Energy in Buildings and
Communities Programme

IEA EBC Annex 58

Reliable building energy performance characterisation based on full scale dynamic measurements

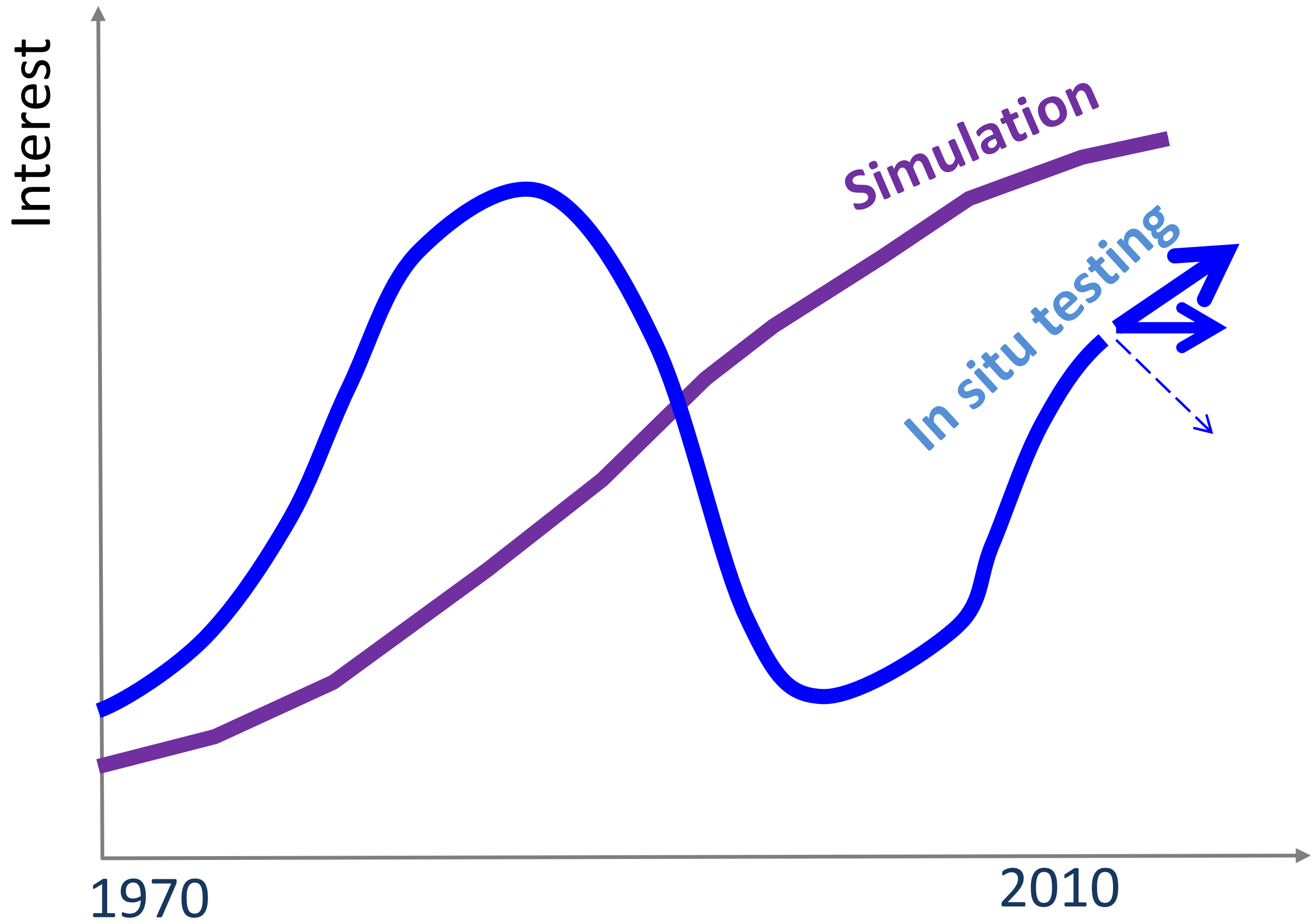
overview and major outcomes

Workshop in preparation of new IEA EBC Annex project – Brussels April 18-19, 2016

14 participating countries:

Austria	Germany
Belgium	Italy
China	The Netherlands
Czech Republic	Norway
Denmark	Spain
Finland	United Kingdom
France	USA

Background: 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 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

Measurements at EnergyFlexHouse at DTI, Denmark

investigate performances in reality and characterise whole building energy performance

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

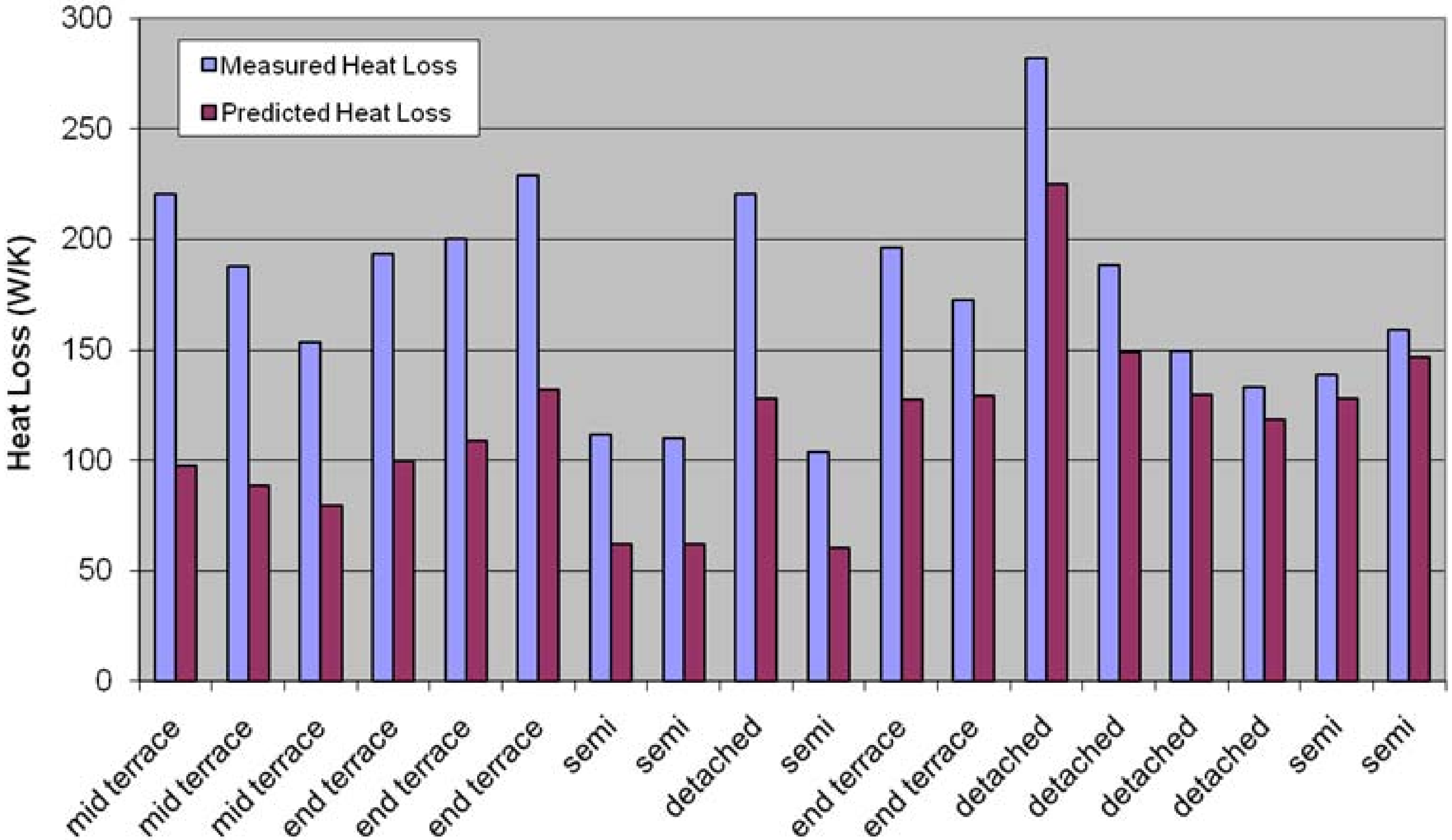
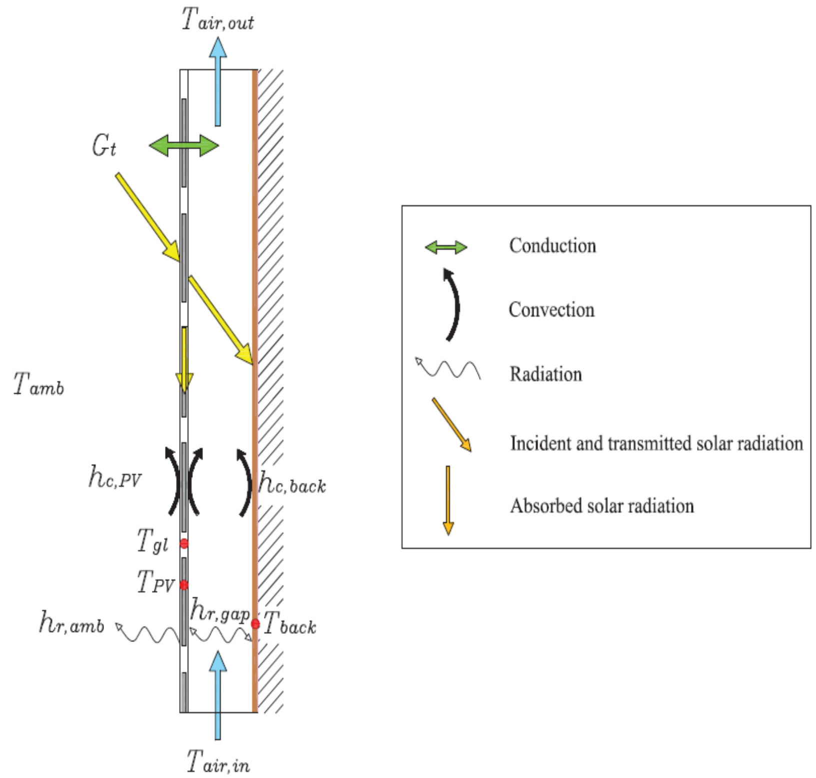


Figure from [Wingfield et al., 2011]

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

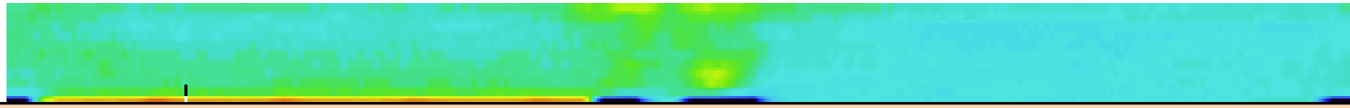
Measurements at CIMNE (Lleida, Spain):
analysis of dynamic thermal response of ventilated photovoltaic double skin facade



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

Measurements at K.U.Leuven VLIET-testbuilding:
impact of workmanship on thermal performance of cavity walls

IR-images of the outer leaf

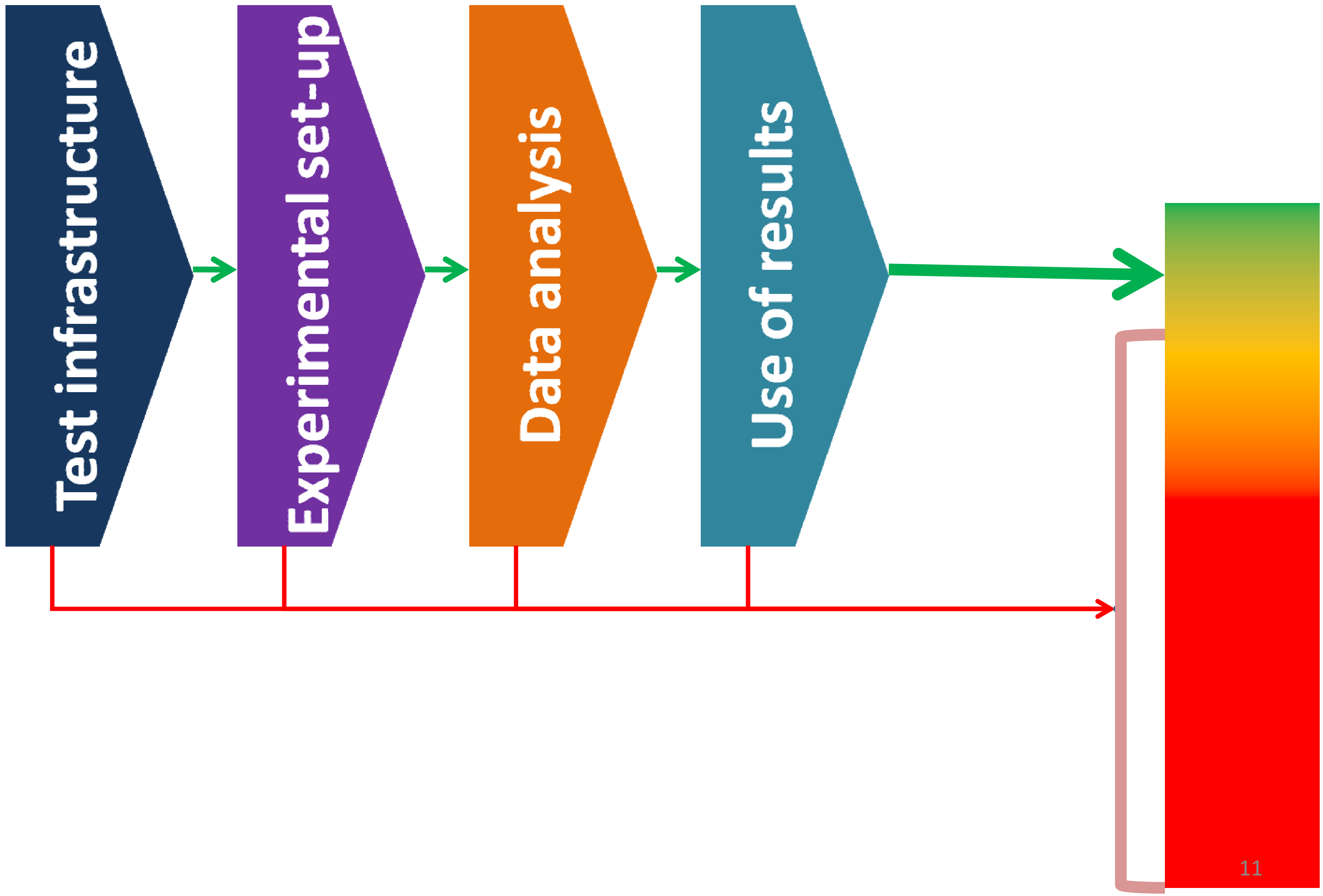


	U_{theor}	measured: good workmanship	measured: poor workmanship
Mineral wool	0.22	0.21 ± 0.01	0.35 ± 0.04
airtight			0.39 ± 0.05
XPS, partial fill	0.21	0.22 ± 0.01	0.86 ± 0.01
airtight			0.97 ± 0.06
XPS, complete fill	0.20	0.21 ± 0.01	0.65 ± 0.14
airtight		0.21 ± 0.01	0.79 ± 0.16

Importance of reliable and conclusive results

poor workmanship good workmanship

Full scale testing requires quality!



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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

major aim of the Annex-project was a collaboration in the ECBCS-context 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 energy performance of building components and whole buildings.

The procedures should focus both on the **test environment and experimental setup** as well as on the **data analysis** and **performance prediction**.

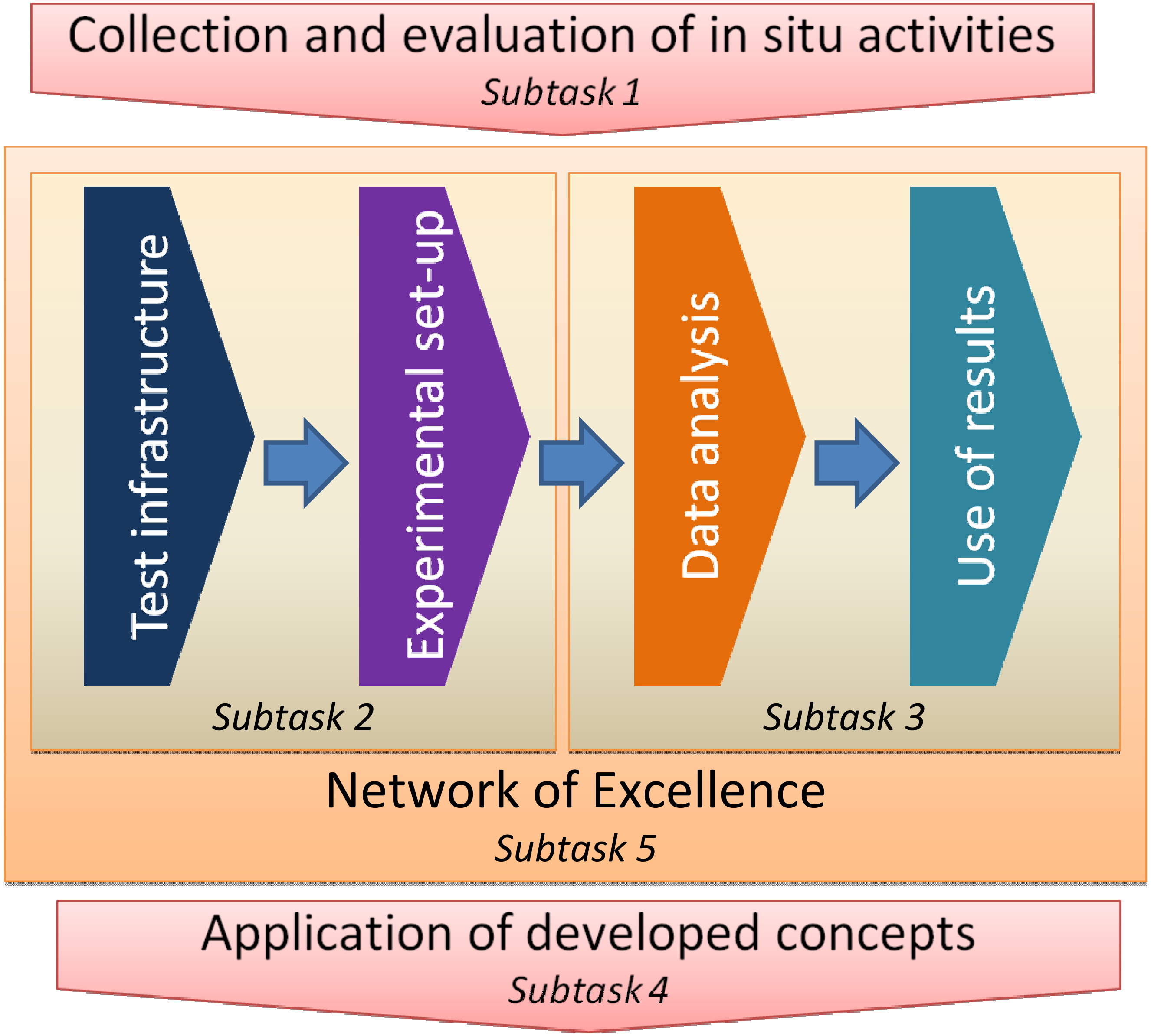
Annex should answer (at least) the following questions:

- How to organise a good full scale test ?
- How to perform a reliable data analysis ?
- How to deduce the performances of the building (component) ?
- How to use measurement results / show applications?

at the same time annex should create a '**network of excellence**' for full scale testing

EBC Annex 58

Structure of Annex 58



EBC Annex 58

Structure of Annex 58

Subtask 1. State of the art on full scale testing and dynamic data analysis

Arnold Janssens

Subtask 2. Optimising full scale dynamic testing

Aitor Erkoreka, Chris Gorse

Subtask 3. Dynamic data analysis and performance characterisation

Maria José Jiménez Taboada, Henrik Madsen

Subtask 4. Application of the developed framework

Paul Strachan, Dirk Saelens, Shengwei Wang

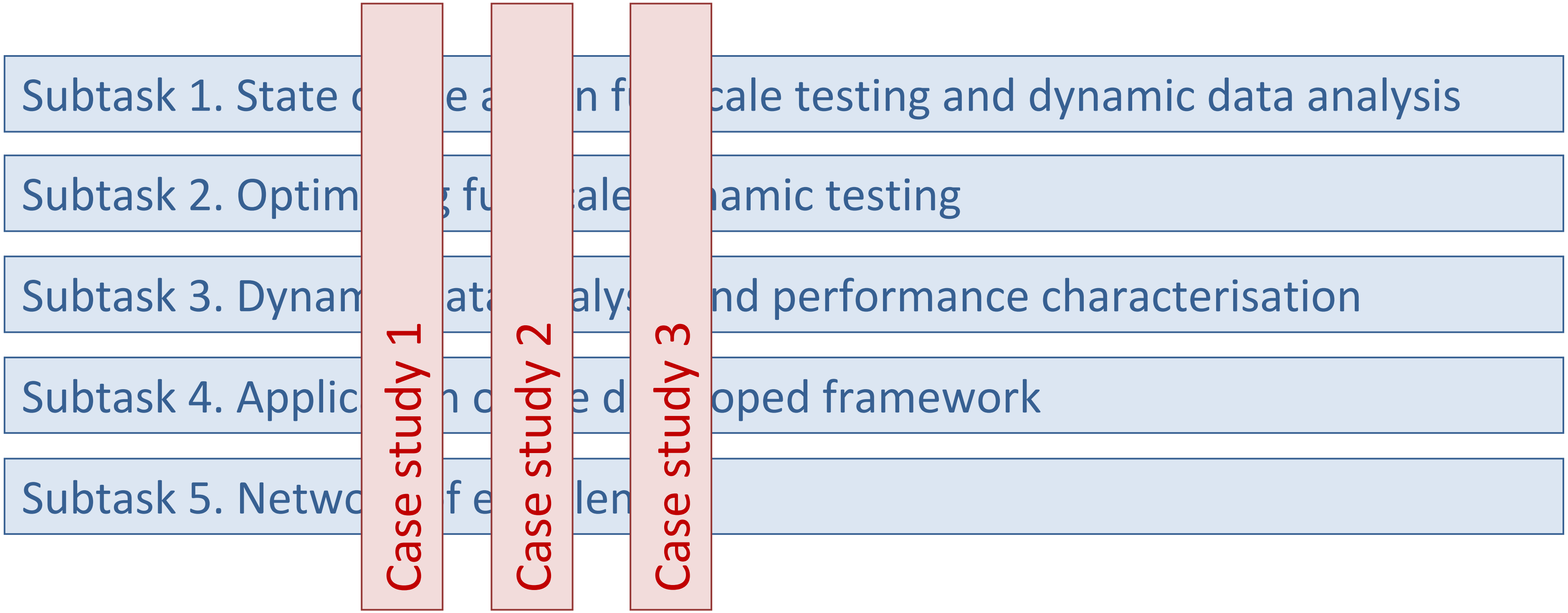
Subtask 5. Network of excellence

Hans Bloem, Luk Vandaele

EBC Annex 58

Structure of Annex 58

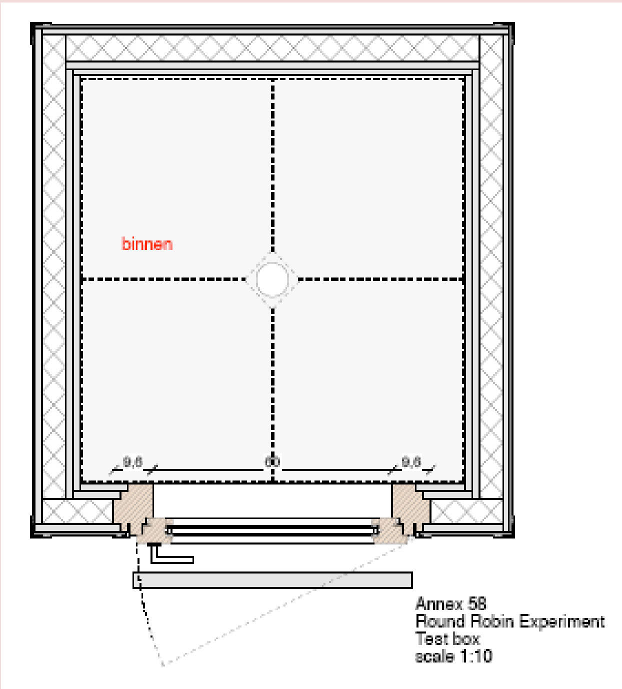
Global framework:



Structure of Annex 58

Global framework:

round robin experiment



Case study 2

Case study 3

sca es and dynamic data analysis

na t ng

anc r nance characterisation

elop fr ework

Round Robin test box

International Energy Agency Energy Conservation in Buildings and Community Systems Programme

Annex 58

RELIABLE BUILDING ENERGY PERFORMANCE CHARACTERISATION BASED ON FULL SCALE DYNAMIC MEASUREMENT

reality check

KNAUF INSULATION

Round Robin **Test Box**

Aim of round robin experiment:

- investigate reliability of full scale testing
- investigate reliability of dynamic data analysis
- investigate impact 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

Global framework:

S ll a lysis
S dy
S is t
S ve
S ce

round robin experiment

Twin houses at IBP

Case study 3

ST1 *State of the art on full scale testing and dynamic data analysis*

Arnold Janssens, UGhent, Belgium

Subtask 1 provides overview of

Existing full scale test facilities

Common data analysis 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.

ST1

State of the art on full scale testing and dynamic data analysis

Existing full scale test facilities

Country	Facility	Year	Institute	Type of facility			
				Façade field test	Outdoor test cell	Test building	In-use testing
Austria	BSRTU facility	2010	BSRTU	X			
	Test site UIBK	2010	UIBK	X	X		
Belgium	VLIET test building	1996	KULeuven	X			
	J. Geelen laboratory	2002	ULg			X	
	Lecture rooms KAHO	new	KULeuven				X
Canada	Field exposure of walls	2006	NRC-IRC	X			
Denmark	The Cube	2005	U-Aalborg	X			
	Energy Flex House	2009	DTI	X		X	X
France	INCAS Platform	2008	INES	X	X	X	
Germany	Test site Holzkirchen	1950	IBP	X			
	VERU facility	2004	IBP	X		X	
	Twin houses	2010	IBP			X	
	Calorimetric test facility	2012	IBP	X	X		
	LWF Façade facility	2011	FH-Rosenheim	X	X		
Italy	Florence test cell	2014	UniFI	X	X		
	Passive house test building	new	Polimi				X
Morocco	DEFI experimental platform	new	ENTPE				X
Norway	ZEB test cell	2015	SINTEF	X	X		
Spain	Eguzki and Ilargi test cells	1988	LCCE	X	X		
	LECE-UiE3	1989	CIEMAT	X	X	X	
	ARFRISOL Buildings	2005	CIEMAT				X
	KUBIK	2010	Tecnalia	X		X	
	Lleida Outdoor Test cell	2011	CIMNE	X			
UK	Salford Energy House	2011	U-Salford			X (in lab)	
USA	FLEXLAB	2014	LBNL	X		X	

ST1 *State of the art on full scale testing and dynamic data analysis*

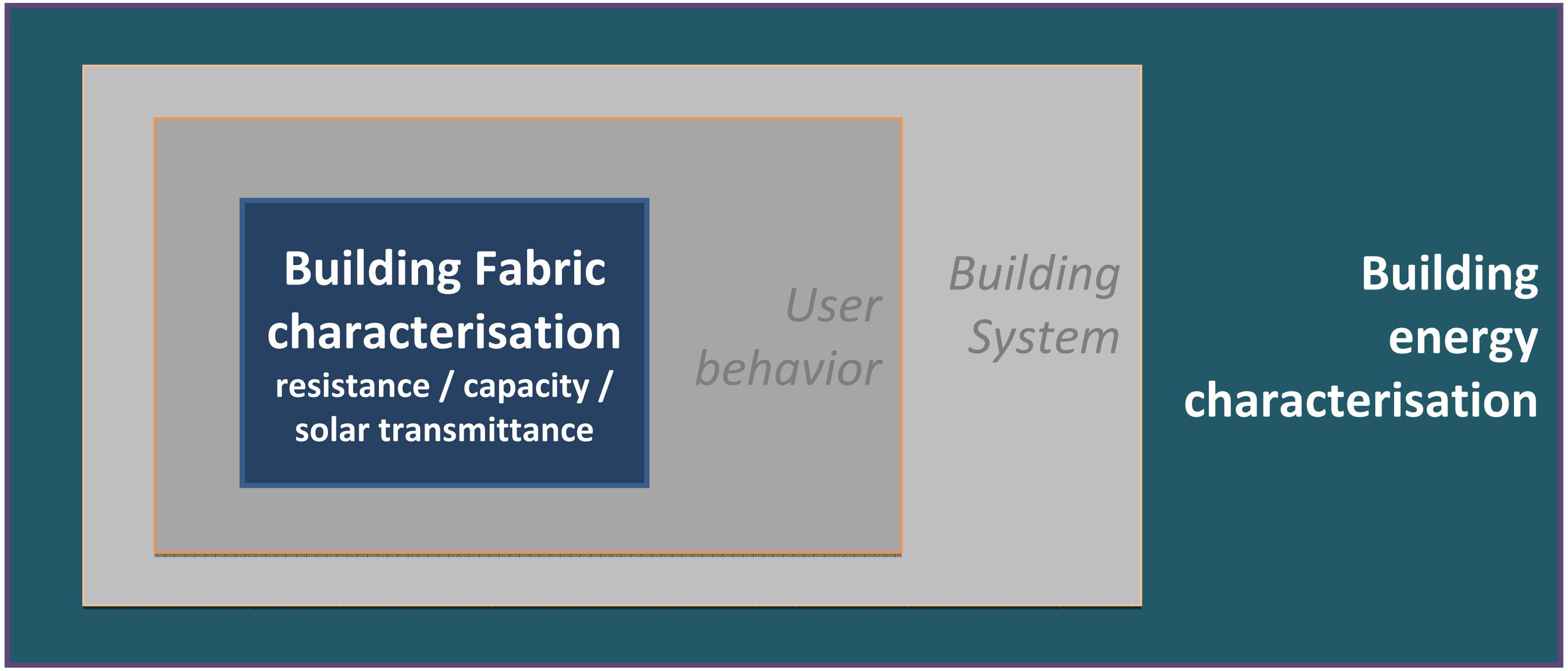
Overview of common data analysis methods

- Measurement of thermal transmittance of building components based on heat flux meters
- Measurement of thermal and solar transmittance of building components tested in outdoor calorimetric test cells
- Measurement of heat loss coefficient of whole buildings based on co-heating tests
- Rapid measurement of heat loss coefficient of whole buildings based on transient heating
- Estimation of the energy signature of buildings in use based on energy use monitoring
- Grey box modeling of buildings in use based on dynamic energy use data

ST2 *Optimising full scale dynamic testing*

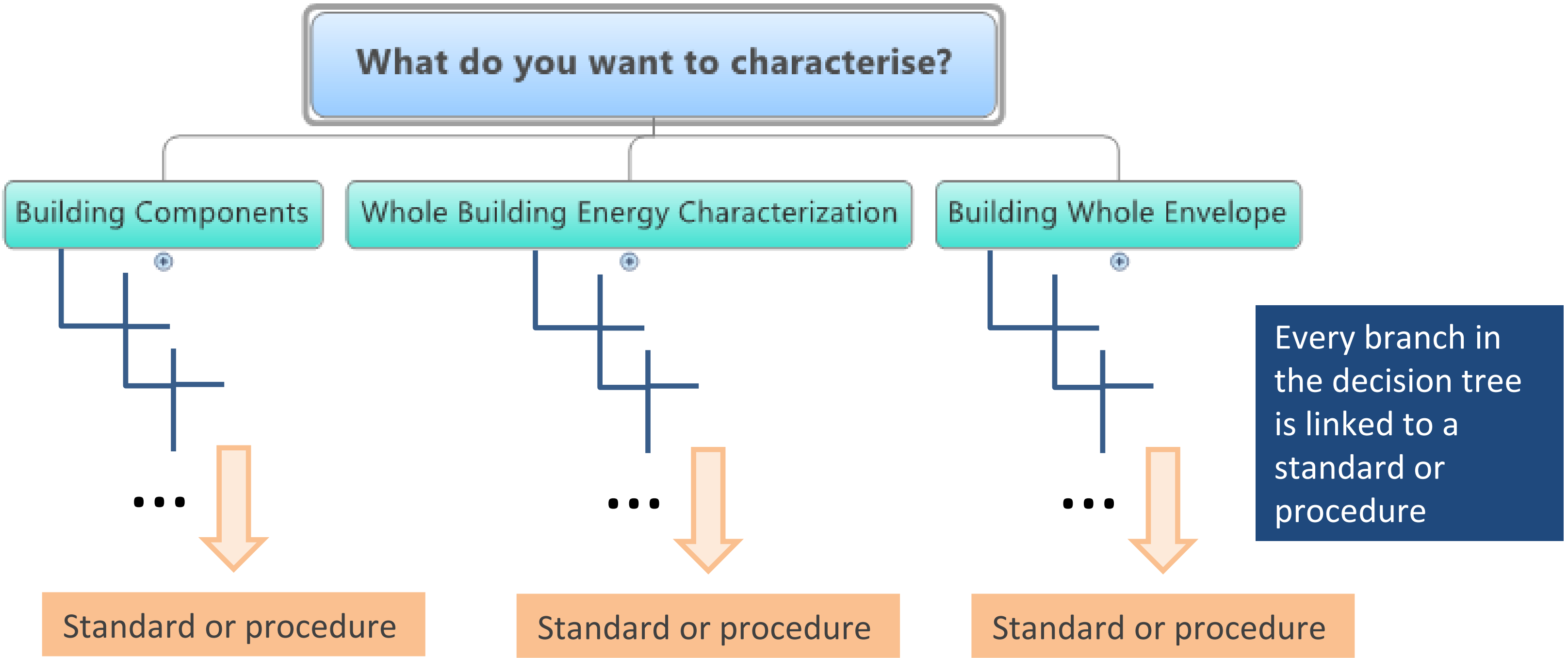
Aitor Erkoreka, EHU, Spain / Chris Gorse, LBU, UK

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



Decision tree

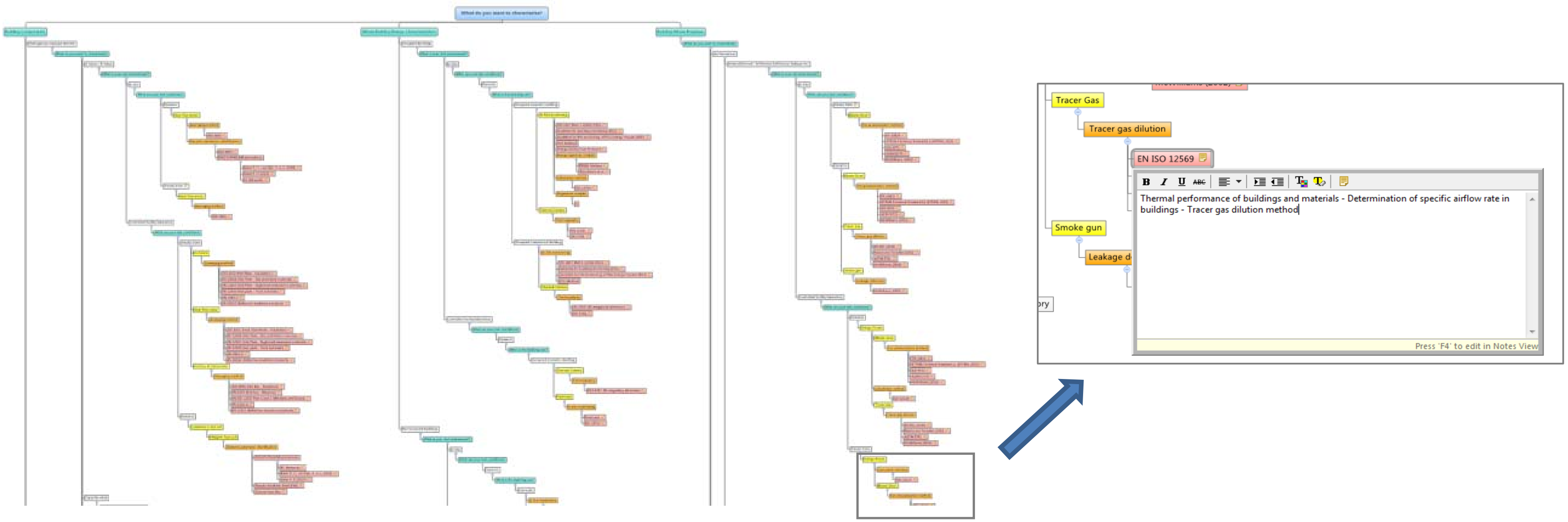
All information collected was transferred onto the Xmind software, which allows easier visualisation and better usability.



ST2 *Optimising full scale dynamic testing*

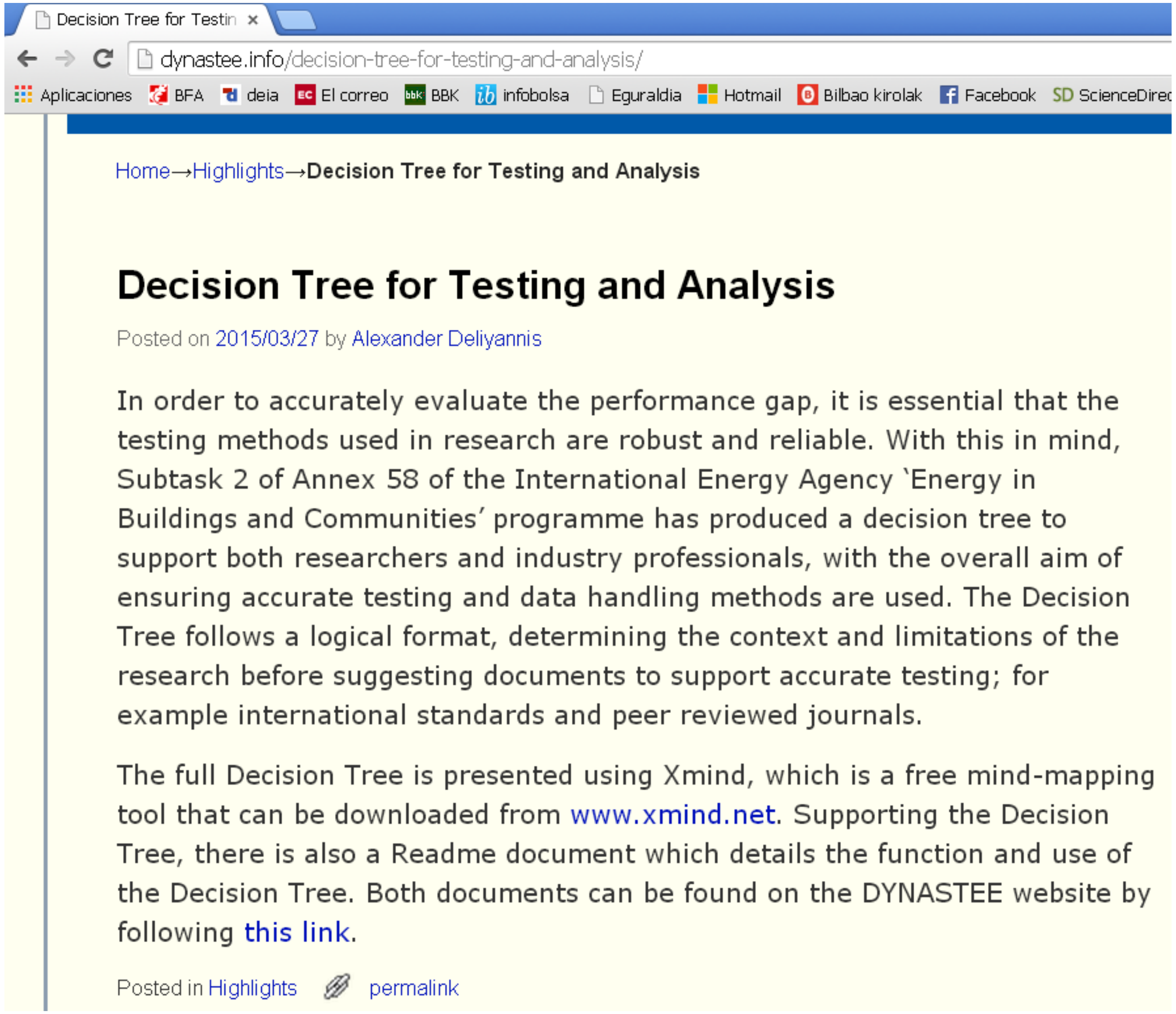
Branches are coloured according to following scheme:

Context & Environment → Experimental Design → Analysis Method → Guidance



ST2 *Optimising full scale dynamic testing*

Documents can be found an Dynastee website: http://dynastee.info/



- DECISION TREE file for xmind free mind-mapping software

- DECISION TREE SUPPORT README document.

- THE DECISION TREE WILL NEED PERIODIC UPDATING WITH NEW TESTING METHODOLOGIES.

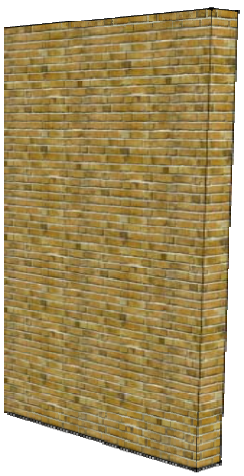
ST3 *Dynamic data analysis and performance characterisation*

Henrik Madsen, DTU, Denmark / Maria José Jiménez Taboada, CIEMAT, Spain

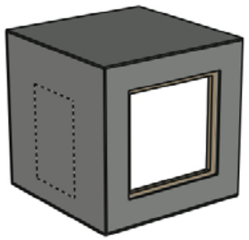
Subtask 3 developed procedures for full scale dynamic data analysis

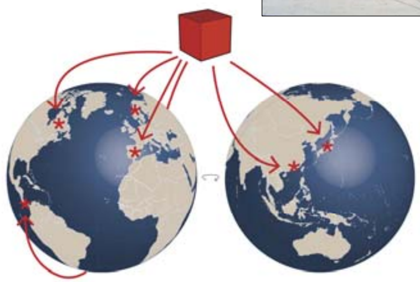
Common exercises to come up with a methodology for a reliable characterisation

CE1-CE2



CE3-CE4





CE5

CE6

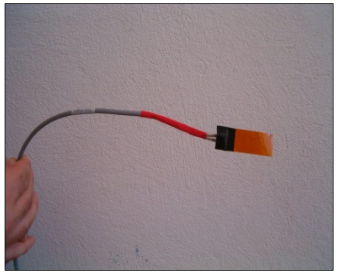
from simple homogeneous opaque walls <u>**TO FULL SIZE BUILDINGS**</u>

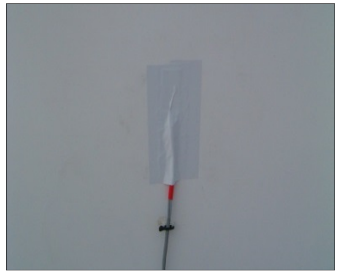
TRADITIONAL PRINCIPLES FOR MODEL BUILDING

1. Physical prior knowledge (energy balance equation, reasonable approximations, etc)
2. Experimental design (objectives, signal to noise ratio, etc)
3. Data collection (experiment)
4. Identification of model structure
5. Estimation of model parameters (tool and appropriate use of tool and model)
6. Model validation. Both statistical and physical validation
   - If fail go back to 4 or maybe 2
7. Validated final model
   - Can be used for characterization, forecasting, simulation and control

ST3 *Dynamic data analysis and performance characterisation*

Example of Round Robin test box in Almeria (Spain)





Data analysis methods

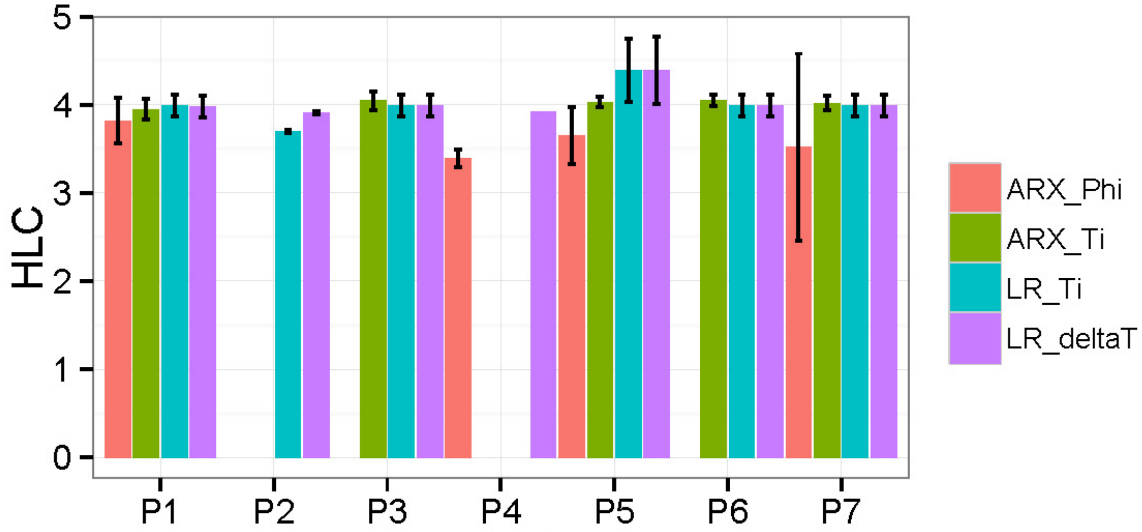
- Averaging methods
- Single and multiple linear regression

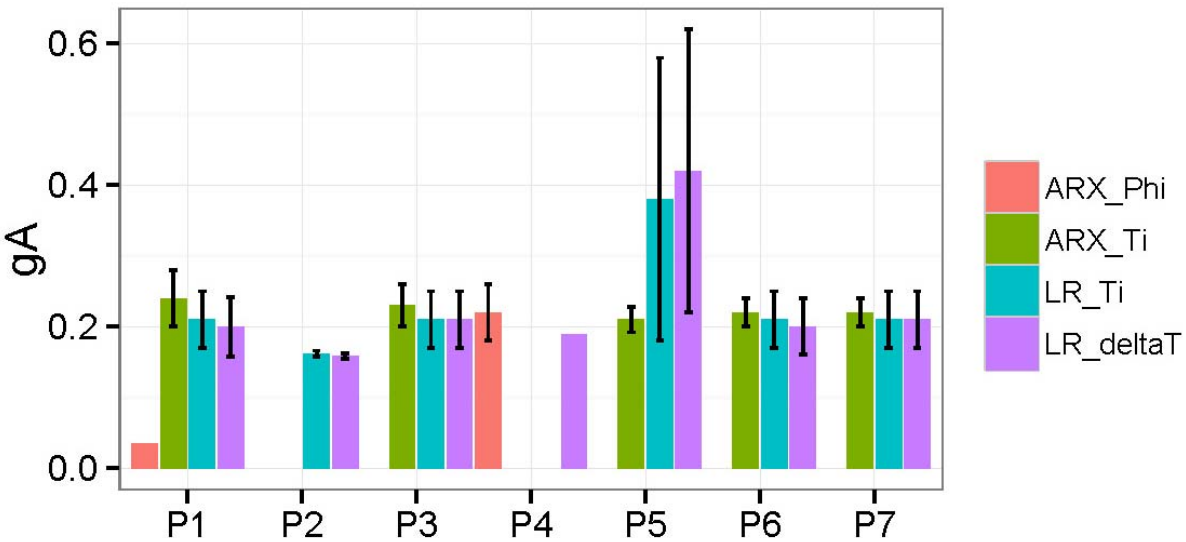
stationary properties

- ARX- and ARMAX-models
- State space models

stationary properties
+
dynamic behaviour

ST3 *Dynamic data analysis and performance characterisation*





ST3 *Dynamic data analysis and performance characterisation*

OUTCOME

- Development and improvement of **Software Tools**
  - Updated versions of CTSM-R. Grey-box modeling. ww.ctsm.info
  - Updated description on the DYNASTEE Web-pages

    http://dynastee.info/data-analysis/software-tools/ctsm-r/

- **Guidelines** for data analysis and instructions and outcome of common exercises in the ST3-reports

ST4 *Application of the developed framework*

Dirk Saelens, KU Leuven, Belgium / Paul Strachan, ESRU, UK /Shengwei Wang, PolyU, China

Subtask 4 showed the applications of the developed concepts and demonstrated the importance of reliable full scale dynamic testing.

Three applications have been put forward:

ST 4.1. full scale experiment to validate numerical BES-models

ST 4.2. Towards a characterisation of buildings based on in situ testing and smart meters

ST 4.3. Application of dynamic building characterisation for optimising smart grids

ST4 *Application of the developed framework*

ST 4.1. full scale experiment to validate numerical BES-models

Two detailed experiments were conducted based on the Twin Houses in Holzkirchen:

•one in summer 2013 with the houses in a side-by-side configuration (one with blinds up and one with blinds down)

•another in spring 2014 on one of the houses.

In each case we have almost 2 months of one-minutely data with high levels of instrumentation.

The experimental specification and measured datasets are considered the best existing empirical validation to date on a full-scale building.

The validation experiment has already proved useful for uncovering program deficiencies and for program development testing.

ST4 *Application of the developed framework*

Over 20 sets of modelling predictions have been made by 16 organisations with 12 different programs (both research and commercial), so the specification has been thoroughly tested.

User input errors were common. It is recommended that future studies are undertaken that focus on the types and impacts of user errors on a range of small and large building designs, with a view to informing program developers.

The time and effort to conduct this empirical validation experiment was substantial, both by the experimental team, the modellers and the analysis team. **And this is a comparatively simple unoccupied building.** More such experiments are needed on other building types: but large resources are required: both time and money.

ST4 *Application of the developed framework*

ST 4.2. Towards a characterisation of buildings based on in situ testing and smart meters

ST 4.3. Application of dynamic building characterisation for optimising smart grids

- Application of grey box models in intelligent networks to use flexibility of grids and buildings (price signal optimisation)
- Characterisation of larger districts via smart meter data
- Use of smart meter data to investigate feasibility of renovation measures, application of energy grids,…

Mainly qualitative onset via presentations of free papers

ST5

Network of excellence

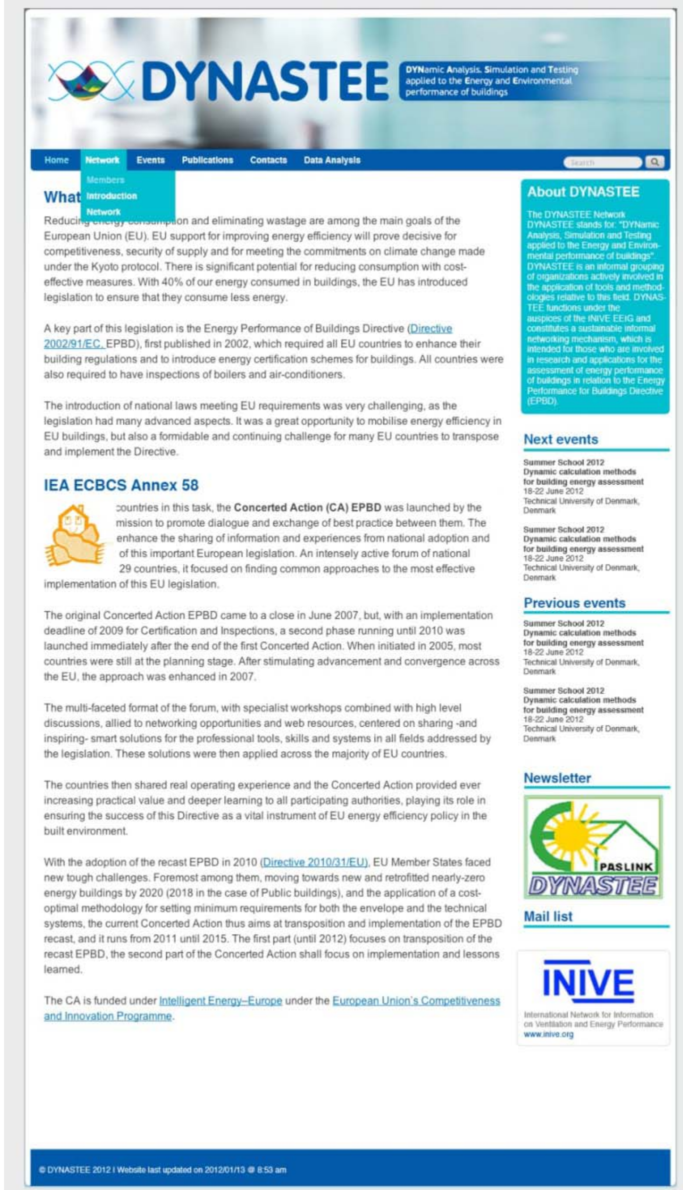
Hans Bloem, JRC, EU / Luk Vandaele, BBRI Belgium

outreach activities via

DYNASTEE

www.dynastee.info

Dynamic analysis, simulation and testing applied to the energy and environmental performance of buildings



DYNASTEE
DYNamic Analysis, Simulation and Testing applied to the Energy and Environmental performance of buildings

Home | Network | Events | Publications | Contacts | Data Analysis

Members
Introduction
Network

What

Reducing energy consumption and eliminating wastage are among the main goals of the European Union (EU). EU support for improving energy efficiency will prove decisive for competitiveness, security of supply and for meeting the commitments on climate change made under the Kyoto protocol. There is significant potential for reducing consumption with cost-effective measures. With 40% of our energy consumed in buildings, the EU has introduced legislation to ensure that they consume less energy.

A key part of this legislation is the Energy Performance of Buildings Directive (Directive 2002/91/EC, EPBD), first published in 2002, which required all EU countries to enhance their building regulations and to introduce energy certification schemes for buildings. All countries were also required to have inspections of boilers and air-conditioners.

The introduction of national laws meeting EU requirements was very challenging, as the legislation had many advanced aspects. It was a great opportunity to mobilise energy efficiency in EU buildings, but also a formidable and continuing challenge for many EU countries to transpose and implement the Directive.

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countries in this task, the **Concerted Action (CA) EPBD** was launched by the mission to promote dialogue and exchange of best practice between them. The enhance the sharing of information and experiences from national adoption and of this important European legislation. An intensely active forum of national 29 countries, it focused on finding common approaches to the most effective implementation of this EU legislation.

The original Concerted Action EPBD came to a close in June 2007, but, with an implementation deadline of 2009 for Certification and Inspections, a second phase running until 2010 was launched immediately after the end of the first Concerted Action. When initiated in 2005, most countries were still at the planning stage. After stimulating advancement and convergence across the EU, the approach was enhanced in 2007.

The multi-faceted format of the forum, with specialist workshops combined with high level discussions, allied to networking opportunities and web resources, centered on sharing -and inspiring- smart solutions for the professional tools, skills and systems in all fields addressed by the legislation. These solutions were then applied across the majority of EU countries.

The countries then shared real operating experience and the Concerted Action provided ever increasing practical value and deeper learning to all participating authorities, playing its role in ensuring the success of this Directive as a vital instrument of EU energy efficiency policy in the built environment.

With the adoption of the recast EPBD in 2010 (Directive 2010/31/EU), EU Member States faced new tough challenges. Foremost among them, moving towards new and retrofitted nearly-zero energy buildings by 2020 (2018 in the case of Public buildings), and the application of a cost-optimal methodology for setting minimum requirements for both the envelope and the technical systems, the current Concerted Action thus aims at transposition and implementation of the EPBD recast, and it runs from 2011 until 2015. The first part (until 2012) focuses on transposition of the recast EPBD, the second part of the Concerted Action shall focus on implementation and lessons learned.

The CA is funded under Intelligent Energy–Europe under the European Union's Competitiveness and Innovation Programme.

About DYNASTEE

The DYNASTEE Network
DYNASTEE stands for: "DYNamic Analysis, Simulation and Testing applied to the Energy and Environmental performance of buildings". DYNASTEE is an informal grouping of organizations actively involved in the application of tools and methodologies relative to this field. DYNASTEE functions under the auspices of the INIVE EEIG and constitutes a sustainable informal networking mechanism, which is intended for those who are involved in research and applications for the assessment of energy performance of buildings in relation to the Energy Performance for Buildings Directive (EPBD).

Next events

Summer School 2012
Dynamic calculation methods for building energy assessment
18-22 June 2012
Technical University of Denmark, Denmark

Summer School 2012
Dynamic calculation methods for building energy assessment
18-22 June 2012
Technical University of Denmark, Denmark

Previous events

Summer School 2012
Dynamic calculation methods for building energy assessment
18-22 June 2012
Technical University of Denmark, Denmark

Summer School 2012
Dynamic calculation methods for building energy assessment
18-22 June 2012
Technical University of Denmark, Denmark

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Current status