EBC

IEA EBC Annex 58

# Reliable building energy performance characterisation based on full scale dynamic measurements

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## Joint workshop Annex 58 – Annex 60

LBNL, Berkeley (CA), USA __ September 17th, 2014

# Background

WUFI® PRO, 2D, Plus

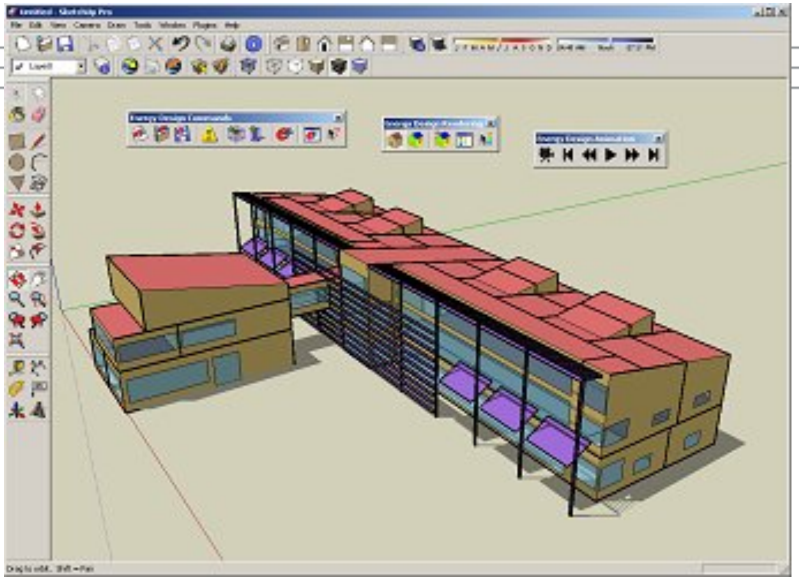
TRNSYS 17

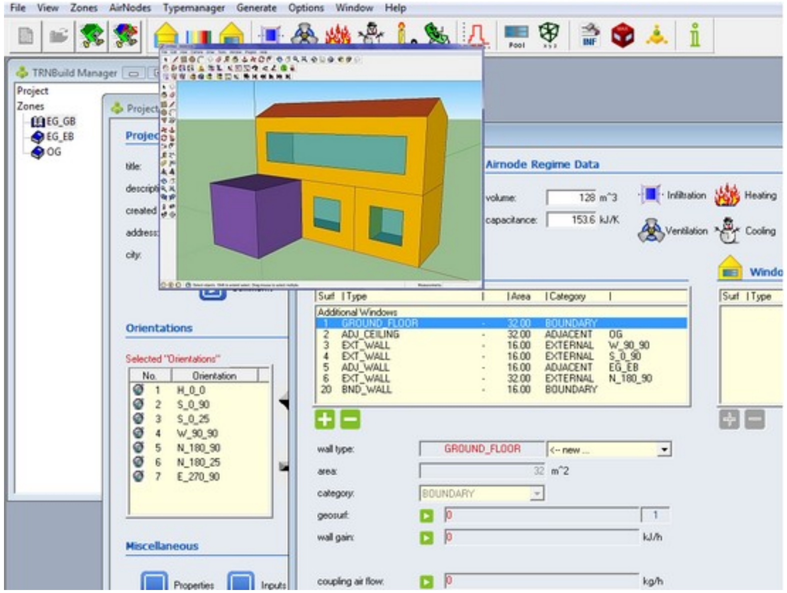
seai SUSTAINABLE ENERGY AUTHORITY OF IRELAND

Dwelling Energy Assessment Procedure (DEAP)

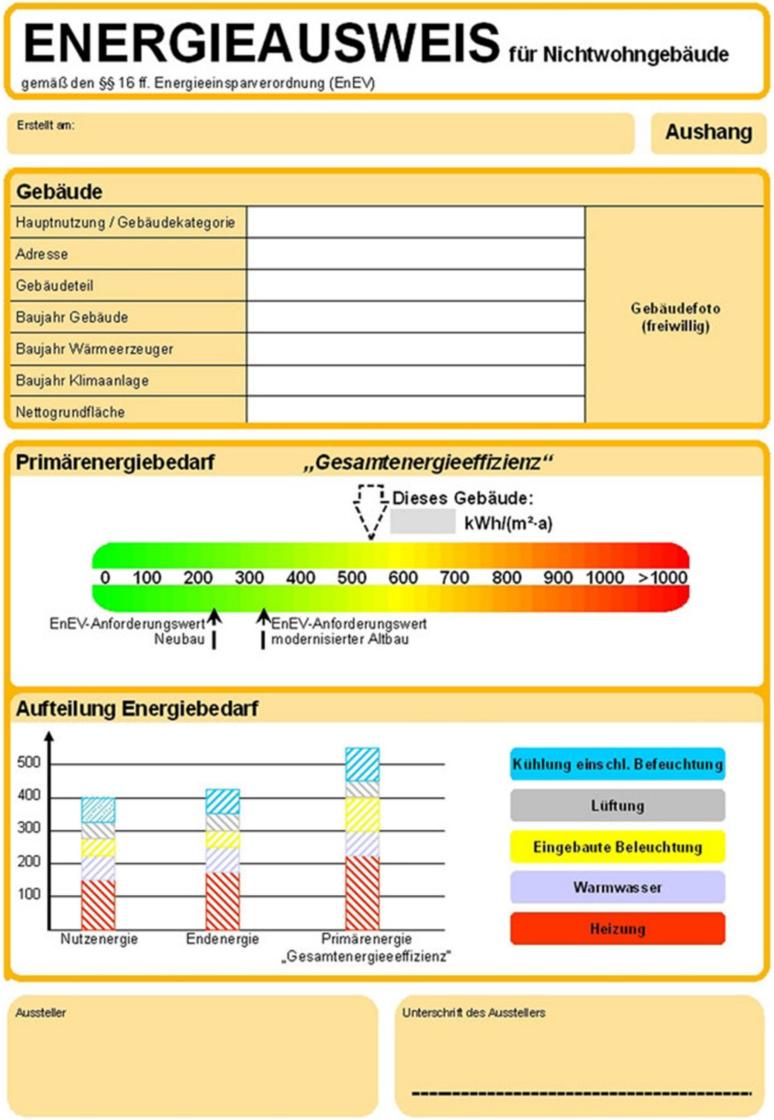
EnergyPlus

MODELICA





# Background


**ENERGIEAUSWEIS** für Nichtwohngebäude

gemäß den §§ 16 ff. Energieeinsparverordnung (EnEV)

Erstellt am:

**Aushang**

**Gebäude**

| | | |
|---|---|---|
| Hauptnutzung / Gebäudekategorie | | Gebäudefoto (freiwillig) |
| Adresse | | |
| Gebäudeteil | | |
| Baujahr Gebäude | | |
| Baujahr Wärmeerzeuger | | |
| Baujahr Klimaanlage | | |
| Nettogrundfläche | | |

**Primärenergiebedarf** ***„Gesamtenergieeffizienz"***

Dieses Gebäude:

kWh/(m²·a)

0 100 200 300 400 500 600 700 800 900 1000 >1000

EnEV-Anforderungswert Neubau

EnEV-Anforderungswert modernisierter Altbau

**Aufteilung Energiebedarf**

500
400
300
200
100

Nutzenergie

Endenergie

Primärenergie „Gesamtenergieeffizienz"

Kühlung einschl. Befeuchtung

Lüftung

Eingebaute Beleuchtung

Warmwasser

Heizung

Aussteller

Unterschrift des Ausstellers


breeam

The Code for Sustainable Buildings

This is to certify that

**Dragonfly House,**
**No 2 Gilders Way,**
**Norwich NR3 1UB**

has achieved a score of 75.81%, and a BREEAM rating of

**EXCELLENT**

Pass

Excellent

This Post Construction assessment was carried out under the 2006 version of BREEAM Offices

Signed on behalf of BRE Global Ltd

22nd January 2009
Date

Lauren Williams
Licensed Assessor

Faber Maunsell
On behalf of

WSP UK Ltd
Building Services Engineer

Aukett Fitzroy Robinson
Architect

R G Carter Ltd
Contractor

Bidwells
Project Manager

Jarrold (St James) D1/D2 Ltd
Client

Certificate Reference: FABM-OFF-LW06-9

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www.breeam.org

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

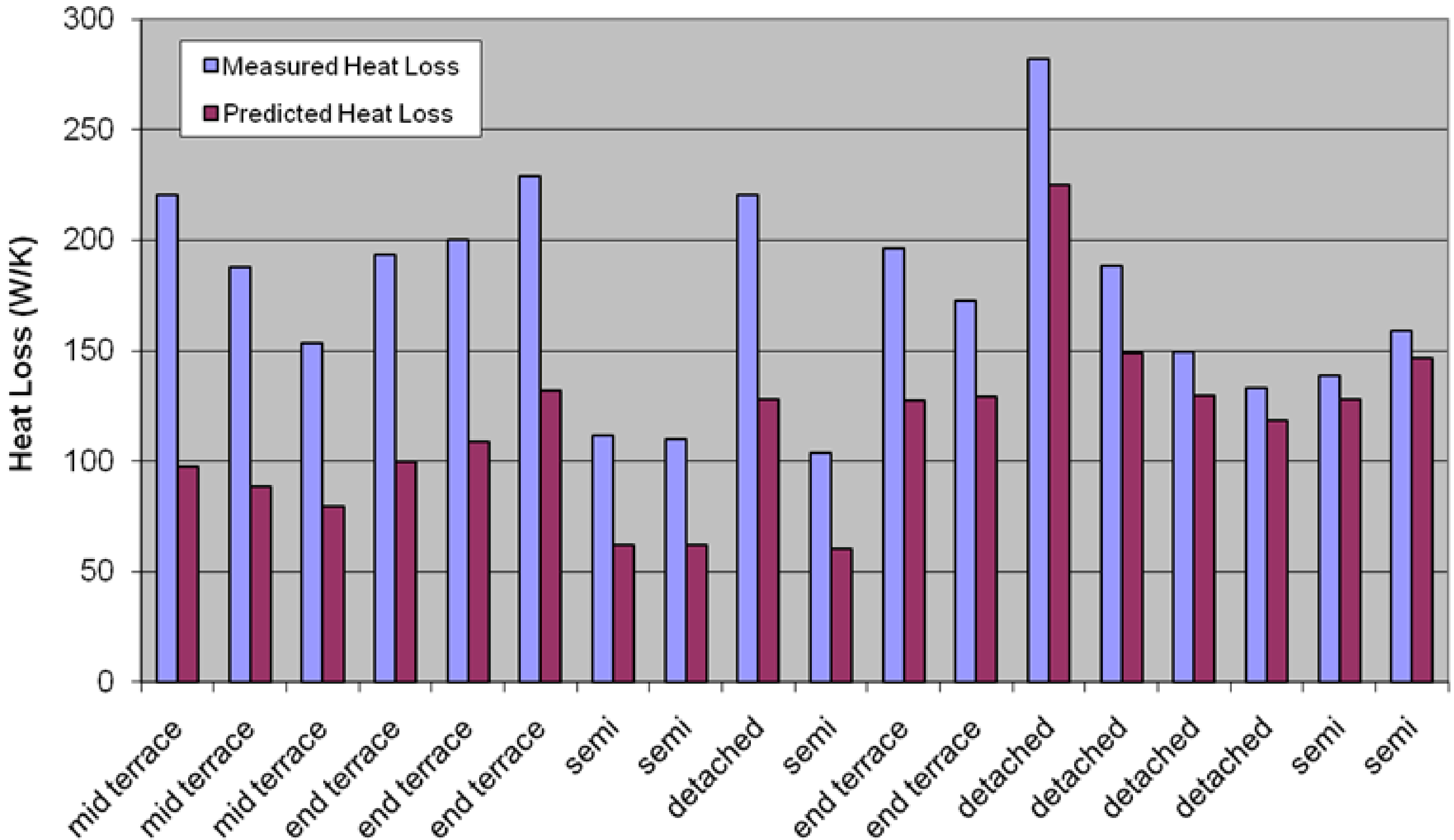
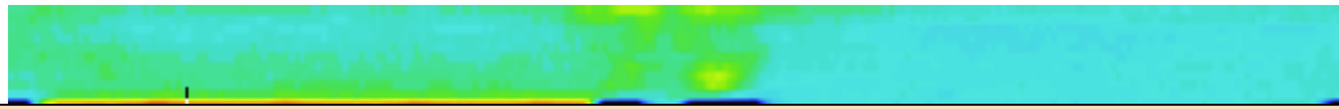



Figure from [Wingfield et al., 2011]

Measurements at KU Leuven VLIET-testbuilding:
impact of workmanship on thermal performance of cavity walls

IR-images of the outer leaf



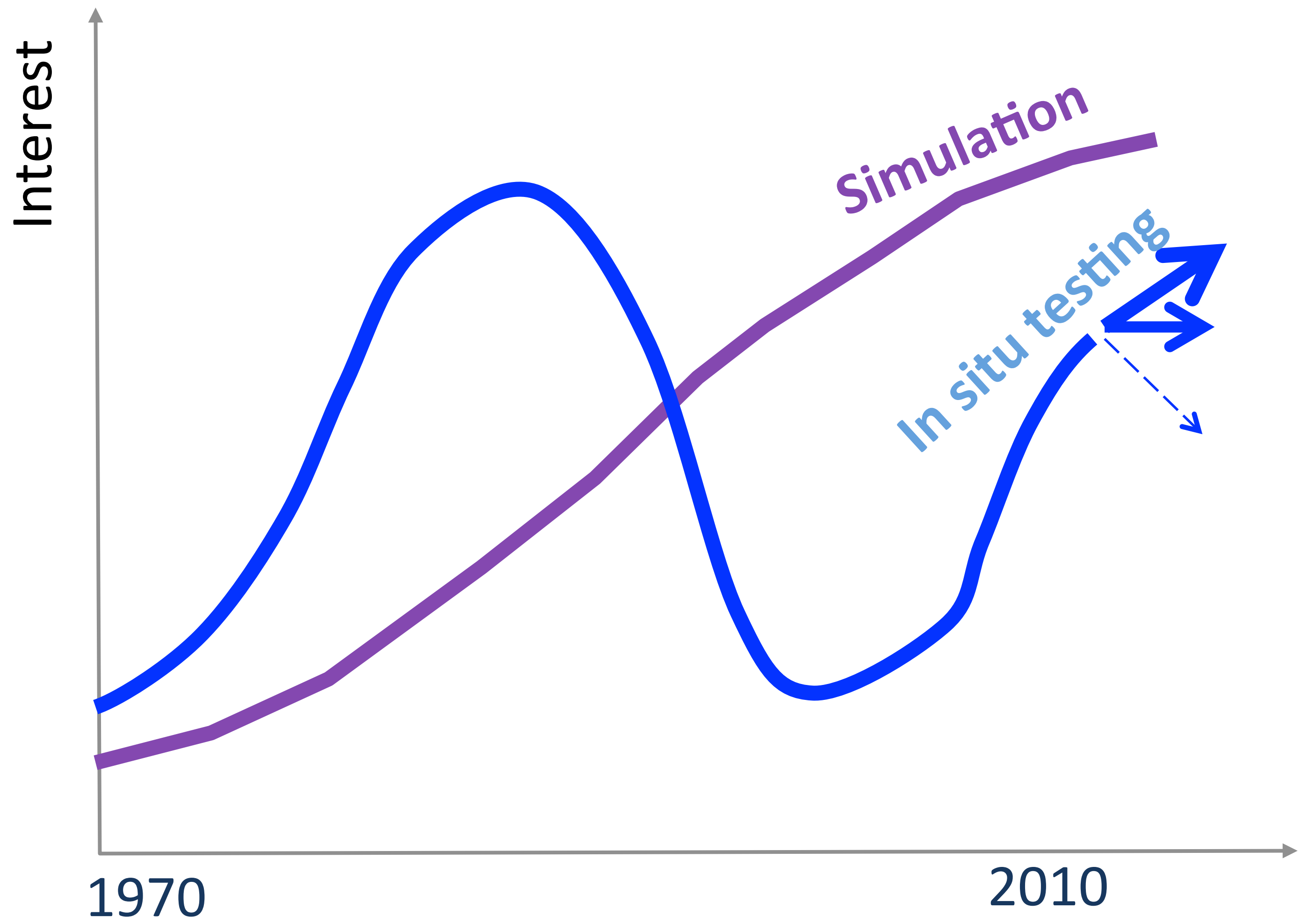
| | $U_{theor}$ | measured: good workmanship | measured: poor workmanship |
|---|---|---|---|
| Mineral wool | 0.22 | 0.21 ± 0.01 | 0.35 ± 0.04 |
| airtight | | | 0.39 ± 0.05 |
| XPS, partial fill | 0.21 | 0.22 ± 0.01 | 0.86 ± 0.01 |
| airtight | | | 0.97 ± 0.06 |
| XPS, complete fill | 0.20 | 0.21 ± 0.01 | 0.65 ± 0.14 |
| airtight | | 0.21 ± 0.01 | 0.79 ± 0.16 |

Importance of reliable and conclusive results

poor workmanship

good workmanship

# As a result: renewed interest in full scale testing



International workshop in 2011 gave a nice overview of existing full scale test facilities


# Possible explanations for renewed interest:

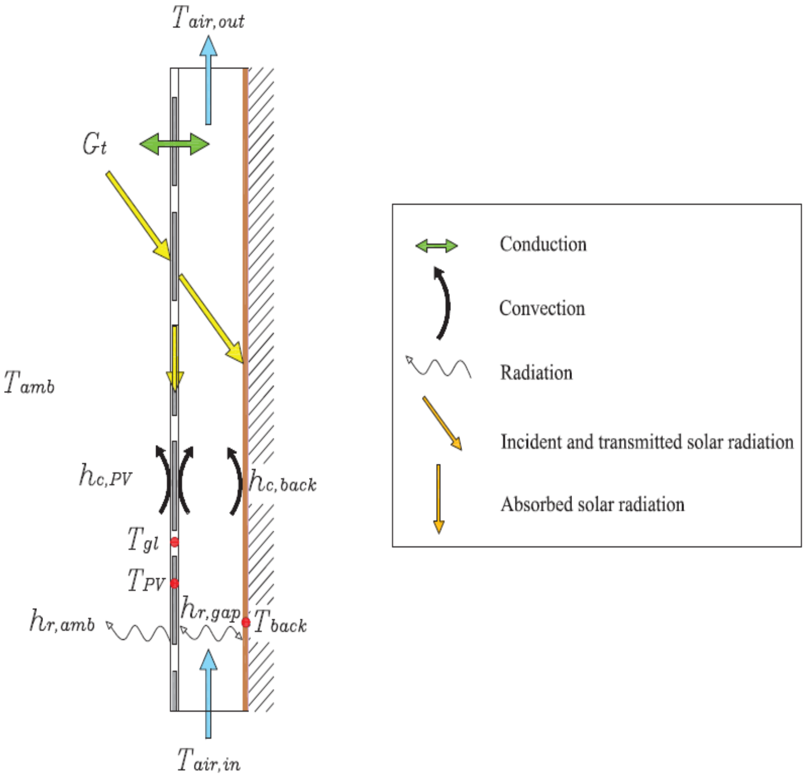
- Full scale testing allows to investigate the **performances in reality** (including workmanship)

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

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

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

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



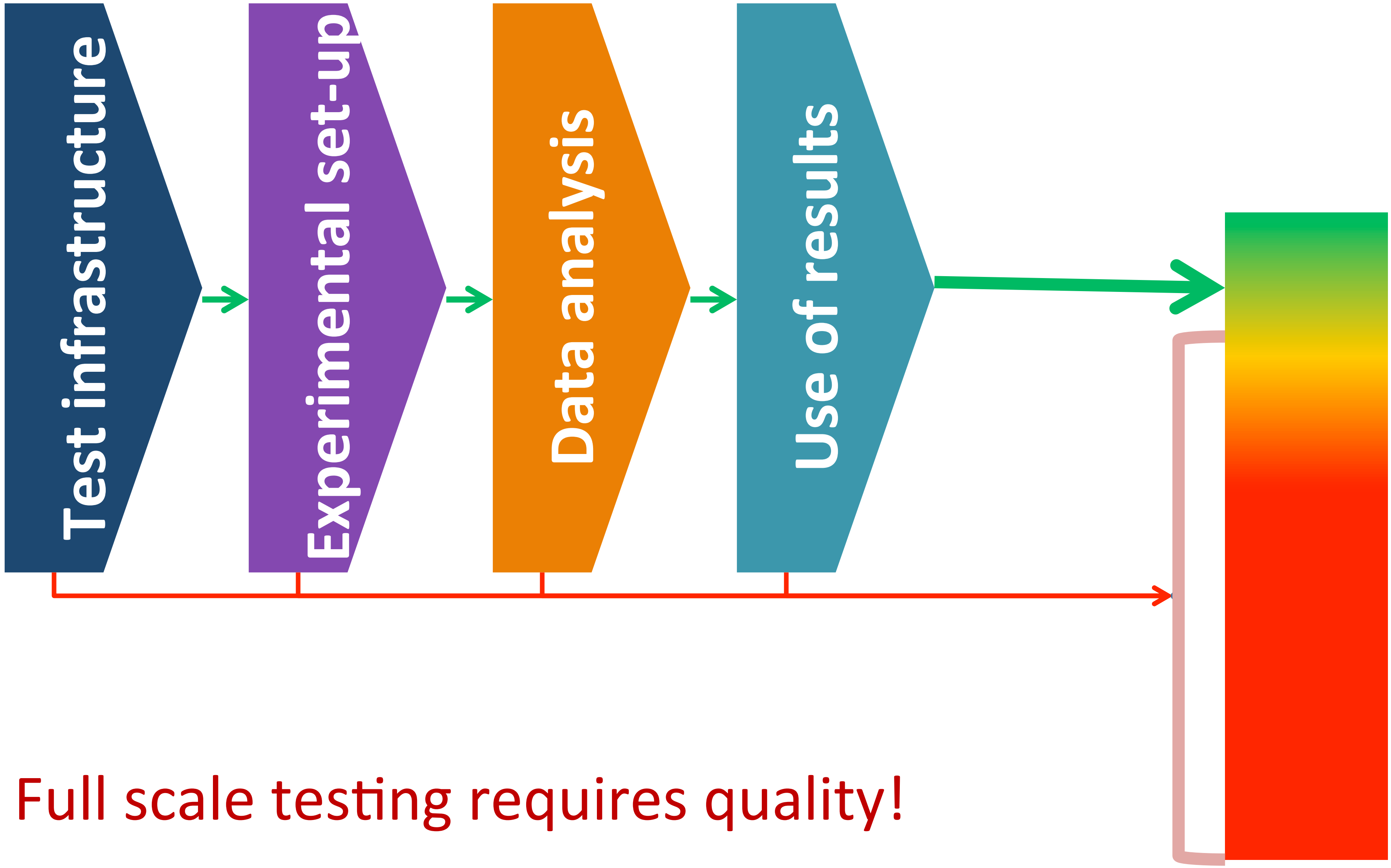

Full scale testing is essential to integrate the behaviour of new advanced building components in a correct way in BES-models

# Background

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

# Background




Full scale testing requires quality!

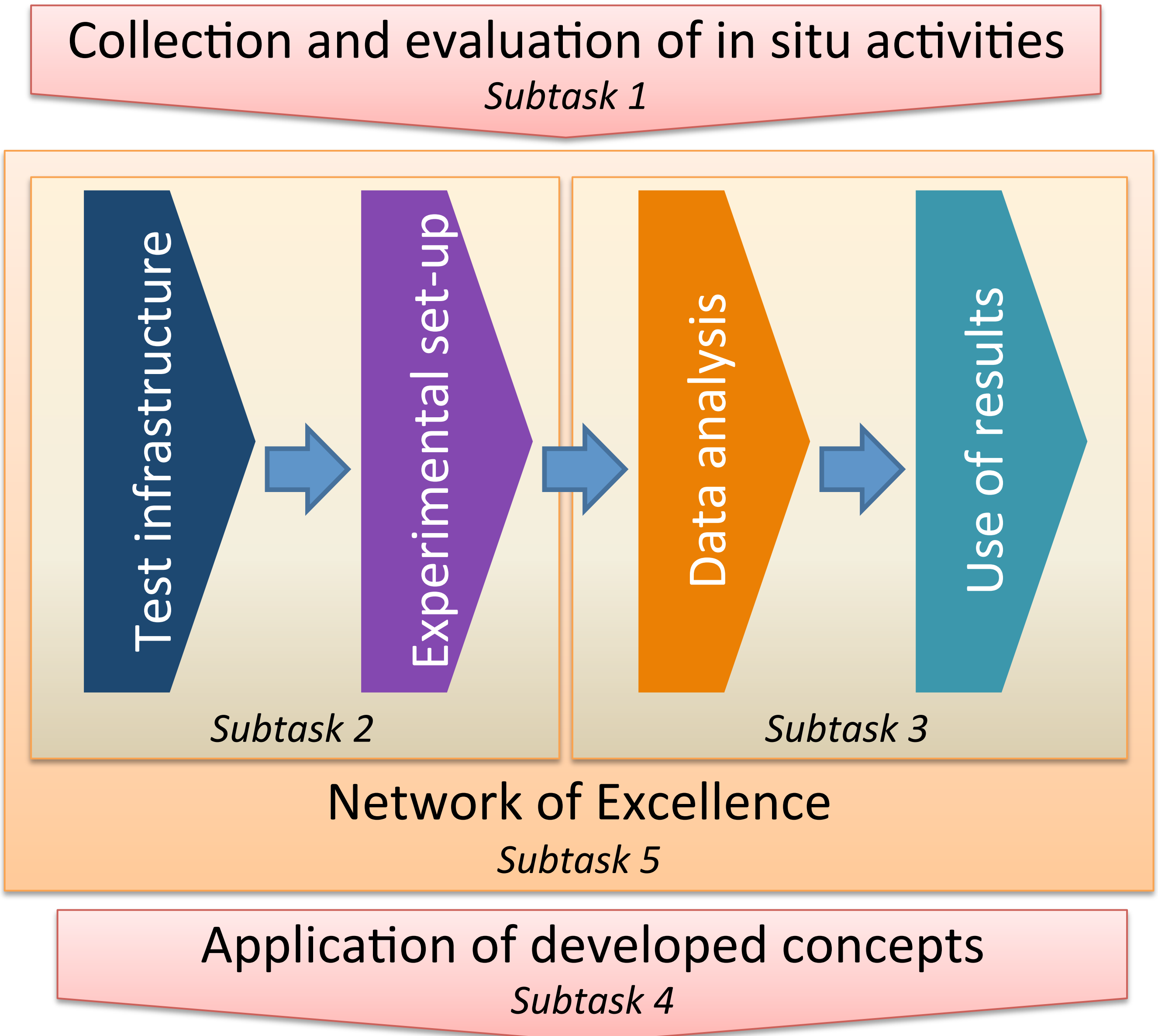
## IEA EBC Annex 58

# 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

EBC Annex 58

# Structure of Annex 58



# Subtask 1 provides overview of

## Existing full scale test facilities



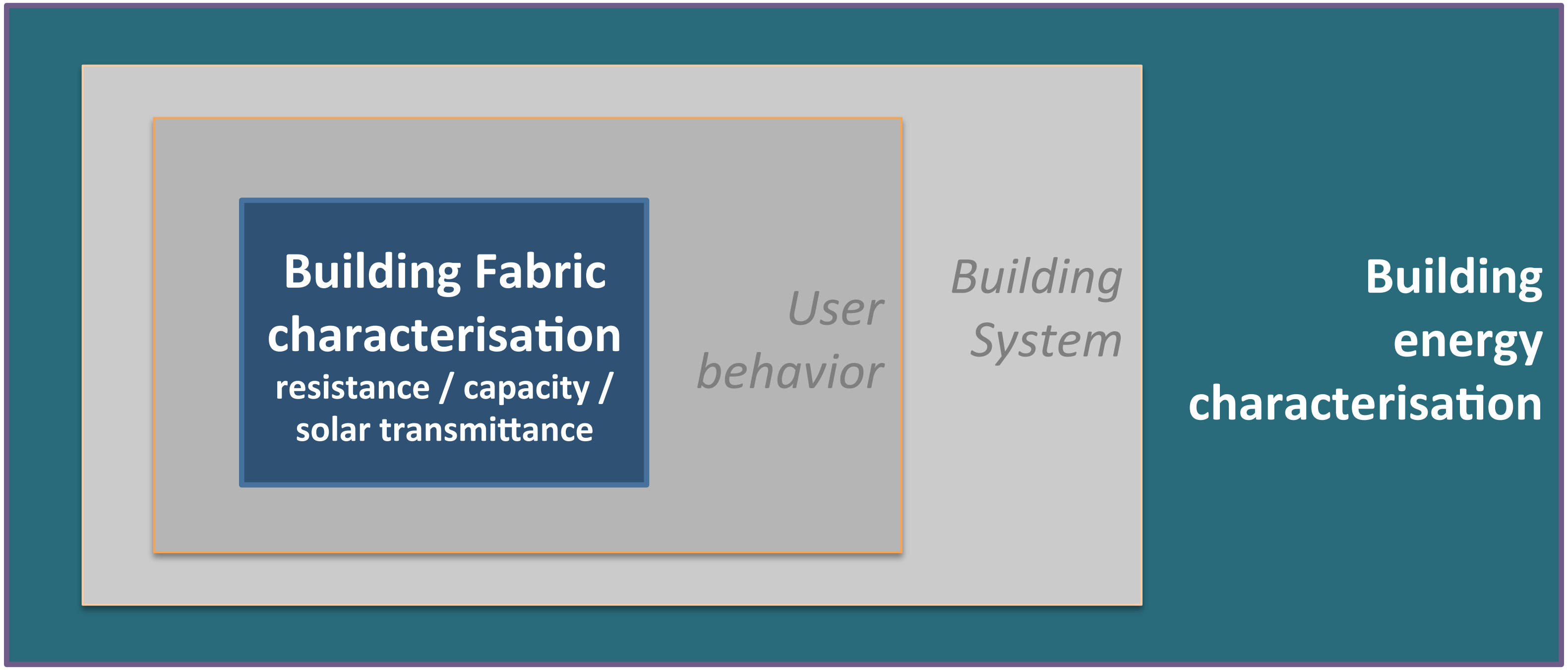

## Common data analyis methods

- U-value of building components based on heat flux meters;
- U & g of building components tested in outdoor calorimetric test cells;
- UA & gA of whole buildings based on co-heating tests;
- Energy model characterization of whole buildings based on monitored dynamic energy and climatic data.

# ST2

*Optimising full scale dynamic testing*

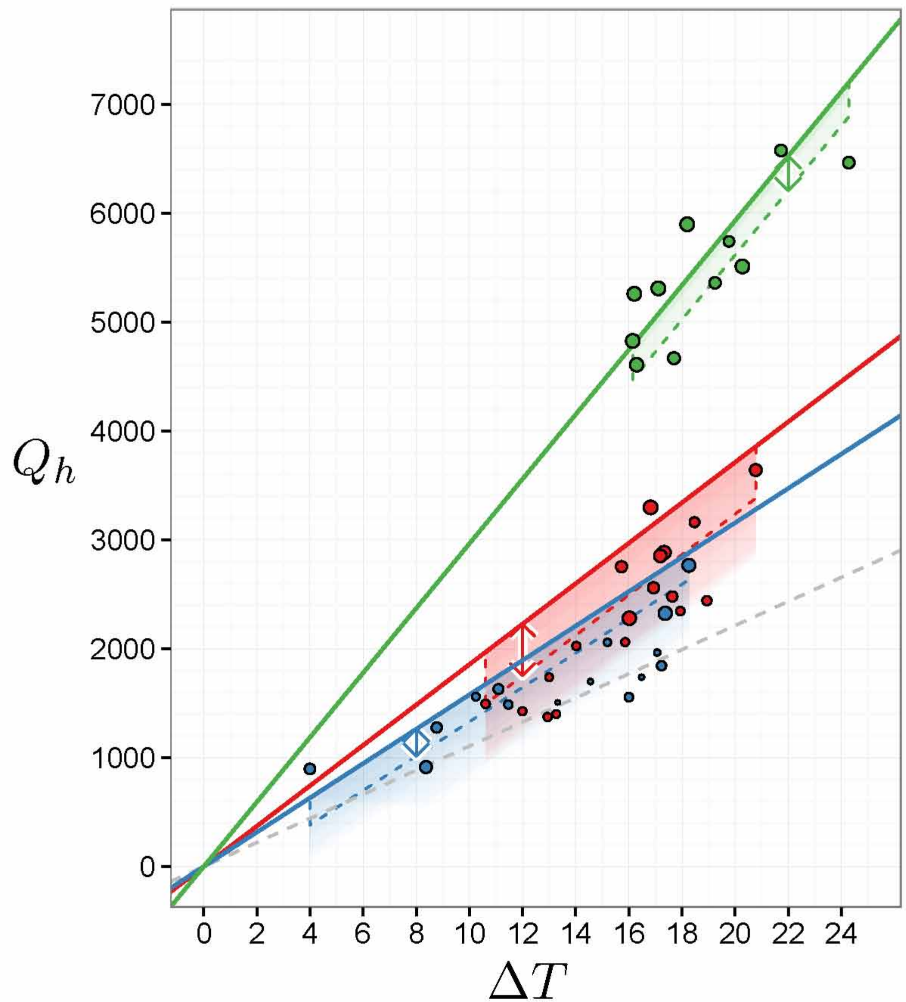
Subtask 2 develops a decision tree for
- building fabric characterisation and
- whole building energy characterisation



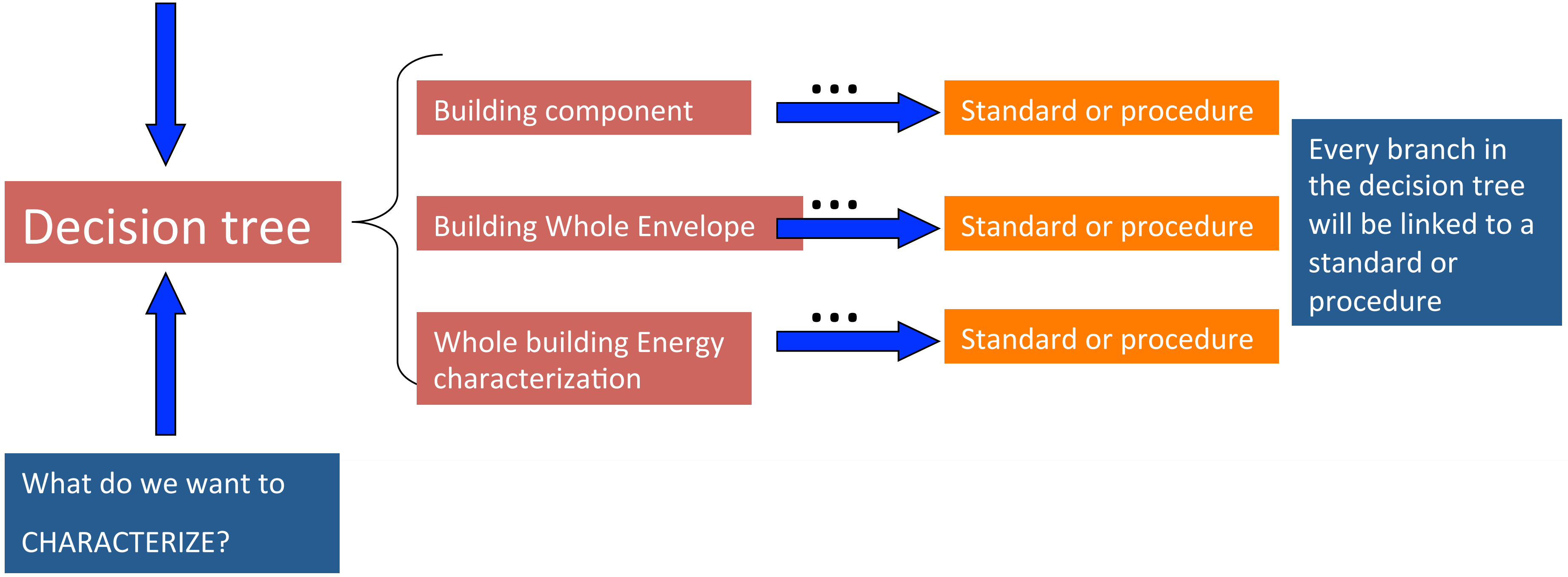
# ST2

## Optimising full scale dynamic testing

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



# Development of a 'decision tree' to steer the choice of infrastructure and optimizing experimental design



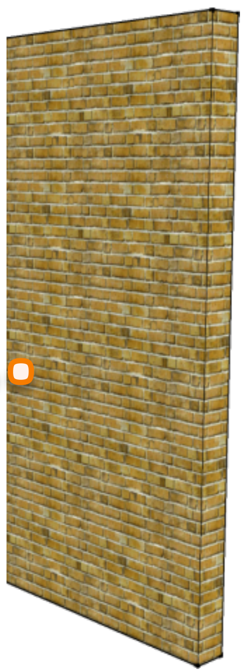
# ST3

## *Dynamic data analysis and performance characterisation*

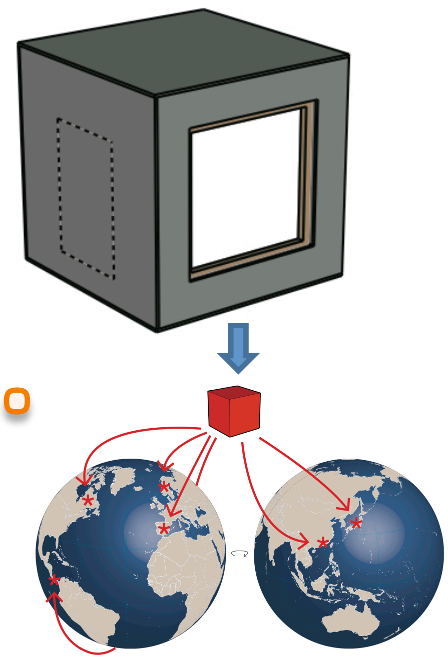
Subtask 3 develops quality procedures for full scale dynamic data analysis

**Common exercises to come up with a methodology for a reliable characterisation**

1.



2.



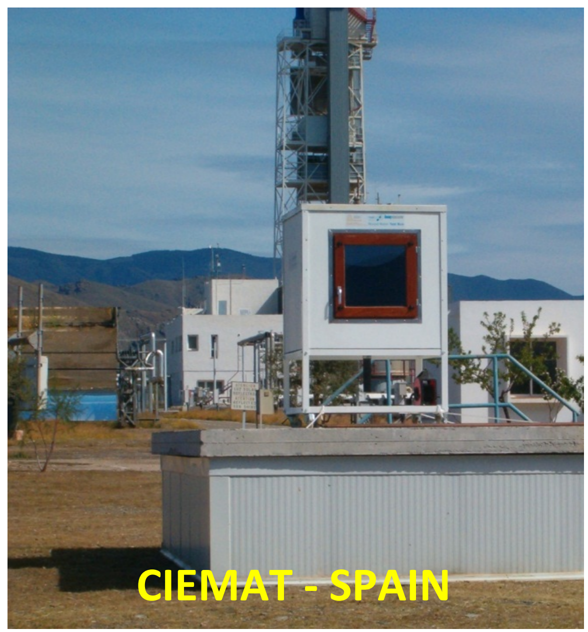
3.

**ST3**

*Dynamic data analysis and performance characterisation*

## ROUND ROBIN EXPERIMENT : general objectives

- Comparative experiment on testing and data analysis
- Scale model of a simplified building (only known by KU Leuven)
- To be tested by different partners: Different weather and measurement devices.


BBRI, Belgium :
January 2013 – February 2013

CIEMAT, Almería, Spain:
April 2013 – December 2013

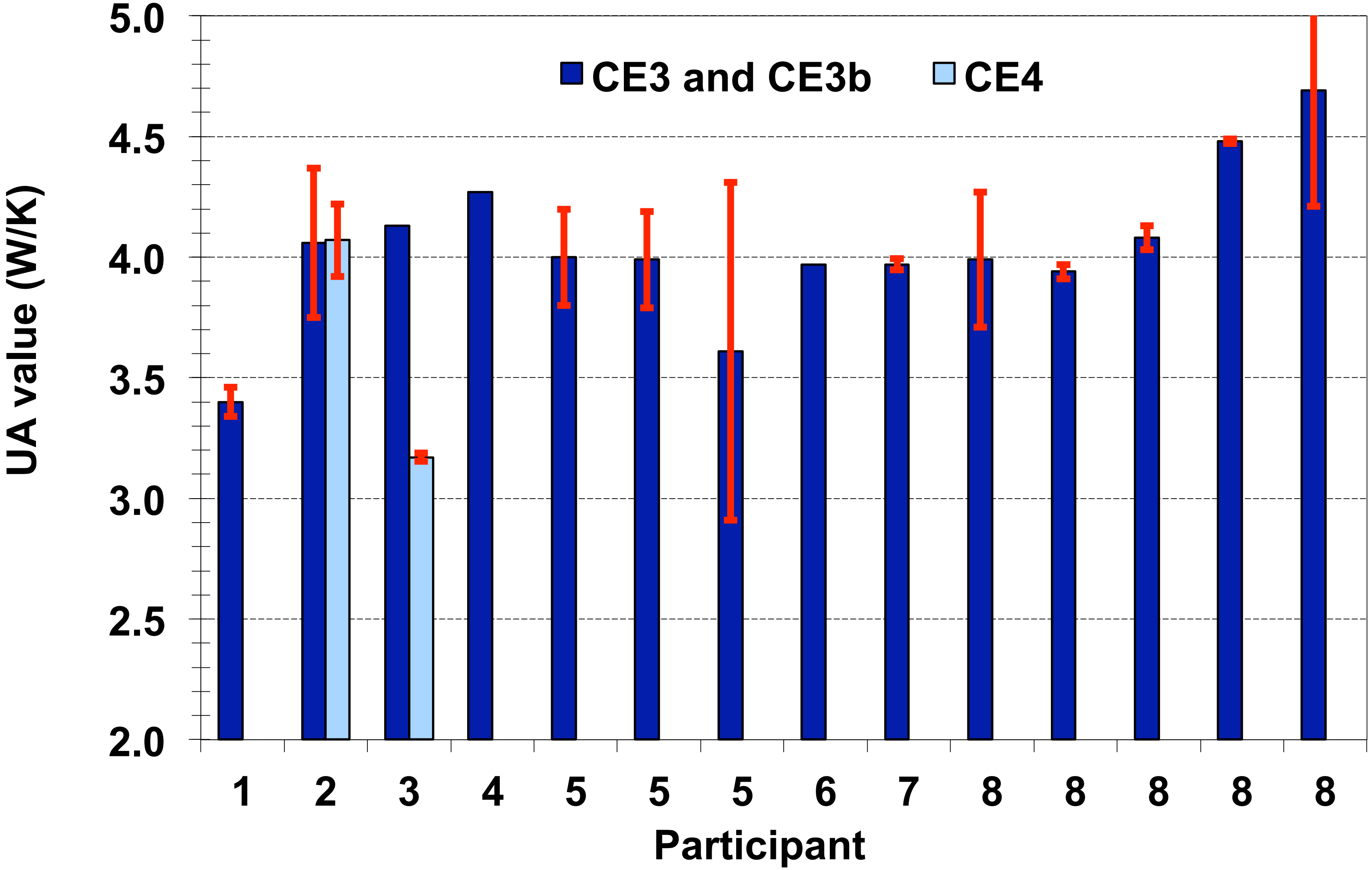
UPV/EHU, Bilbao, Spain:
January 2014 - December 2014

ENTPE, Lyon, France:
January 2015 – July 2015

CTU, Prague, Czech Republic
July 2015 -…

| TEAM | Applied Methods | Parameter | CE3 Est. (W/K) | CE4 Est. (W/K) |
|---|---|---|---|---|
| 1 | Average method | HLC | 3.77–3.92 | |
| | State space thermal model identification(RC using LORD) | 1/R | 3.07–3.42 | |
| 2 | Linear regression; 5 min data | HLC | 2.84–4.11 | |
| | Average method | HLC | 2.86–4.15 | |
| | Linear regression; daily averaged data | HLC | 3.68–4.12 | 4.32–4.48 |
| | State space thermal model identification (RC using LORD) | 1/R | 3.98–4.04 | 4.23 |
| | ARX and ARMAX models (using SIT Matlab) | HLC | 4.06 | 4.07-4.32 |
| 3 | Multiple linear regression; Daily averaged data | HLC | 3.73–4.39 | |
| | Multiple linear regression; Hourly averaged data | HLC | 4.77-5.24 | |
| | Multiple linear regression; Recorded data | HLC | | 3.17-3.55 |
| 4 | State space thermal model identification | 1/R | 4.27–4.56 | |
| 5 | Linear regression; daily averaged data | HLC | 3.99–4.08 | |
| | State space thermal model identification (RC using CTSM-R) | 1/R | 3.99 | |
| | QUB-test | HLC | 3.54–3.70 | |
| 6 | State space thermal model identification (RC using SIT Matlab) | 1/R | 3.97 | |
| 7 | ARX models (Using R) | HLC | 3.95 | |
| 8 | Average method | UA | 3.72–3.99 | |
| | Linear regression; 5 min data | UA | 2.98–3.94 | |
| | ARX and ARMAR (Using R) | UA | 4.01–4.08 | |
| | CTSM-R | UA | 4.48 | |
| | TRNSYS-GenOpt | UA | 4.69 | |
| 9 | ????? | ?? | | ?? |

# ST3 *Dynamic data analysis and performance characterisation*



# ST4



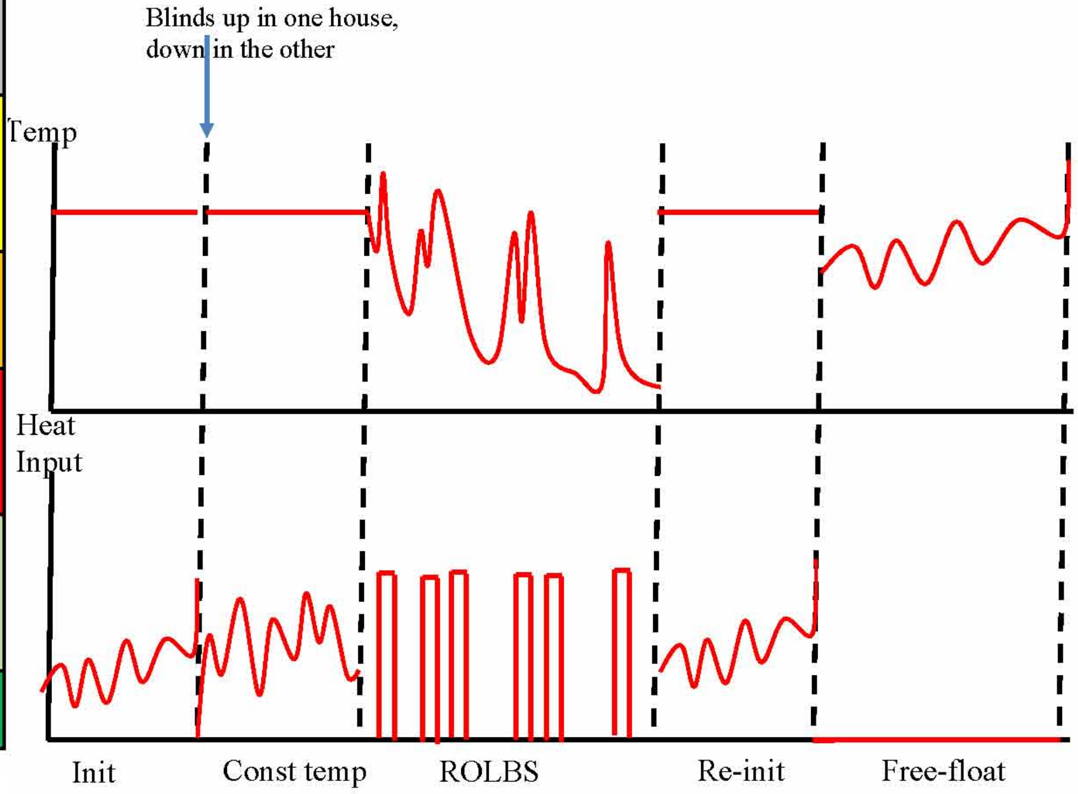
Three applications have been put forward:

- **ST4.1. Verification of common BES-models based on in situ dynamic data**
- ST4.2. Characterisation of buildings based on in situ testing and smart meters
- ST4.3. Dynamic building characterisation for optimising smart grids

## FULL SCALE EXPERIMENT TO VALIDATE NUMERICAL BES-MODELS

# ST4 *Application of the developed framework*

| | | Twinhouse O5 | Twinhouse N2 |
|---|---|---|---|
| Days 1-20 | Initialisation – constant temperature 30°C in all spaces (with adjustments and data losses corresponding the minute book) | Blinds down | Blinds down |
| Days 21-22 | Initialisation – constant temperature 30°C in all spaces | Blinds down | Blinds down |
| Days 23-29 | Constant temperature – 30°C in all spaces | Blinds up | Blinds down |
| Days 30-44 | ROLBS sequence in living room. No heat inputs elsewhere. | Blinds up | Blinds down |
| Days 45-50 | Re-initialisation – constant temperature 25°C in all spaces. | Blinds down | Blinds down |
| Days 51-61 | Free-float | Blinds up | Blinds down |



# ST4 Application of the developed framework

Empirical Whole Model Validation
Modelling Specification

Test Case Twin_House_1
IEA ECBCS Annex 58
Validation of Building Energy Simulation Tools
Subtask 4

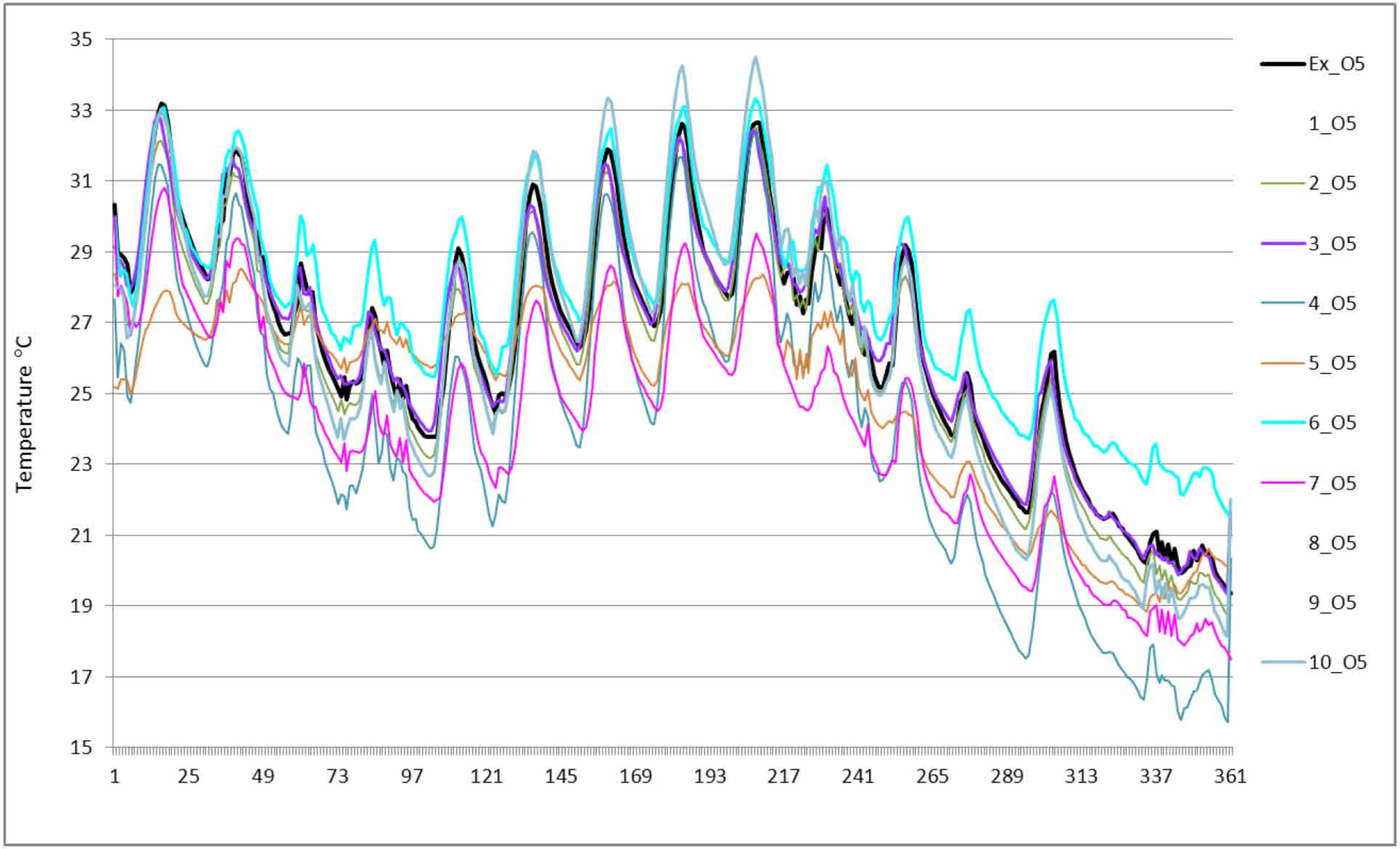
Version 3

Paul Strachan and Ingo Heusler
10.10.13

**21 modelling methods confirmed**

| | |
|---|---|
| TRNSYS | 4 |
| Modelica | 4 |
| EnergyPlus | 2 |
| ESP-r | 2 |
| EES | 2 |
| Matlab | 2 |
| eQuest | 1 |
| IDA-ICE | 1 |
| Wufi | 1 |
| IESVE | 1 |
| Dynbil | 1 |

# Living room temperature ROLBS sequence:



# ST5

*Network of excellence*

## http://www.just-pm.eu/dynastee

# DYNASTEE

**DYN**amic **A**nalysis, **S**imulation and **T**esting applied to the **E**nergy and **E**nvironmental performance of buildings

Home | Network | Data Analysis | Events | Publications | Contact

Search Site

### High Energy Performance Buildings Workshop, 24-26 June 2013, Brussels

(during the EU Sustainable Energy Week) Organised by INIVE-DYNASTEE, EC-JRC-IET, ENEA High energy performance and nZEB buildings (recast-EPBD 2010/31/EU) can become reality when the design process takes into account the energy flows, in particular from passive solar and landscape design, …

Continue reading →

### Summer School 2013 in Almeria, Spain

***Dynamic Calculation Methods for Building Energy Performance Assessment.***

The second edition of the DYNASTEE Summer School will take place in Spain organised again by DYNASTEE in close collaboration with CIEMAT, EC-JRC-IET, DTU-IMM (Denmark) and ESRU (Glasgow, UK). It will be organised in Almeria from 9 – 13 September, 2013.

#### Highlights

- High Energy Performance Buildings Workshop, 24-26 June 2013, Brussels
- Summer School 2013 in Almeria, Spain
- DYNASTEE Newsletter 2013/2 now available
- Building nearly zero-carbon housing: for real!
- Editorial for special issue: Outdoor Testing, Analysis and Modelling of Building Components

#### About DYNASTEE

DYNASTEE stands for: "**DYN**amic **A**nalysis, **S**imulation and **T**esting applied to the **E**nergy and **E**nvironmental performance of

# Annex 58 and DYNASTEE: current activities

- **Website of Dynastee:**
  http://www.just-pm.eu/dynastee;
- **Regular newsletters**;
- **Organisation of workshops**:
  - high performance buildings, Brussels 2013
  - workshop @A58 meeting, spring 2014, Belgium
  - workshop @A58 meeting, autumn 2014, USA
- **Summer school**
  - Copenhagen, Denmark 2012
  - Almeria, Spain, 2013
  - Leuven, Belgium, 2014

# IEA EBC Annex58-team

**14 countries – 38 institutes**

Austria, Belgium, China, Czech Republic, Denmark, Finland, France, Germany, Italy, The Netherlands, Norway, Spain, UK, USA

## Conclusions

- IEA EBC Annex 58 shows that there is a large international interest in full scale testing and dynamic data analysis

- Different reasons why full scale testing remains necessary:
  - verification of numerical models
  - evaluation of performance in reality
  - characterisation of advanced components
  - development of reliable simplified models for optimisation of predictive control, smart grids,…

- With IEA EBC Annex 58, research institutes and industrial partners join their effort to make a step forward towards **real energy efficient buildings**