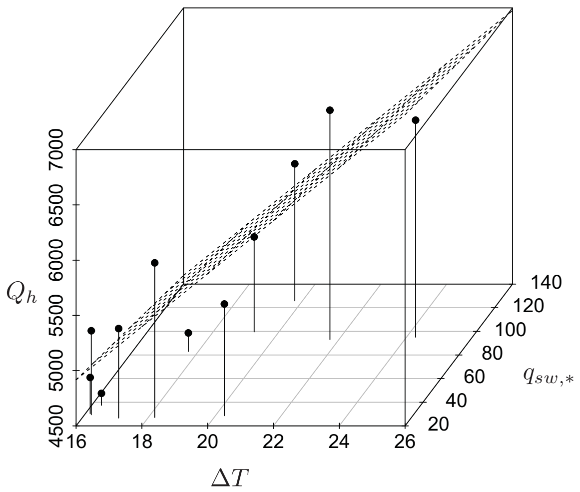
$$Q_h = HLC\Delta T - A_{sw,*}q_{sw,*} + c$$

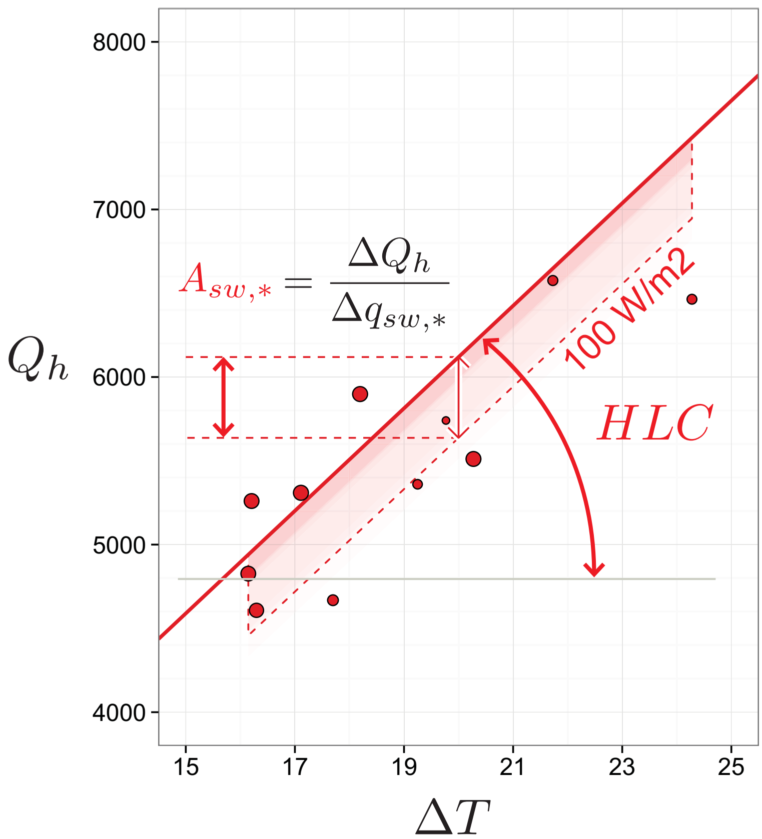




Multiple linear regression

$$Q_h = HLC \Delta T - A_{sw,*} q_{sw,*} + c$$





3

Reliability

4 factors influence co-heating test reliability

- duration of experiment
- weather conditions
- test case
- analysis method

4 factors influence co-heating test reliability

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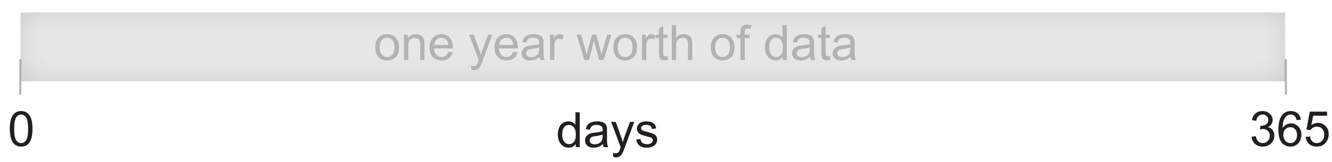
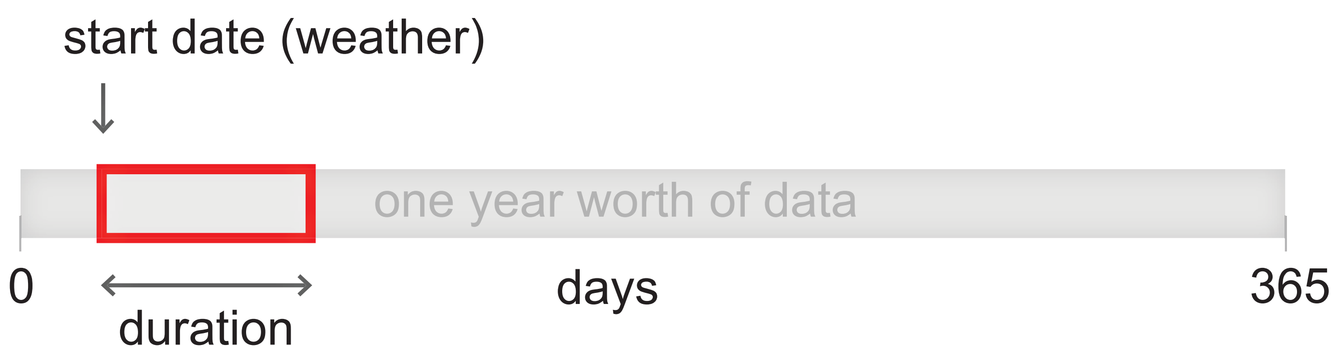
4 factors influence co-heating test reliability

- duration of experiment
- weather conditions
- test case 🔒
- analysis method 🔒



4 factors influence co-heating test reliability

- duration of experiment
- weather conditions
- test case 🔒
- analysis method 🔒



4 factors influence co-heating test reliability

- duration of experiment
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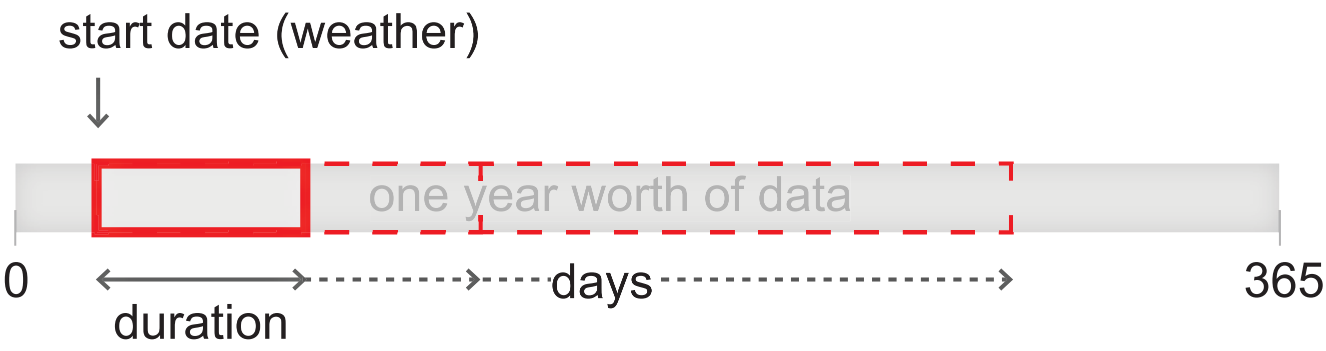
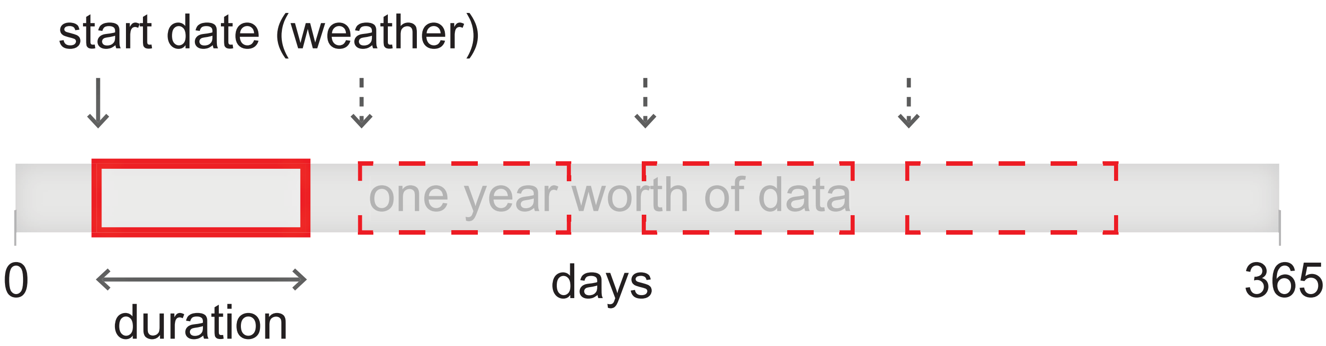
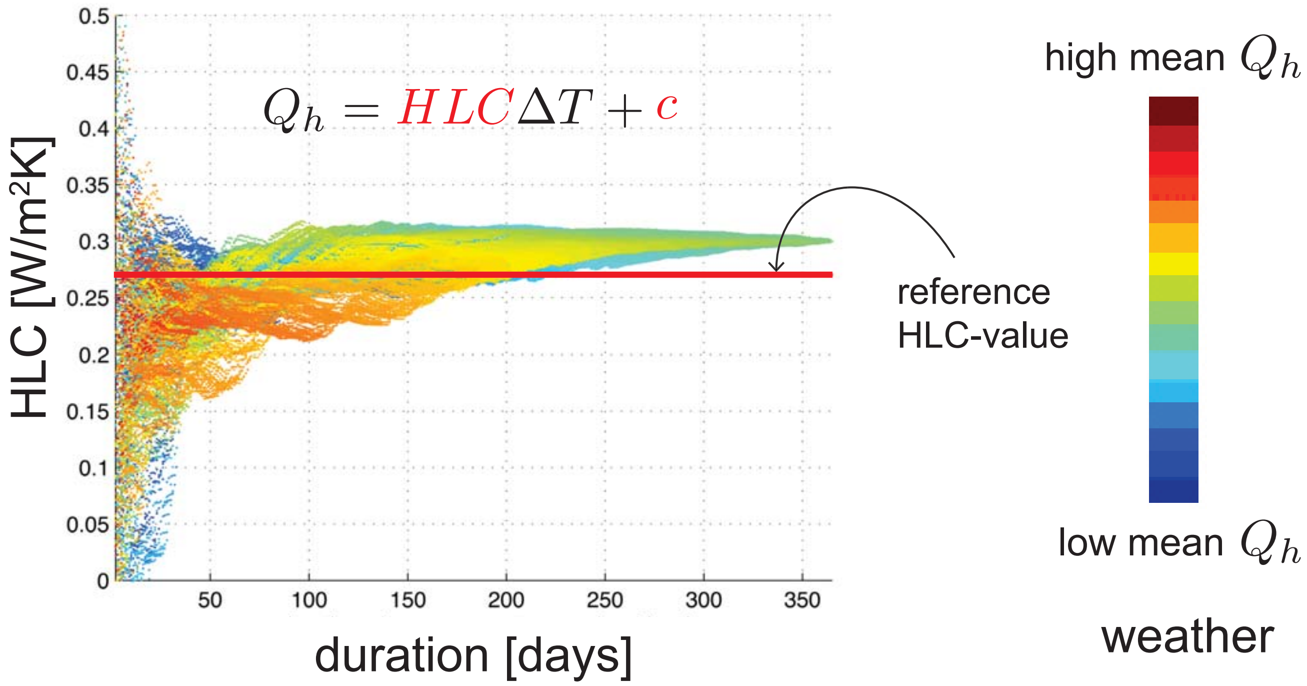


4 factors influence co-heating test reliability

- duration of experiment
- weather conditions
- test case
- analysis method

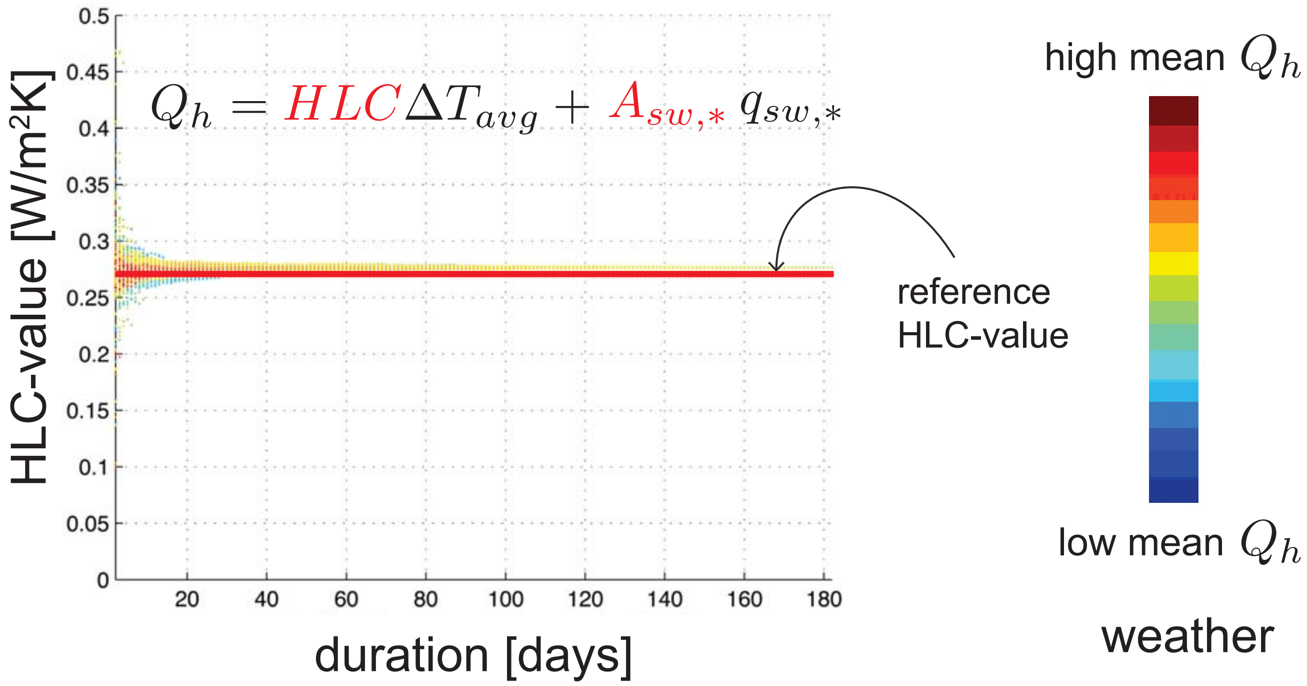


Fixed test case & analysis methodology:



Fixed test case & analysis methodology:

Zero intercept, winter data, solar radiation, thermal lag



Reliable results:

- appropriate analysis method

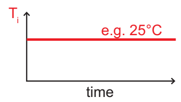
- sufficient duration

- winter measurements (high mean Q_h)

5

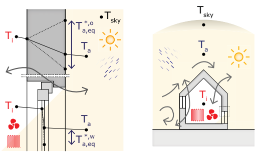
Conclusions

Co-heating test to assess thermal performance of buildings

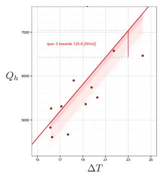


Stationary analysis of quasi-stationary test

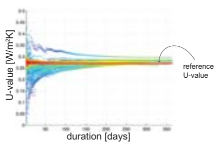
Limited model complexity



Underlying physical phenomena identified



Multiple linear regression and visualisation



Reliability

Annex 58 Seminar
Real building energy performance assessment
Wednesday 16 April 2014

KU LEUVEN

Co-heating test: a state-of-the-art

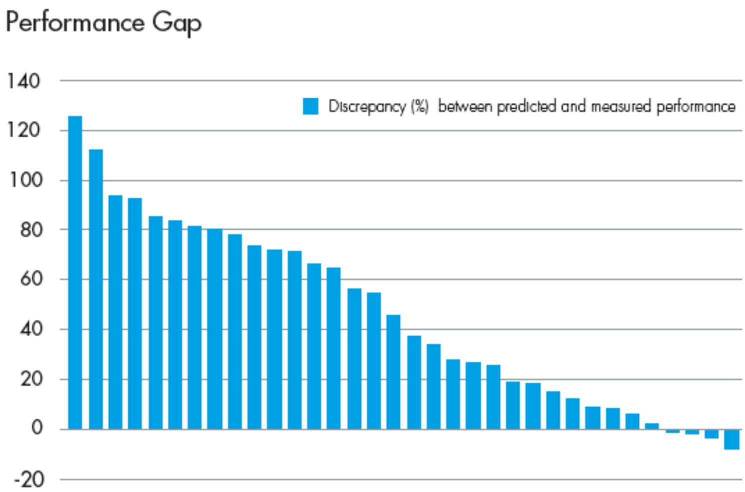
Thank you.

Geert Bauwens, Staf Roels
Building Physics Section, Department of Civil Engineering, KU Leuven

Annex 58 Seminar
Real building energy performance assessment
Learning from real buildings
Delcuve Frédéric
Knauf Insulation

Mind the Gap - Evidence from the UK

KNAUF INSULATION
it's time to save energy



Performance gap (%) for dwellings in UK study

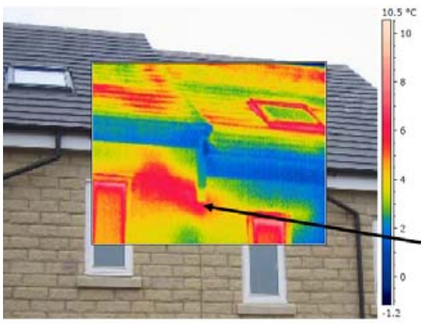
Sources – Bell et. al., Wingfield et. al. (2010), Wingfield et. al. (2009), Wingfield et. al. (2008), Stevenson and Rijal (2008)

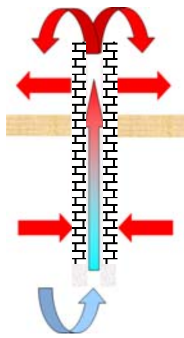
Bad Workmanship

Bad/No Design

Airflow - The biggest uncertainty

Understanding the Gap



Design U-value for performance prediction = 0 [W/m²K]

Measured U-value with Co heating test = 0,4 to 0,6 [W/m²K]

Understanding the Gap



U-Values

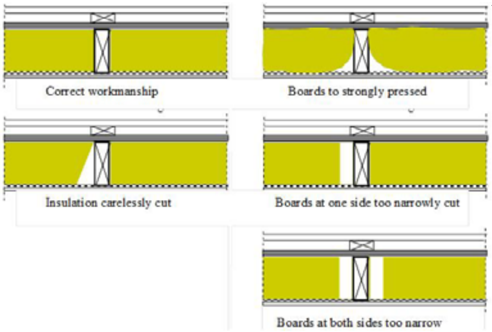
100% 63%

Construction	Calculated	Measured values	
		Good workmanship	Poor workmanship
Full fill Min fibre	0.22	0.22	0.395
Partial Fill XPS rigid board	0.21	0.24	0.985

87% 21%

Brick Cavity Walls: A Performance Analysis Based on Measurements and Simulations H. Hens, A. Janssens, W. Depraetere, J. Carmeliet and J. Lecompte
Journal of Building Physics 2007; 31; 95

Understanding the Gap



Measurements

Timber framed walls

Workmanship inaccuracies

Hot Box/Cold Box data

Timber studs 60cm center, 15cm insulation Imperfections	U measured W/m²K	U Reference W/m²K	η %
None	**0,230**	0,230	**100%**
Boards too strongly pressed against the studs	**0,238**	0,230	**97%**
Insulation carelessly cut, wedge-shaped at studs	**0,263**	0,230	**87%**
Insulation narrowly cut, 50mm leak at one of the studs	**0,246**	0,230	**93%**
Insulation narrowly cut, 50mm leak at both studs	**0,350**	0,230	**65%**

Buildings must deliver real performance

Sir Andrew Stunell OBE MP
Former Parliamentary Under Secretary of State at the UK Department for Communities and Local Government (with responsibility for building regulations)

…those zero carbon homes already constructed are not living up to their name… many processes and cultures within the industry and its supply chain need to change if zero carbon is to be more than an empty slogan.

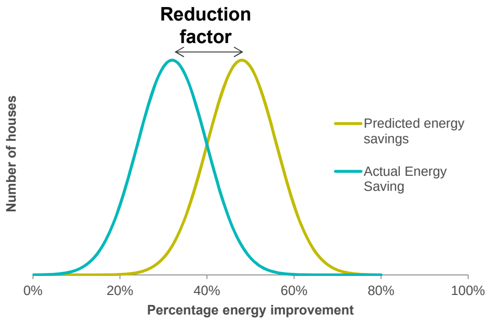
I intend to make sure that performance equals design....

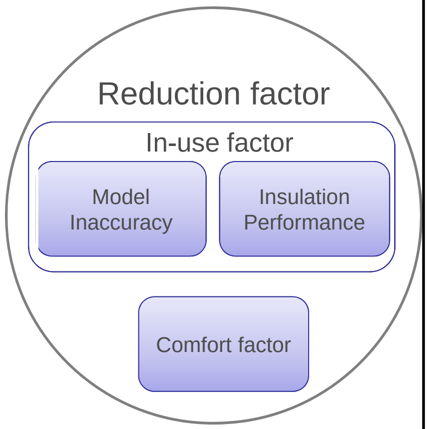
UK – Green Deal and ECO Obligation

Measure	*In-use factor*
Cavity wall insulation (including insulation of hard to treat cavities)	35%
Connection to a district heating system	10%
Draught proofing	15%
External solid wall insulation for a mobile home	25%
Flat roof insulation	15%
High performance external doors and passageway walkthrough doors	15%
Loft or rafter insulation (including loft hatch insulation)	35%
Pipework insulation	15%
Room in roof insulation	25%
Secondary or replacement glazing	15%
Solid wall insulation for a solid brick wall built before— (a) 1967, if situated in England or Wales; (b) 1965, if situated in Scotland	33%
Solid wall insulation for— (a) a solid wall which is not built of brick; (b) a solid brick wall built in— (i) 1967 or later, if situated in England or Wales; (ii) 1965 or later, if situated in Scotland	25%
Under-floor insulation	15%

Reduction factors

- Difference between RdSAP predicted saving and actual energy saving seen by the customer
- Includes in-use factor and comfort factor





Challenges for the supply chain

. TODAY

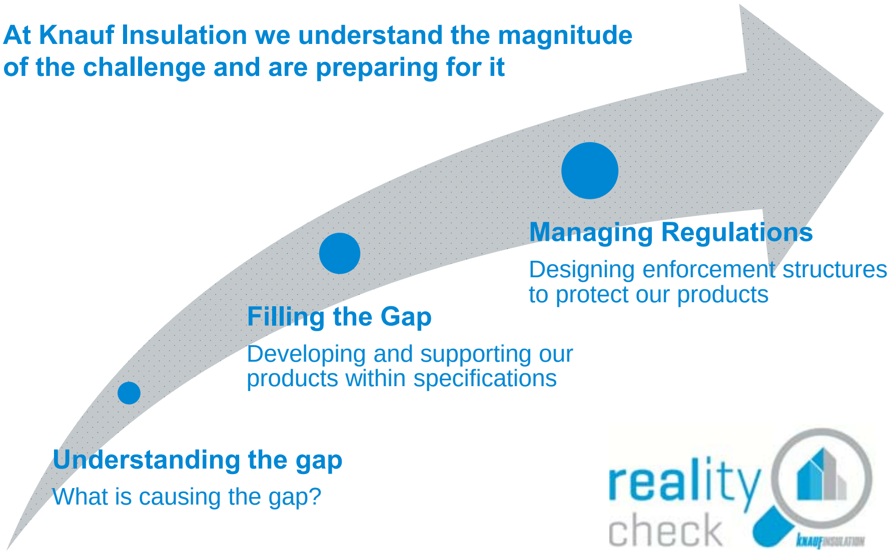
- Assessment based on standards and calculation methods based on European standards
- Performance claims based on theoretical and laboratory performance test

TOMORROW

- Supply chain needs to develop knowledge of "in-situ" performance
- Utilities, customers, banks, etc. all need objective and reliable energy efficiency metrics to recover investments.
- For renovation, energy efficiency improvements need to be verifiable and quantifiable in reality.

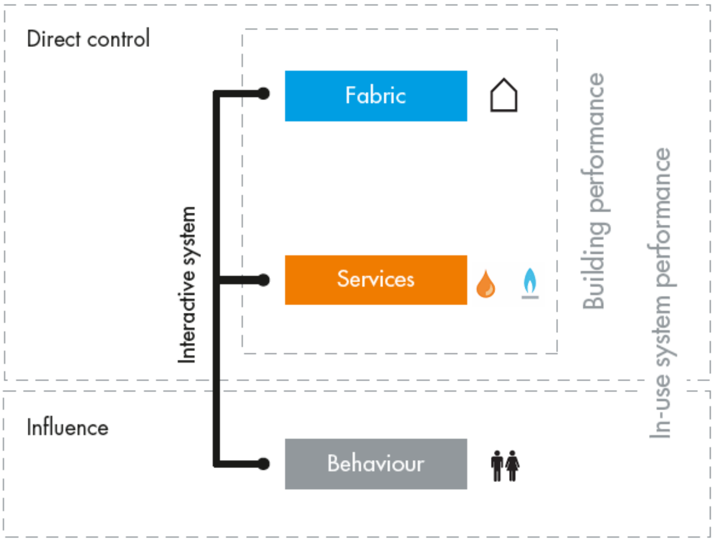
Overall objectives

At Knauf Insulation we understand the magnitude of the challenge and are preparing for it



reality check

A complex interactive system



Semi detached house in Visé Belgium

Semi detached house in Visé Belgium

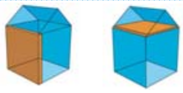
Semi detached house in Visé Belgium

Semi detached house in Visé Belgium

Extended co-heating test: February – May
2 renovation steps:

STEP 1

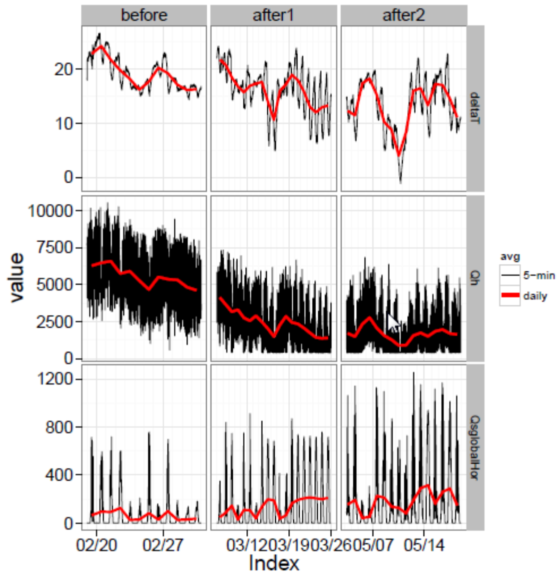
- Blown in insulation in façade and party wall cavities
- Insulating the attic floor slab



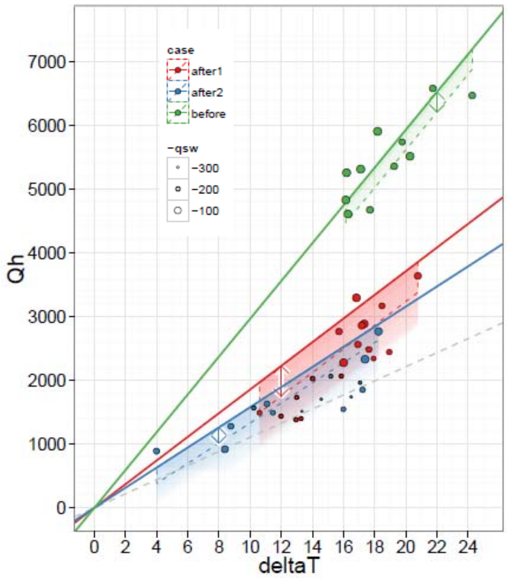
STEP 2

- Insulating floor above basement

Co-heating
Measurement data



Co-heating analysis results



HLC Before
296,55 W/K

HLC after 1
185,63 W/K

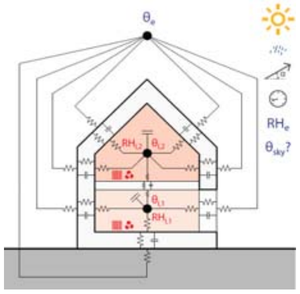
HLC after 2
157,84 W/K

Towards Dynamic Analysis Methods

- HLC as sole characterization output, decoupling HLC into transmission and ventilation heat loss difficult
- Use of daily-averaged data limits amount of informative data points
- Steady-state assumption: important simplification of dynamic and partly non-linear thermal processes

COMBINING

SIMULATION



ON-SITE MEASUREMENTS

Conclusions

- The challenge before the whole construction industry is huge. It is no easy task, but **transition to nearly-zero energy buildings can and must happen**
- Real performance of buildings will become all the more critical. The whole building industry must get much better at understanding it, communicating about it, educating people about it and developing **solutions that really work**
- Cooperation across the whole building chain and with academics will be crucial, but the **benefits for everyone are clear**
- In short: **We must become better at building what we say we build**.

DYNASTEE

EBC
Energy in Buildings and Communities Programme

Seminar

Real building energy performance assessment

Reliability of characterisation models and methods: A Round Robin Experiment on a test box

Maria José Jimenez, CIEMAT, Spain

Staf Roels, KU Leuven

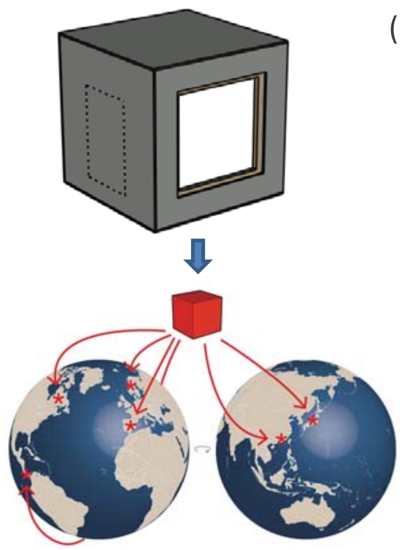
EBC Annex 58

Round Robin experiment

Round robin experiment

well controlled comparative test on testing and data analysis

(comparable with BESTEST for numerical modelling)



Test box send around to different institutes to be measured under different climatic conditions

cross round robin testing

Obtained dynamic data send around to different institutes to characterise the test box

EBC Annex 58

Round Robin experiment

Aim of round robin experiment:

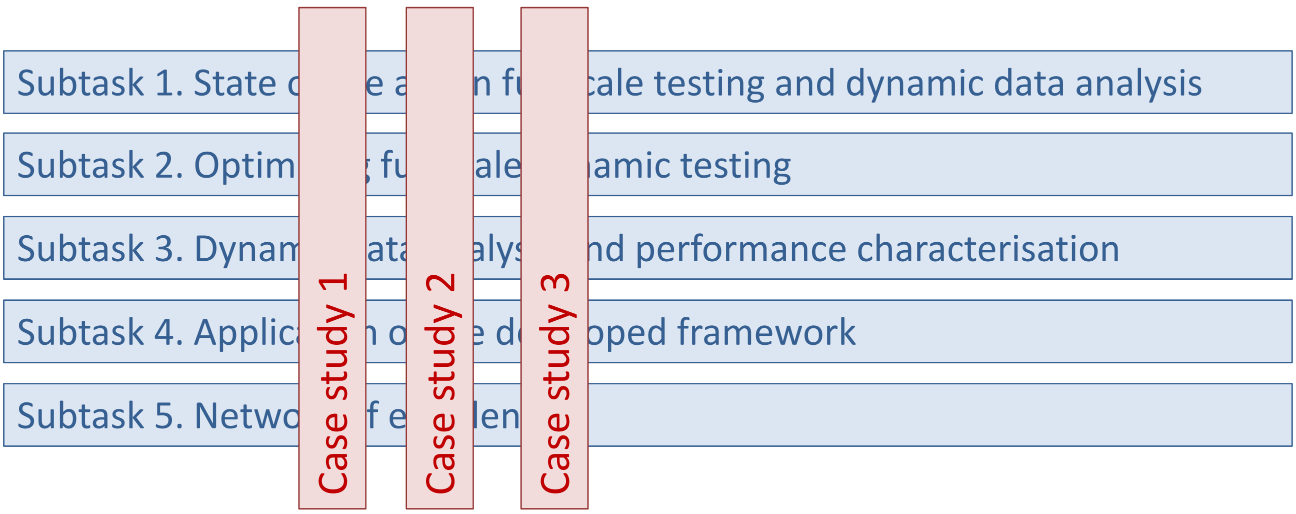
- investigate reliability of full scale testing
- investigate reliability of dynamic data analysis
- investigate influence of climatic conditions on characterisation
- provide well documented data set for validation
- determine state-of-the-art: where are we now?
- first step to go to more complex (real) buildings

round robin experiment (as other case studies) links the different subtasks

EBC Annex 58

Round Robin experiment

Global framework of IEA EBC Annex 58:



Global framework of IEA EBC Annex 58:

Subt ... ca ... s ... and dynamic data analysis

Subt ... a ... t ... ng

Subt ... nc ... rf ... ance characterisation

Subt ... op ... fr ... ework

Subt

round robin experiment

Case study 2

Case study 3

Global framework of IEA EBC Annex 58 :

Sub ... 1 ... ir ... nd dynamic data analysis

Sub ... 2 ... st

Sub ... 3 ... r ... nce characterisation

Sub ... 4 ... r ... ork

Sub ... 5

Case study 1

Verification of BES-models

Case study 3

Global framework of I

S ask ta ... amic data analysis

S ask Op

S ask Dy ... aracterisation

S ask Ap

S ask Ne

round robin experiment

Case study 2

Case study 3

International Commerce Centre (ICC)

EBC Annex 58

Round Robin experiment

Annex 58

RELIABLE BUILDING ENERGY PERFORMANCE CHARACTERISATION BASED ON FULL SCALE DYNAMIC MEASUREMENT

reality check KNAUFINSULATION

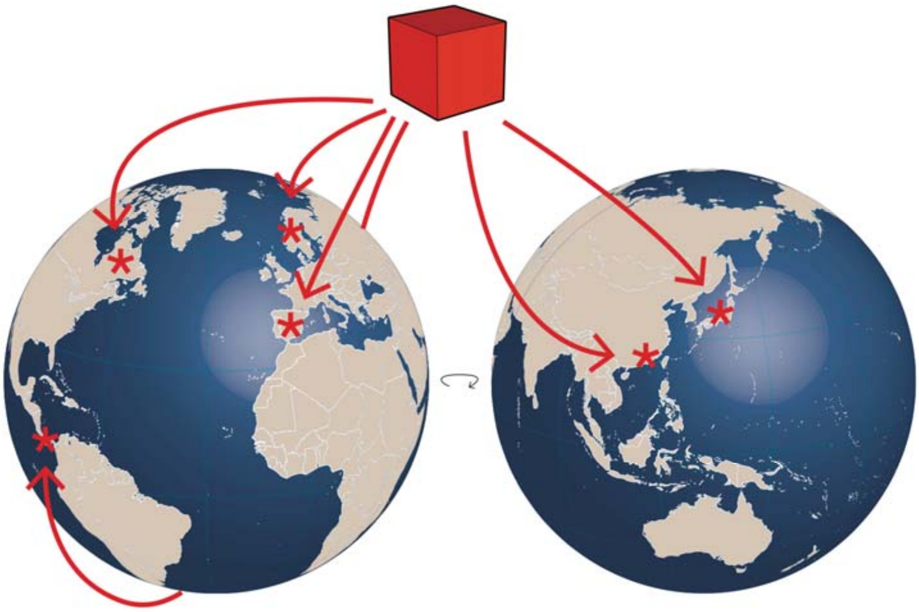
Round Robin Test Box

RR Test box made by KU Leuven, exact composition unknown to all other participants

EBC Annex 58

Round Robin experiment

Test box shipped to different partners (different climatic conditions)



BBRI, Belgium :
Jan. 2013 – Feb. 2013

CIEMAT, Almería, Spain:
April 2013 – Sep. 2013

UPV/EHU, Bilbao, Spain:
Oct. 2013- May. 2014

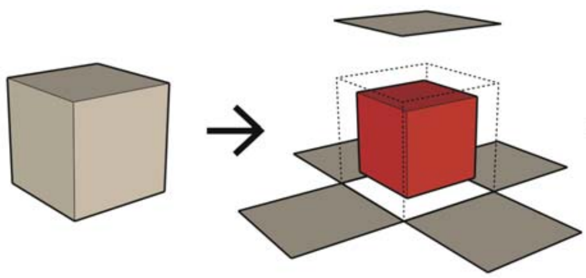
ENTPE, Lyon, France:
June 2014 – Sep. 2014

CTU, Prague, Czech Republic
Oct. 2014 -…

EBC Annex 58

Round Robin experiment

At these locations: full scale dynamic testing of the test box



Obtained dynamic data is send to other institutes for data analysis

EBC Annex 58

Round Robin experiment

Data analysis based on two measurement campaigns

BBRI, Belgium

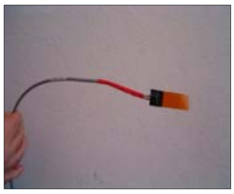
January 2013 – February 2013

CIEMAT, Almeria, Spain

April 2013 – August 2013

ROUND ROBIN EXPERIMENT.
SET UP BY CIEMAT IN ALMERÍA (SPAIN)








REQUESTED OUTPUT

1. Freedom to choose what physical characteristics
   - overall heat loss coefficient, solar aperture, effective heat capacities, time constants, ….

   Suggested: At least one of the following:
   - U value (W/m^{2}K) of each opaque wall of the test box
   - overall heat loss (W/K) of the test box
   - solar gains
   - dynamic behavior of the test box
2. Validation. Statistical and physical criteria
3. Describe step by step the analysis and validation carried out. Try to be as clear and illustrative as possible

EBC Annex 58 Round Robin experiment

REQUESTED OUTPUT

Aim: analyse the capability of a model identified from one data set, to predict the box's behaviour during another period, for which only the inputs are available.

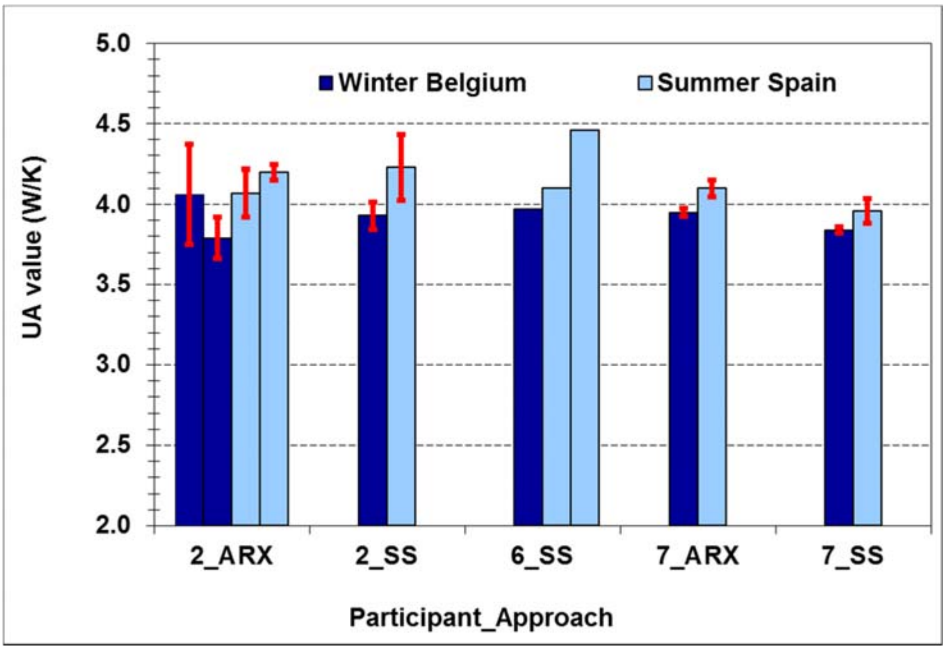
1. Using models identified measurement at BBRI, predict the output using the data recorded at CIEMAT-PSA.
2. Using models identified using data recorded at CIEMAT-PSA, predict the output for a measurement period different from the one used to identify model.
3. Discuss difference between predicted and simulated output in both cases.

TEAM	Applied Methods	CE3 Est. (W/K)	CE4 Est. (W/K)
1	Average method	3.77–3.92	
	State space thermal model identification(RC using LORD)	3.07–3.42	
2	Average method	2.86–4.15	
	Linear regression; 5 min data	2.84–4.11	
	Linear regression; daily averaged data	3.68–4.12	4.32–4.48
	ARX and ARMAX models (using SIT Matlab)	3.79-4.06	4.07-4.20
	State space thermal model identification (RC using LORD)	3.93	4.23
3	Multiple linear regression; Hourly averaged data	4.77-5.24	
	Multiple linear regression; Daily averaged data	3.73–4.39	
	Multiple linear regression; Recorded data		3.17-3.55
4	State space thermal model identification	4.27–4.56	
5	Linear regression; daily averaged data	3.99–4.08	
	State space thermal model identification (RC using CTSM-R)	3.99	
	QUB-test	3.54–3.70	
6	State space thermal model identification (RC using SIT Matlab)	3.97	4.1-4.46
7	ARX models (Using R)	3.95	4.05-4.10
	State space models (RC using CTSM-R)	3.84	3.96
8	Average method	3.72–3.99	
	Linear regression; 5 min data	2.98–3.94	
	ARX and ARMAR (Using R)	4.01–4.08	
	CTSM-R	4.48	

Data analysis methods

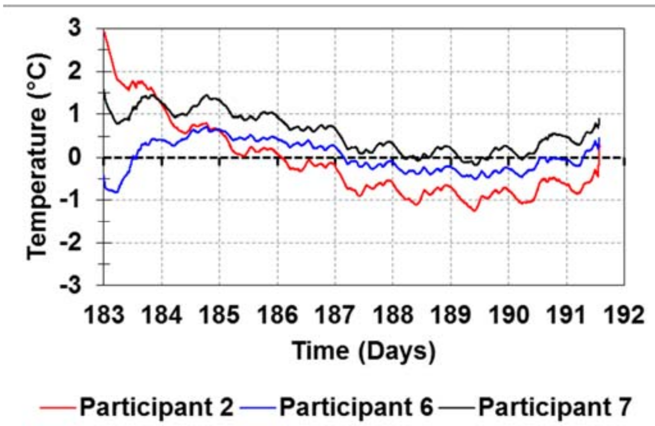
- **Preprocessing**
- **Physical hypothesis and approximations**
  - Starting point: energy balance equations (Differential or implicitly integrated).
  - Most results around 4W/K
  - Minority of results out of tendency: Models just applying formulas far from their hypotheses of validity
- **Mathematical approach**
  - Average methods
  - Linear and multi-linear regressions.
  - ARX and ARMAX models
  - Stochastic differential equations: Wide potential but only very simple RC applied.

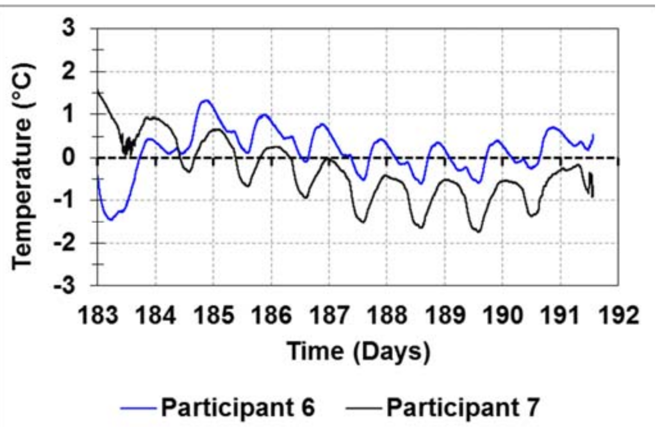
Results applying dynamic approaches



EBC Annex 58
Round Robin experiment

Difference between predicted and measured indoor air temperature





	Model based on Summer Spanish data		Model based on Winter Belgian data	
Participant	Mean (°C)	Stdv (°C)	Mean (°C)	Stdv (°C)
2	-0.108	0.896		
2	-0.435	0.471		
6	0.025	0.372	0.149	0.549
7	0.590	0.458	-0317	0.712

CONCLUSSIONS

- A round robin test box experiment has been performed in the framework of Annex 58.
- Global objective of the experiment:
  - Well-controlled comparative experiment on testing and data analysis.
- It is shown how different techniques can be applied to characterise the thermal performance of the test box
  - From (quasi)stationary techniques to dynamic system identification.
- (Quasi) stationary techniques are only able to estimate the steady state properties of the box (e.g. overall heat loss coefficient)
- Dynamic approaches can give additional information on the dynamic behaviour of the box and can be used to simulate the dynamic response of the box in a simplified way.
- In a next step the investigated methods will be applied to characterise real buildings.

Next common exercise: characterisation of real building

THANKS FOR THE ATTENTION

Dynamic building envelopes; testing, analysis and simulation

Hans BLOEM

INTRODUCTION

EPBD (2010) mentions for the energy performance assessment by

- measurement or
- calculation

- European standards
- Passive design for new buildings and building elements
- Innovation in construction products, building elements, buildings

CONTEXT

Directive 2010/31/EU article 2:

The ‘energy performance of a building’ means the ***calculated*** *or* ***measured*** *amount of energy needed to meet the energy demand associated with a typical use of the building, which includes, inter alia, energy used for heating, cooling, ventilation, hot water and lighting;*

CONTEXT

*A ‘**nearly zero-energy building**’ means "a building that has a **very high energy performance** (very low amount of energy required associated with a typical use of the building including energy used for heating, cooling, ventilation, hot water and lighting).*

*The very low amount of energy required by a nearly zero-energy building has to be covered to a very significant extent by energy from renewable sources, including **energy from renewable sources produced on site or nearby**".*

EXAMPLES

Building envelope dynamic technologies

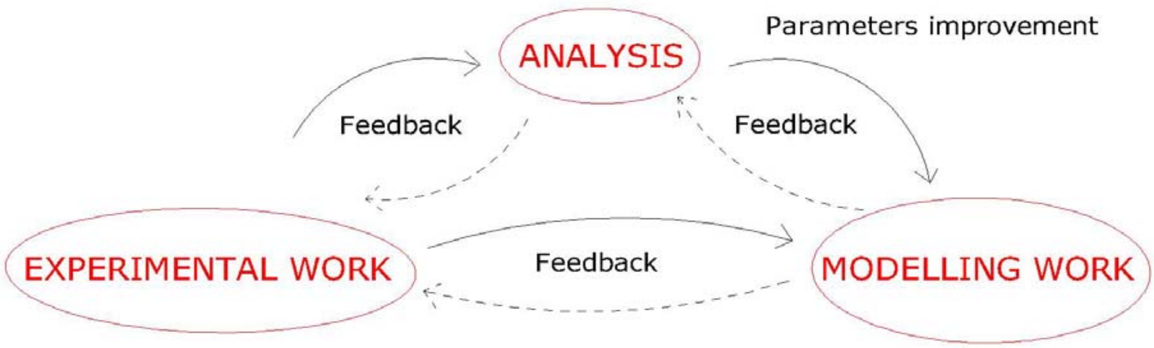
- Trombe wall
- Ventilated roof or wall, curtain wall
- Multi-functional wall
- Solar wall and solar chimney
- Building Integrated solar
  - PV roof and PV façade
  - Solar water collectors

HIGH PERFORMANCE

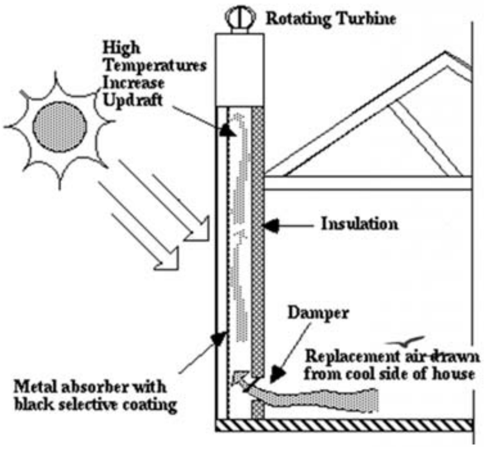
High performance buildings need high performance envelopes

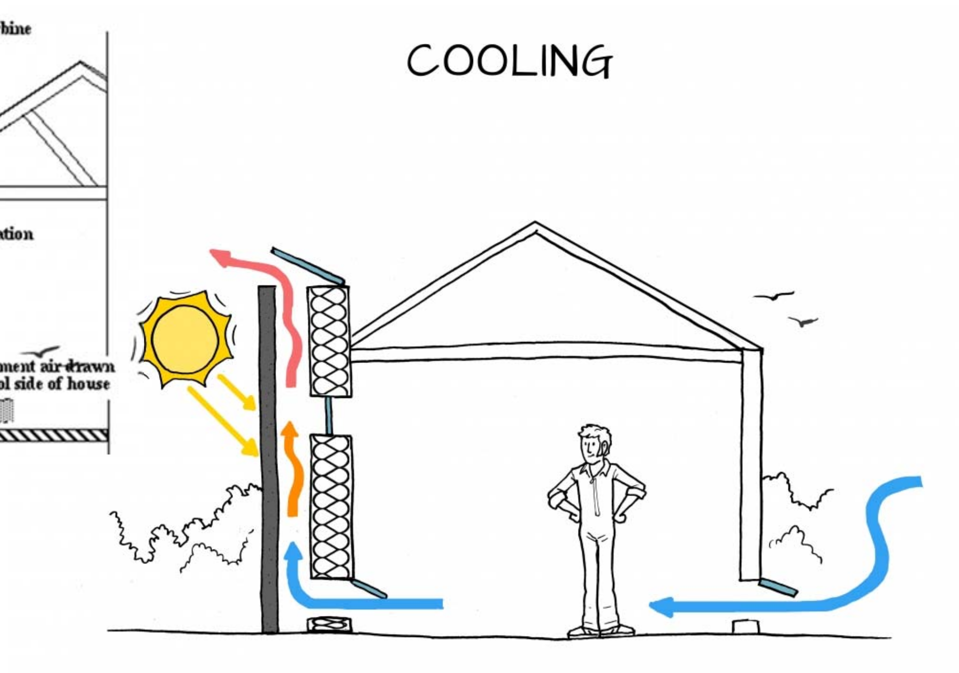
Performance assessment through

- Testing, Evaluation and Simulation
- TC89 working on calculation methods

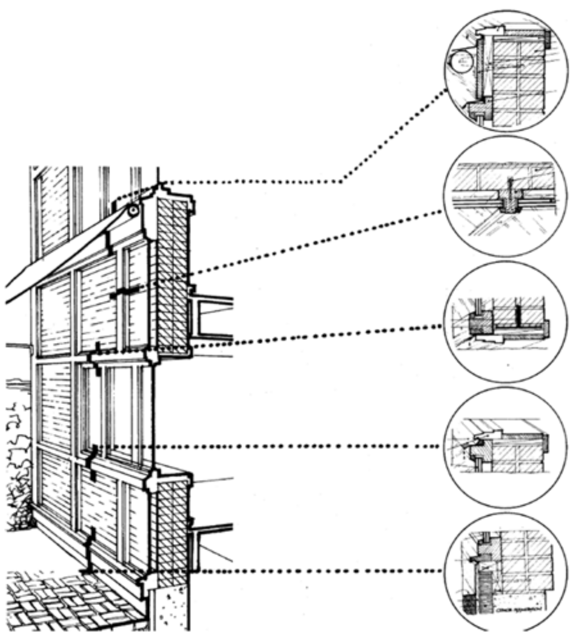


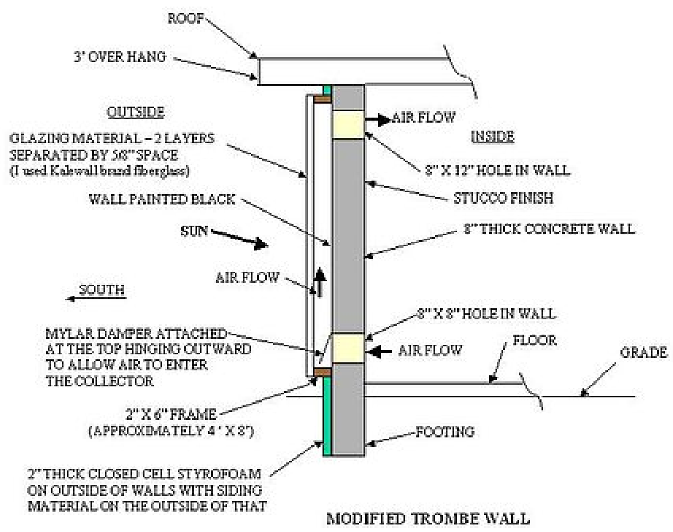
SOLAR DRIVEN VENTILATION





PASSIVE SOLAR WALL





BIPV obstacles

Existing standards address different requirements:

- CENELEC/IEC standards for electrical performance and safety
- CEN/ISO on building energy performance and energy related standards (as required under the Energy Performance of Buildings Directive)
- EuroCodes for the mechanical/construction part (as required under the Construction Products Directive and Regulation)

COMMON APPROACH

Standardisation should consider:

- **Calculation Method** for design purposes
- **Test Measurement Method** for energy performance assessment
- **Evaluation Methodology** for assessment of characteristic parameters
- In-situ testing **Verification Methodology**

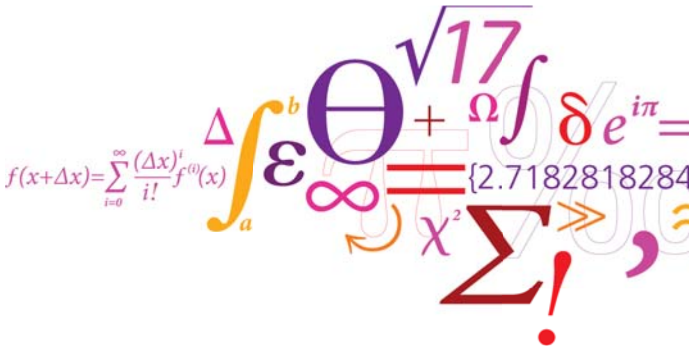
CONCLUSIONS

- Experimental work is needed to support developments in harmonised calculation rules for innovative technologies
- Reduce the gap between measurement and calculation of energy performance values for buildings and building elements
- Consensus required between different objectives of different regulations

Some possibilities for future use of Smart Meter data

Annex 58/Dynastee Workshop
Ghent, April 2014

Henrik Madsen, Henrik Aalborg Nielsen, Peder Bacher



DTU Compute
Department of Applied Mathematics and Computer Science

Contents

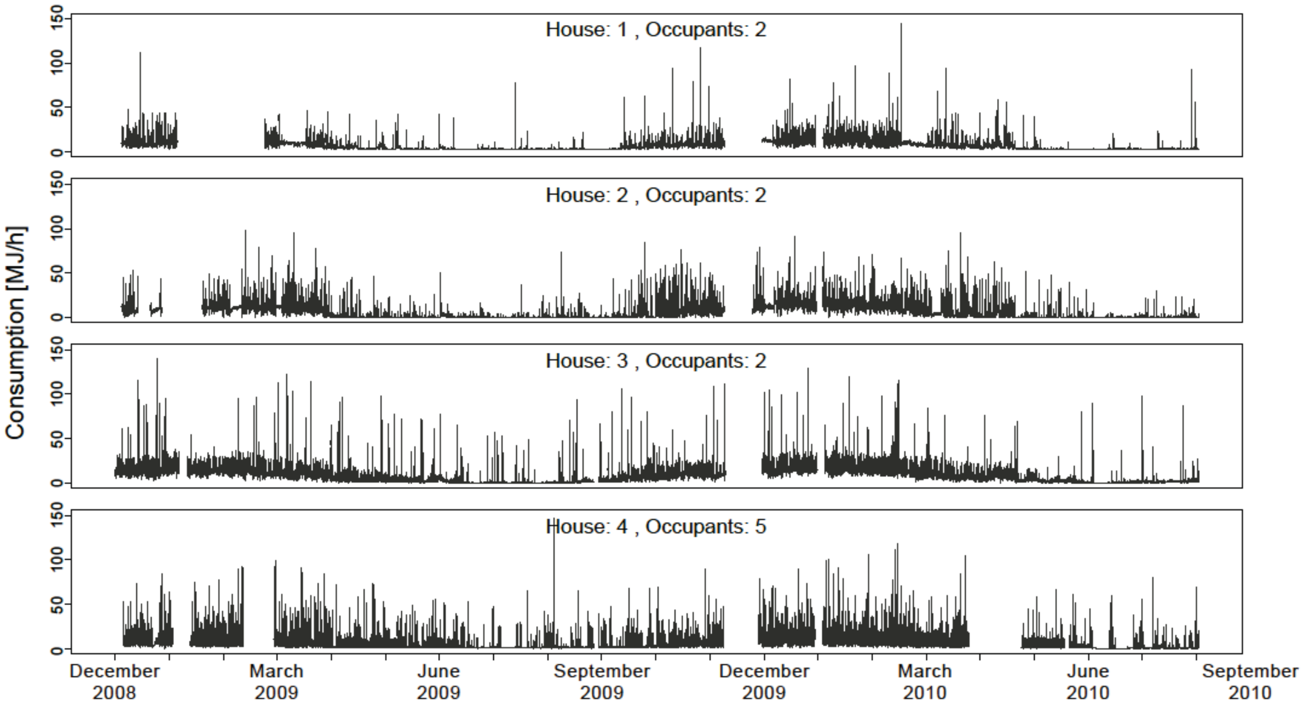
- Smart Meters and data splitting
- Smart Meters and Thermal Characteristics
  - Problem setting
  - Simple tool
- Smart Meters and Control (DSM)

Case Study No. 1

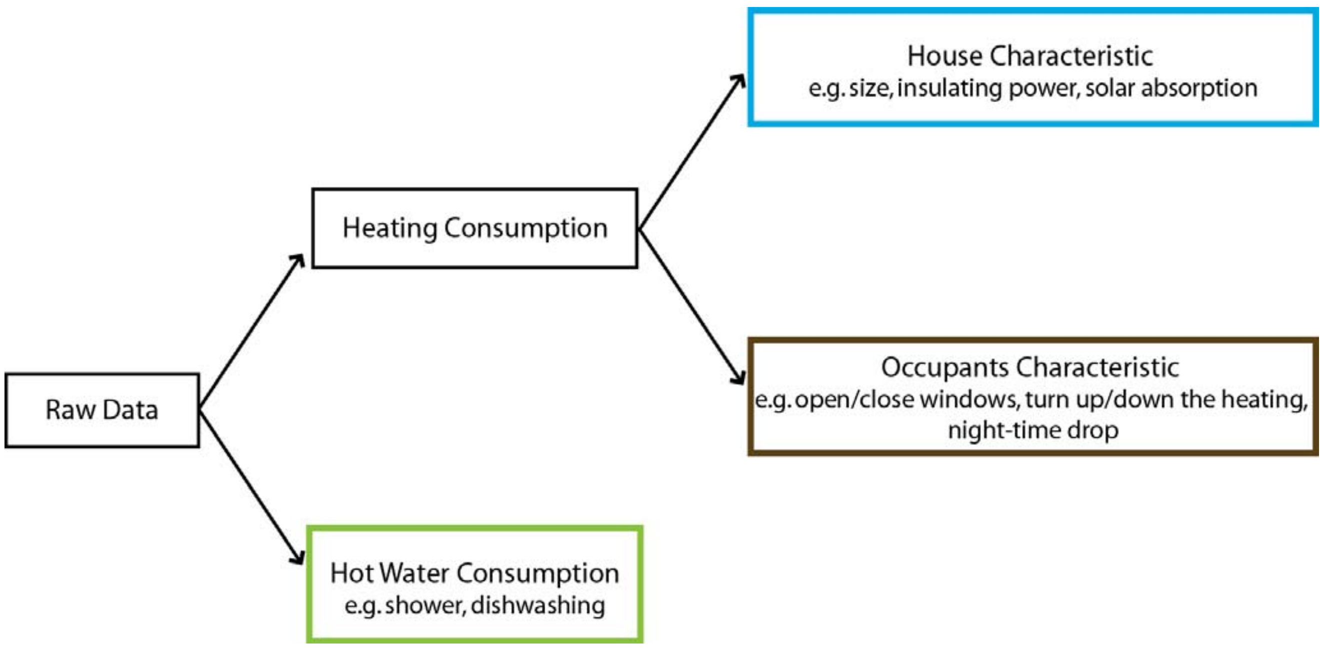
Split of total readings into space heating and domestic hot water using data from smart meters

Data

- 10 min averages from a number of houses

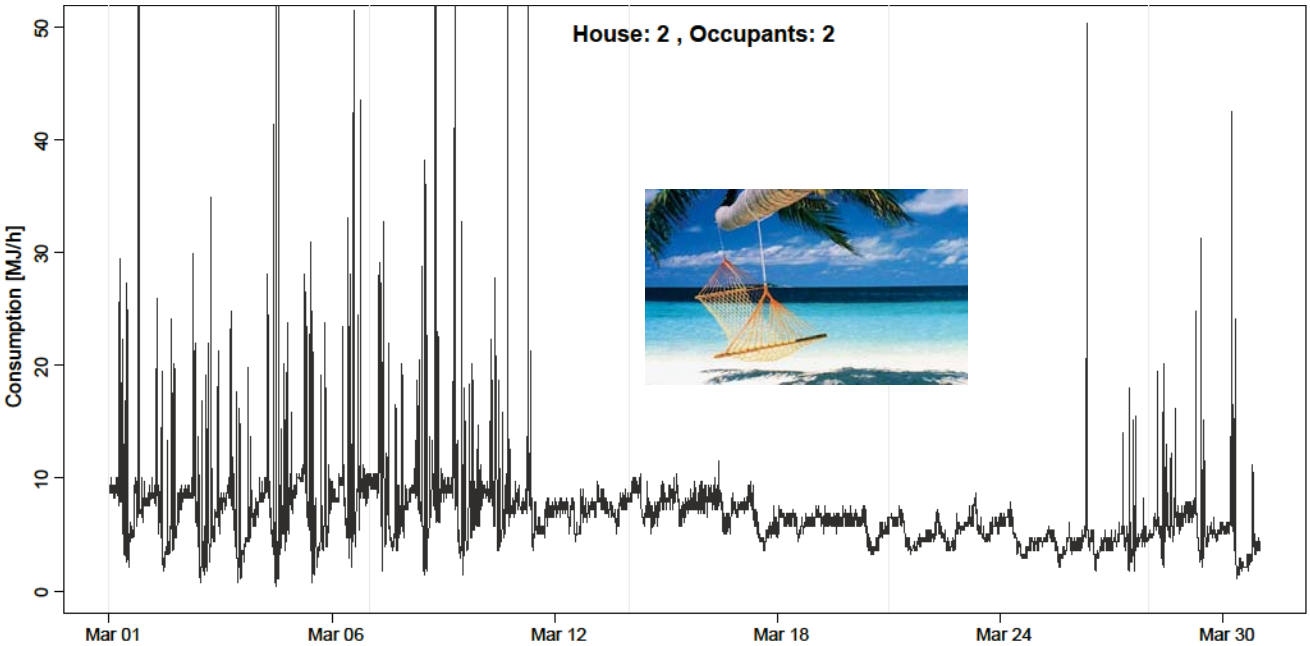


Data separation principle



ANNEX 58 / DYNASTEE WORKSHOP
Ghent, April 2014

Holiday period



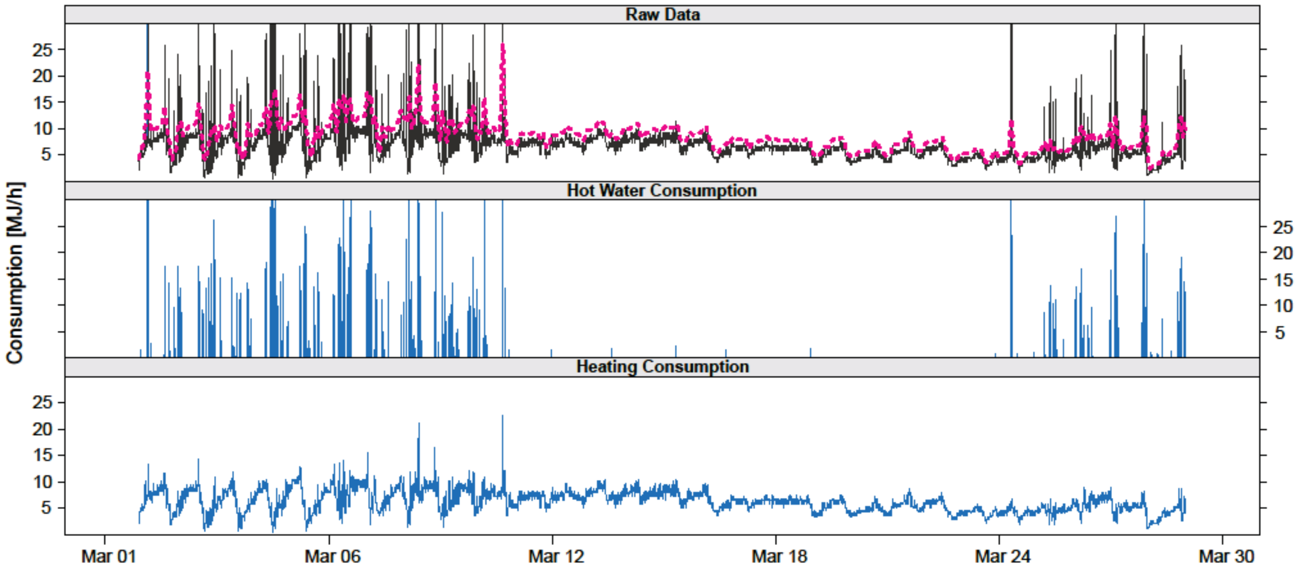
Non-parametric regression

$$\hat{g}(x) = \frac{\sum_{s=1}^{N} Y_s k\{\frac{x-X_s}{h}\}}{\sum_{s=1}^{N} k\{\frac{x-X_s}{h}\}} \qquad k(u) = \frac{1}{2\pi}\exp\{-\frac{u^2}{2}\}$$

Weighted average

Every spike above $1.25 \cdot \hat{g}(x)$ Is regarded as hot water use.

Kernel



Robust Polynomial Kernel

To improve the kernel method

Rewrite the kernel smoother to a Least Square Problem

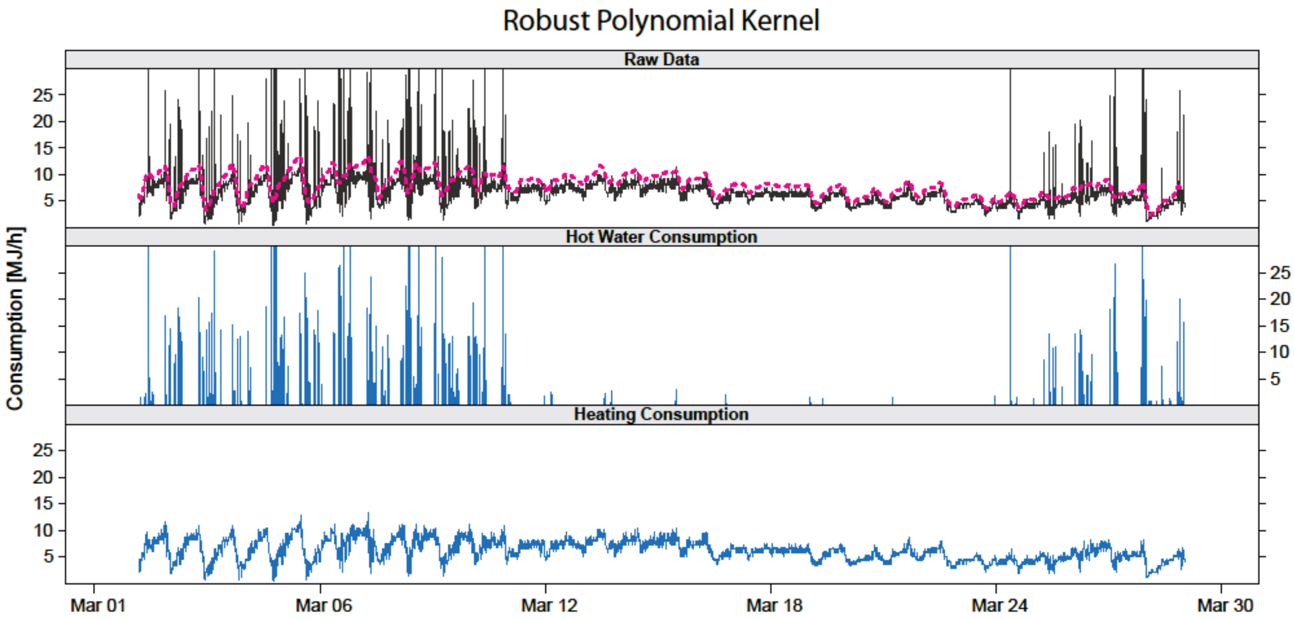
$$\arg\min_{\theta} \frac{1}{N} \sum_{s=1}^{N} w_s(x) \left(Y_s - \theta\right)^2 \qquad w_s(x) = \frac{k\{x - X_s\}}{\frac{1}{N}\sum_{s=1}^{N} k\{x - X_s\}}$$

Make the method robust by replacing $(Y_s - \theta)^2$ with

$$\rho_{\text{Huber}}(\varepsilon) = \begin{cases} \frac{1}{2\gamma}\varepsilon^2 & \text{if } |\varepsilon| \le \gamma \\ |\varepsilon| - \frac{1}{2}\gamma & \text{if } |\varepsilon| > \gamma \end{cases} \qquad \varepsilon_s = Y_s - \theta$$

Make the method polynomial by replacing θ with

$$P_s = \theta_0 + \theta_1(X_t - x) + \theta_2(X_t - x)^2$$



ANNEX 58 / DYNASTEE WORKSHOP
Ghent, April 2014

Case Study No. 2

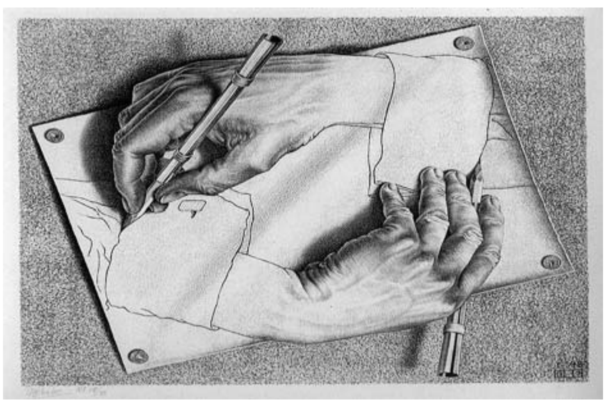
Identification of Thermal Performance using Smart Meter Data

Characterization using Smart Meter Data

- Energy labelling
- Estimation of UA and gA values
- Estimation of energy signature
- Estimation of dynamic characteristics
- Estimation of time constants

Energy Labelling of Buildings

- Today building experts make judgements of the energy performance of buildings based on drawings and prior knowledge.
- This leads to 'Energy labelling' of the building
- However, it is noticed that two independent experts can predict very different consumptions for the same house.



Simple estimation of UA-values

- Consider the following model (t=day No.) estimated by kernel-smoothing:

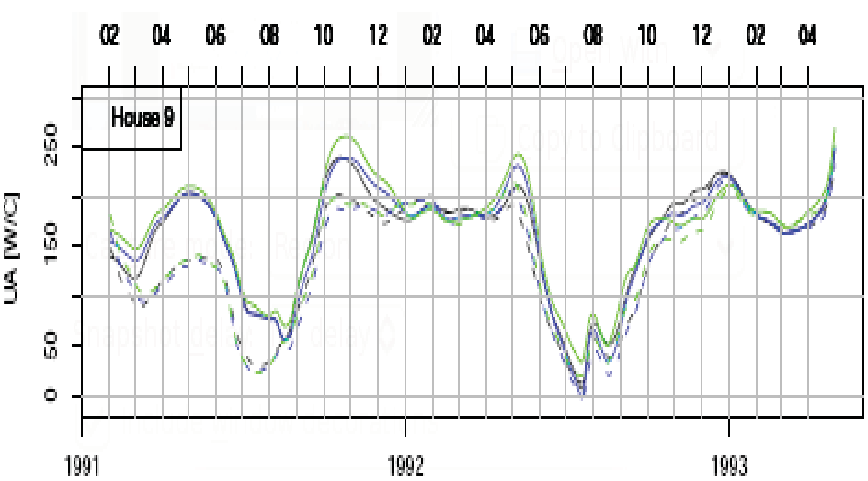
$$Q_t = Q_0(t) + c_0(t)(T_{i,t} - T_{a,t}) + c_1(t)(T_{i,t-1} - T_{a,t-1}) \quad (1)$$

- The estimated UA-value is

$$\hat{UA}(t) = \hat{c}_o(t) + \hat{c}_1(t) \quad (2)$$

- With more involved (but similar models) also gA and wA values can be stimated

Estimated UA-values



Results

	UA	σ_{UA}	gA^{max}	wA$_E^{max}$	wA$_S^{max}$	wA$_W^{max}$	T_i
	W/°C		W	W/°C	W/°C	W/°C	°C
4218598	211.8	10.4	597.0	11.0	3.3	8.9	23.6
4218600	98.7	10.8	-96.2	23.6	10.1	13.0	22.3
4381449	228.2	12.6	1012.3	29.8	42.8	39.7	19.4
4711160	155.4	6.3	518.8	14.5	4.4	9.1	22.5
4711176	178.5	7.3	800.0	1.9	-7.6	8.5	26.4
4836681	155.3	8.1	591.0	39.5	28.0	21.4	23.5
4836722	236.0	17.7	1578.3	4.3	3.3	18.9	23.5
4986050	159.6	10.7	715.7	10.2	7.5	7.2	20.8
5069878	144.8	10.4	87.6	3.7	1.6	17.3	21.8
5069913	207.8	9.0	962.5	3.7	8.6	10.6	22.6
5107720	189.4	15.4	657.7	41.4	29.4	16.5	21.0

Notice: Still some issues with negative values but often they are not significiant.

Based on measurements from the heating season **2009/2010** your typical indoor temperature during the heating season has been estimated to **24** ^oC. If this is not correct you can change it here [24] ^oC.

If your house has been left empty in longer periods with a partly reduced heat supply you have the possibility of specifying the periods in this [calendar].

According to BBR the area of your house is **155** m^2 and from **1971**.

Based on BBR information it is assumed that **you do not use any supplementary heat supply**. If this is not correct you can specify the type and frequency of use here:

- Wood burning stove used [0] times per week in cold periods.
- Solar heating [y/n], approximate size of solar panel [0] × [0] meters.

Based on the indoor temperature **24** ^oC, the use of a wood burning stove **0** times per week, and **no** solar heating installed, the response of your house to climate is estimated as:

- The response to outdoor temperature is estimated to **200** $W/^oC$ **which given the size and age of your house is expectable**[a].
- On a windy day the above value is estimated to increase with **60** $W/^oC$ **when the wind blows from easterly directions. This response to wind is relatively high and indicates a problem related to the air sealing on the eastern side of the house.**
- On a sunny day during the heating season the house is estimated to receive **800** W as an average over 24 hours. **This value is quite expectable.**

[a] Many kind of different recommendations can be given here.

Perspectives for using Smart Meters

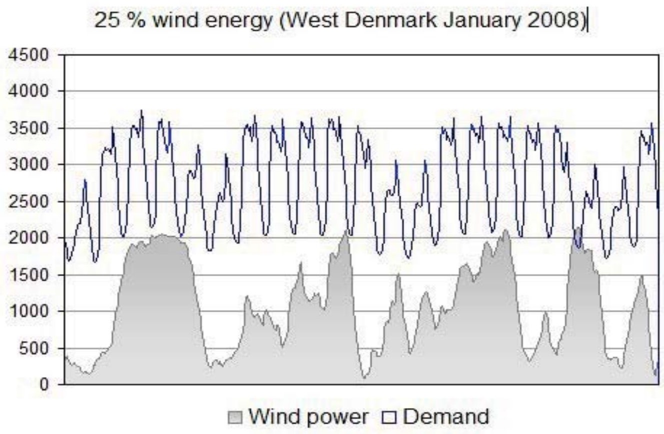
- Reliable Energy Signature.
- Energy Labelling
- Time Constants (eg for night set-back)
- Proposals for Energy Savings:
  - Replace the windows?
  - Put more insulation on the roof?
  - Is the house too untight?
  - ......
- Optimized Control
- Integration of Solar and Wind Power using DSM

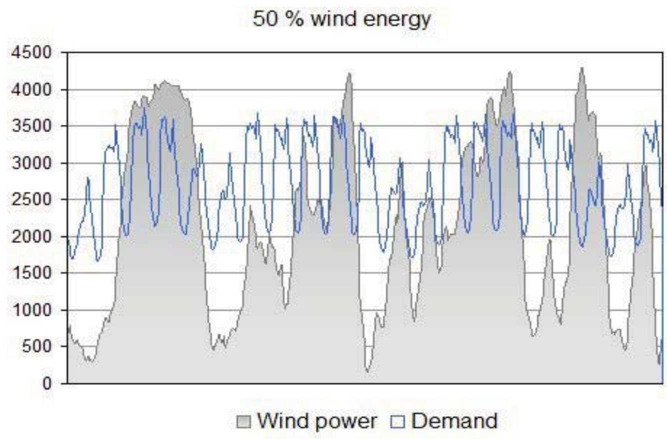
Case Study No. 3

Control of the Power Consumption

The Danish Wind Power Case

.... balancing of the power system

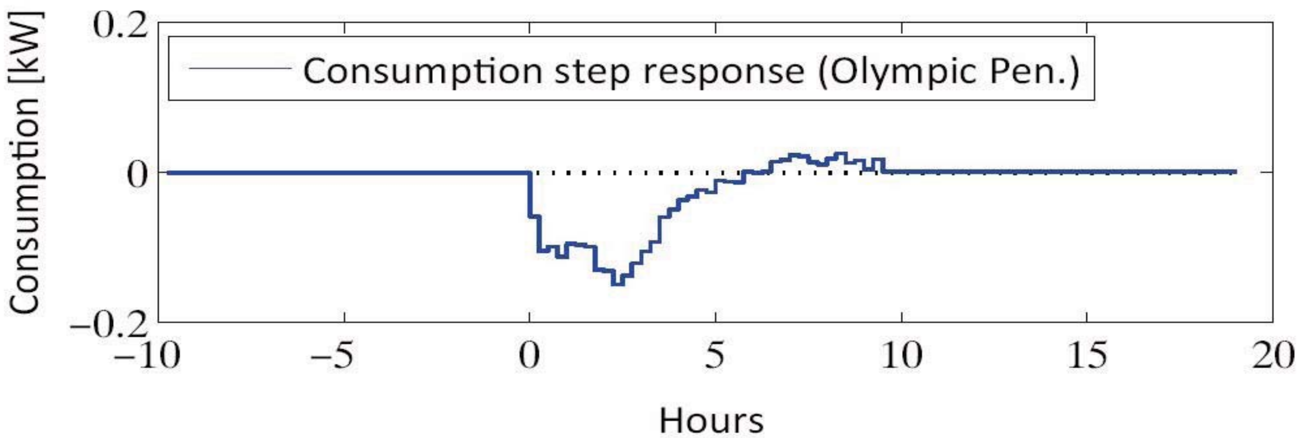




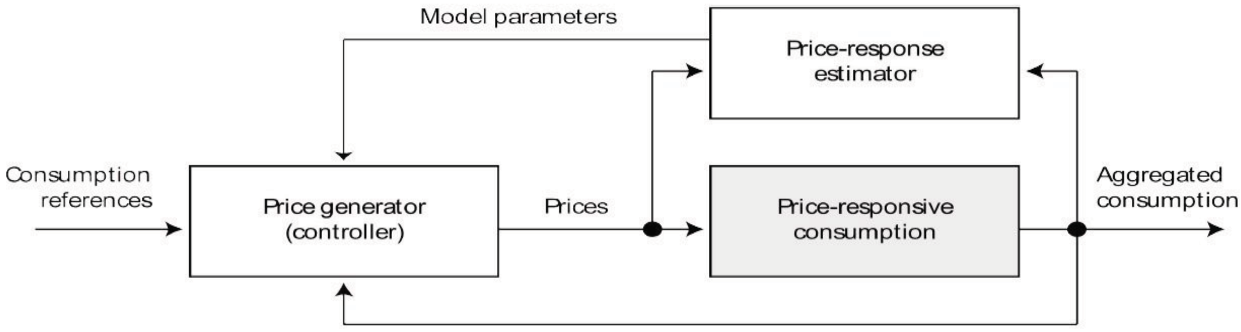
Wind power covers the entire demand of electricity in 200 hours (West DK)

In the future wind power will exceed demand in more than 1,000 hours

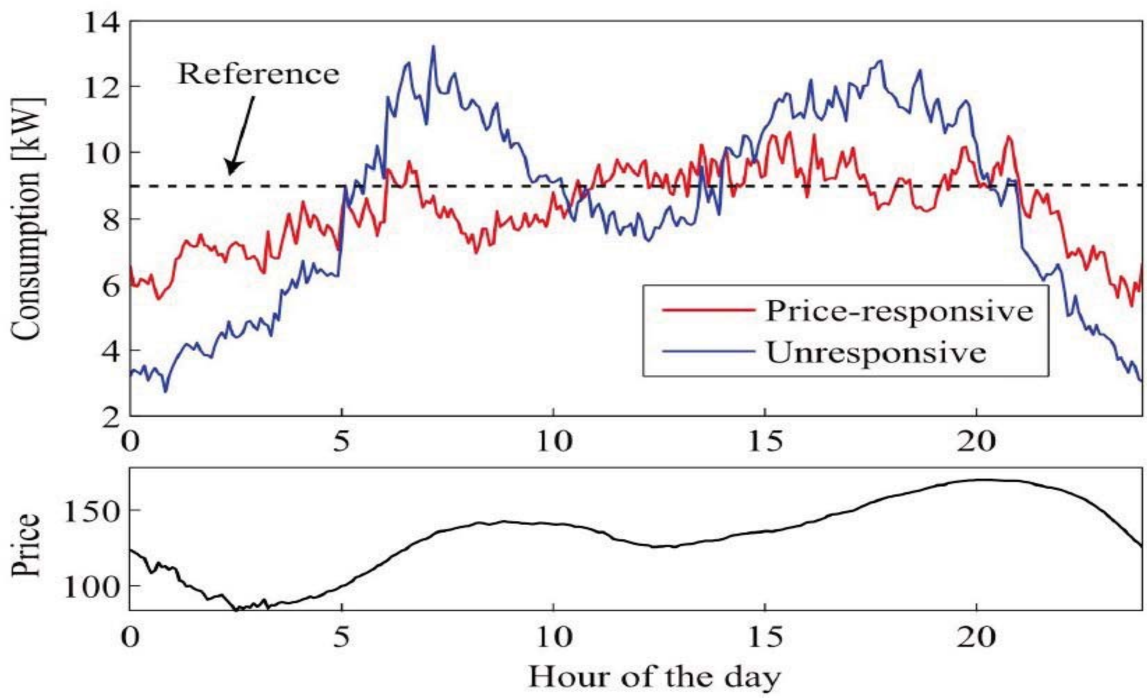
Smart Meter Data --> Model for control



Control of Energy Consumption



Control of Energy Consumption



Conclusions

- Smart Meters (or frequent readings) can give:
  - Split of total readings into hot tap water and the rest
  - Energy signatures / labels of buildings
  - Time constants for optimal control
  - Advanced knowledge about potentials for energy savings
  - Controller for integration of wind/solar power
- All methods need large scale testing before final conclusions

More information ...

- See for instance

  www.henrikmadsen.org

  www.smart-cities-centre.org

- ...or contact

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    pbac@dtu.dk