Department for Business, Energy & Industrial Strategy
Leeds Beckett University
UCL
Loughborough University

Requirements for an effective UK system of in use thermal performance metrics

Workshop, Monday 12th April 2021

How you contribute today.

- We will be using **MS Teams** and **Xleap** in this session. XLeap runs separately outside of MS Teams in your internet browser.

- Key combinations to toggle between MS Teams & XLeap

(i)

(ii)

- We will use XLeap to facilitate a text-based discussion to enable you to respond to the questions we are posing today. All thoughts shared will be recorded anonymously in the software.

- As a general rule please remain on mute and off camera.

- If you are presenting then please put on your camera while you are speaking and obviously come off mute. As we have so many presenters today we do need to ask you to stay to the time you have been allotted. The facilitator will let you know when you have one minute left. All the slides will be controlled by the facilitators.

- Any problems as we go please use the MS Teams chat.

Requirements for an effective UK system of in use thermal performance metrics

Welcome and introduction

Professor Paul Monks
Chief Scientific Adviser, BEIS

30 April, 2021

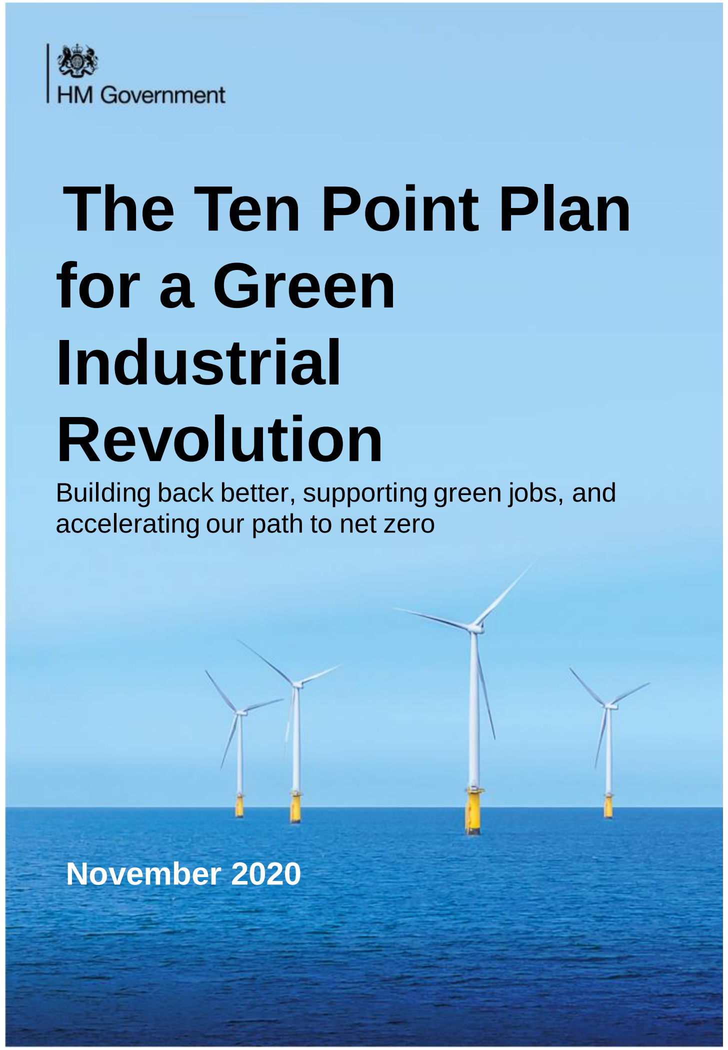
Net Zero

- In 2008 the UK set an ambitious goal of decreasing its greenhouse gas emissions by 80% of 1990 levels by 2050; on 27 June 2019 the Government legislated to increase its ambition, **committing to net zero emissions by 2050** (i.e. a reduction of 100% compared to 1990 levels).

- The Climate Change Act also sets **legally binding interim targets for five-year Carbon Budget periods**. In the short-term, policy decisions aim to meet the 4th and 5th carbon budgets (CB4, 2023-27, and CB5, 2028-32) with a requirement for the 6th Carbon Budget to be set during the first half of 2021.

- Under the Paris Agreement, each signatory must publish a **Nationally Determined Contribution (NDC)** which is a signal of their “highest possible ambition” – and the UK’s 2030 NDC will set tone for ambition at COP26.

- While we have made strong progress to date, **UK emissions are currently projected to significantly exceed our legal emissions caps (Carbon Budgets 4 and 5, 2023-32) and a considerable step change is required**.



Point 1
Advancing Offshore Wind

Point 2
Driving the Growth of Low Carbon Hydrogen

Point 3
Delivering New and Advanced Nuclear Power

Point 4
Accelerating the Shift to Zero Emission Vehicles

Point 5
Green Public Transport, Cycling and Walking

Point 6
Jet Zero and Green Ships

Point 7
Greener Buildings

Point 8
Investing in Carbon Capture, Usage and Storage

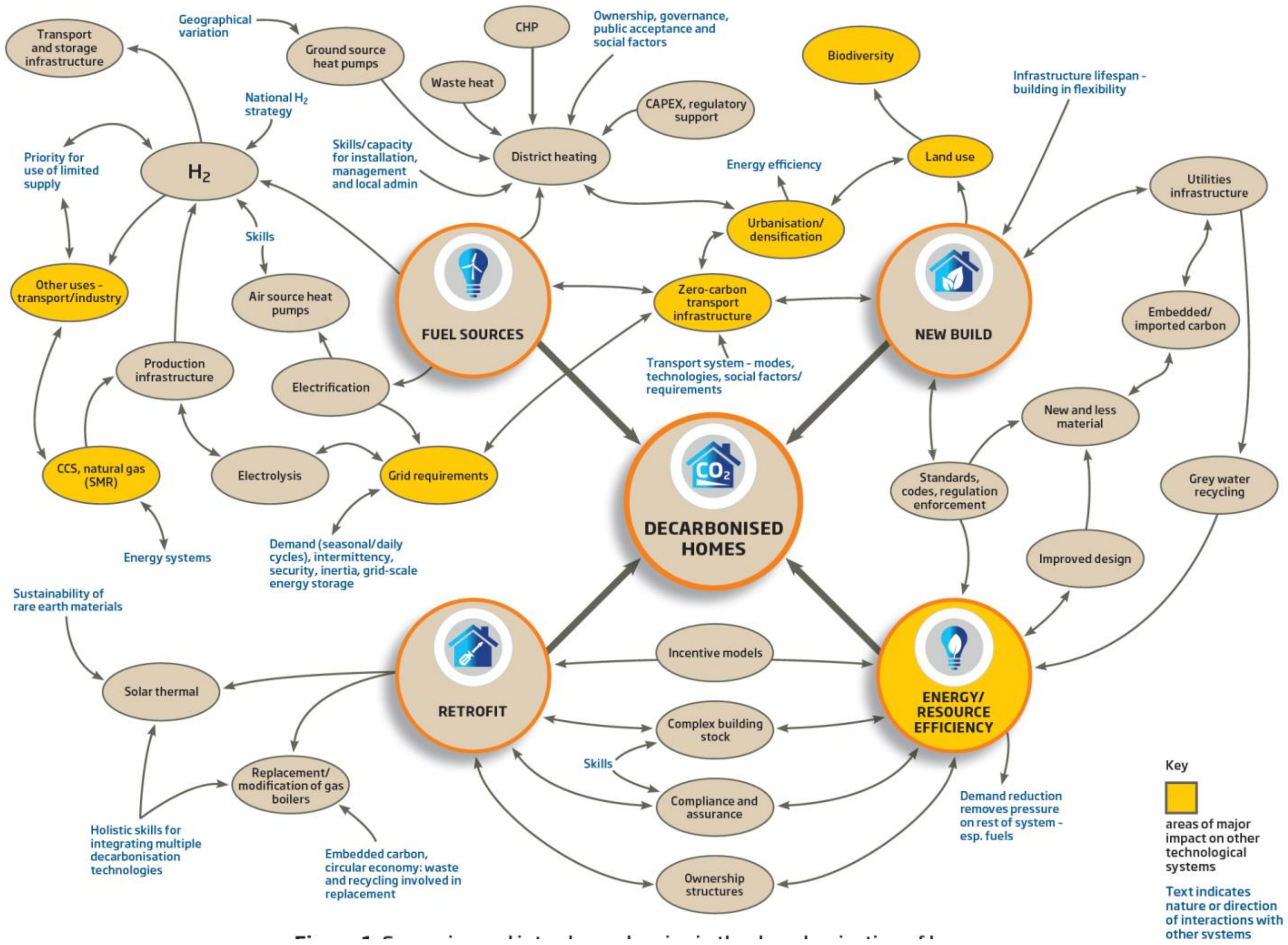
Point 9
Protecting Our Natural Environment

Point 10
Green Finance and Innovation

Systems approaches

- Interacting systems
- Planning
- Feedback and monitoring

“To make plans and project designs brings with it many good sensations; and whoever had the strength to be nothing but a forger of plans his whole life long would be a very happy man. But he would occasionally have to take a rest from this activity by carrying out a plan – and then comes the vexation and the sobering up.”
Friedrich Nietzsche 1878



Source: Royal Academy of Engineering (2020) [Net Zero: A systems perspective on the climate challenge]

Technical Evaluation of SMETER Technologies (TEST) Project

Smart Meter Enabled Thermal Efficiency Ratings (SMETER) Technical Assessment Contractor

Tender Reference Number: TRN1608/08/2018

SMETER Workshop 12/4/2021

Dr David Allinson - Loughborough University
Professor Chris Gorse - Leeds Beckett University
Dr Cliff Elwell - UCL
Professor Dennis Loveday - Loughborough University

Department for Business, Energy & Industrial Strategy

Halton Housing

LBU LEEDS BECKETT UNIVERSITY

UCL

Loughborough University

TEST Project: Project Team

Loughborough University
Building Energy Research Group

- **Loughborough University**: David Allinson, Ben Roberts, Kevin Lomas, and Dennis Loveday.

Halton Housing

- **Halton Housing**: Gavin Roberts, Lee Reevell, and the wider team.

LEEDS BECKETT UNIVERSITY
Leeds Sustainability Institute

- **Leeds Beckett University**: Chris Gorse, Adam Hardy, Felix Thomas, Dominic Miles-Shenton, David Johnston, David Glew, Fiona Fylan, and David Farmer.

UCL ENERGY INSTITUTE

- **UCL**: Cliff Elwell, Jenny Crawley, Frances Hollick, and Jez Wingfield.

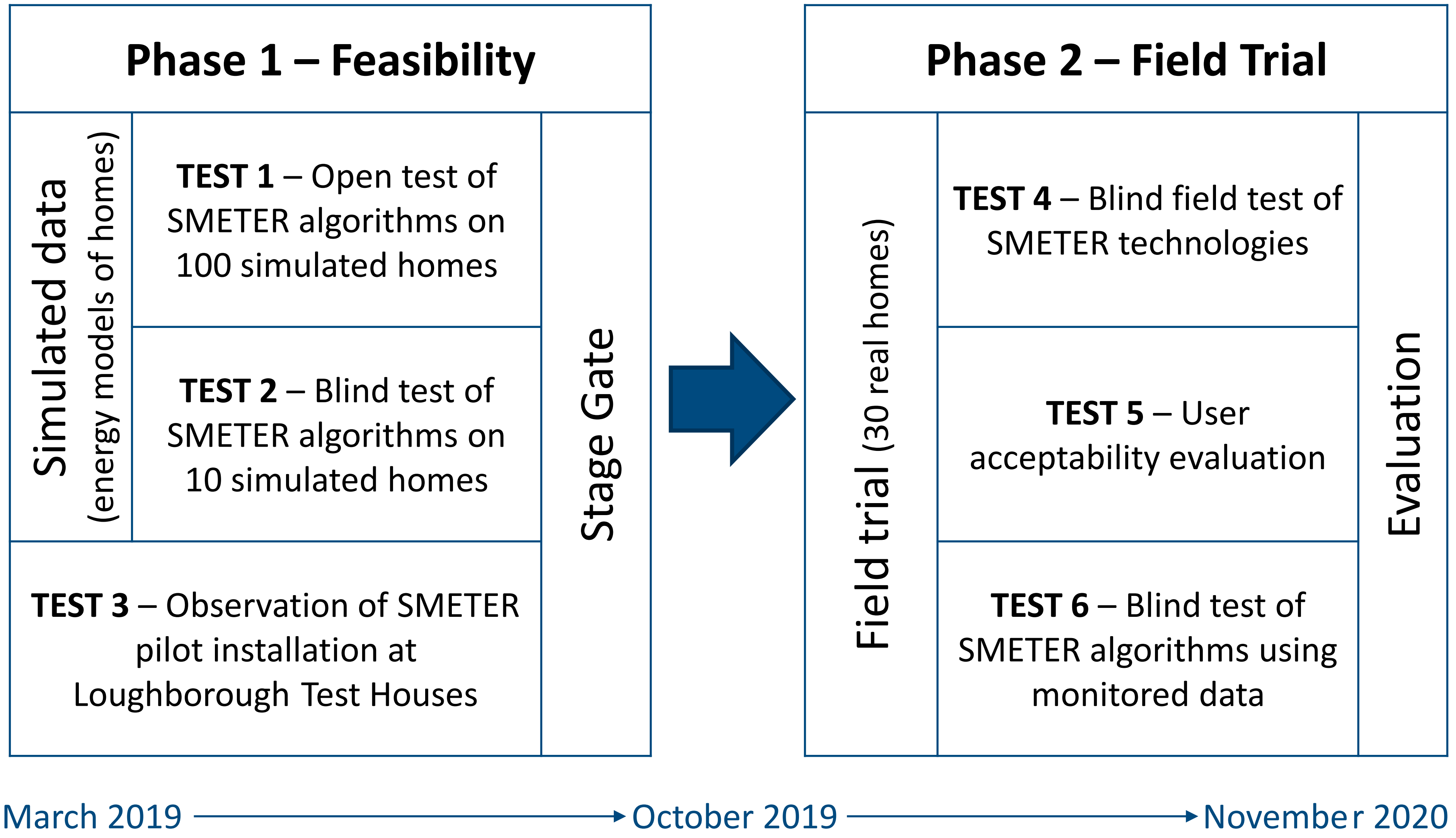
EBC Annex 71

IEA EBC Annex 71:
lding energy performance assessment
based on in-situ measurements

TEST Project: Aim and overview

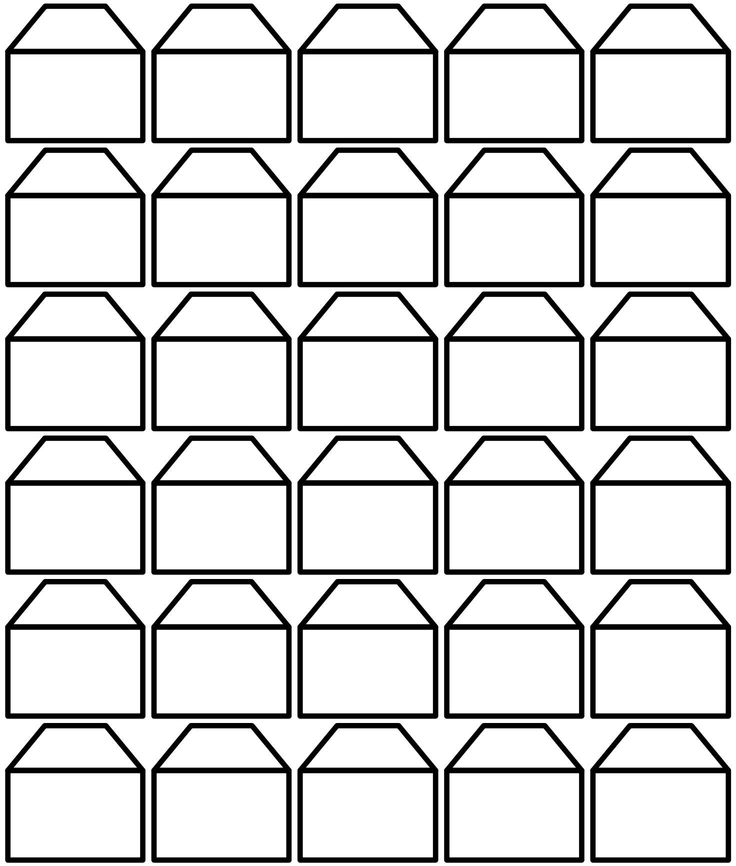
- Aim
  - Evaluate the performance of SMETER Technologies (developed under separate BEIS funding)
  - Support the developers (Participating Organisations) with data, information and knowledge
- Eight SMETER Technologies from eight Participating Organisations
  - Two SMETER Technologies required no product installation, using only gas and electricity smart meter data
  - Six SMETER Technologies included a product to be installed in the home (e.g. sensors and/or a heating controller)
- Two project phases
  - Phase 1: feasibility - time to develop algorithms, demonstrate feasibility, and set-up phase 2
  - Phase 2: field trial - evaluation of SMETER performance

TEST Project: Six stages across two project phases



TEST Project: Phase 2 Field Trial

Co-heating test, instrumentation & SMETERs installed, new tenant.



- 30 homes identified, surveyed, and co-heating/blower door test to measure HTC
- Secondary gas and electricity meters, and T/RH sensors installed (monitored data)
- Each SMETER technology allocated to 10 homes and SMETER product installed where needed
- A household moved into each home

TEST Project: Phase 2 Field Trial

- TEST 4: blind field test of SMETER technologies
  - Participating organisations calculated the HTC from their 10 allocated homes (SMETER product installed where required)
- TEST 6: blind field test of SMETER algorithms using monitored data
  - Participating organisations calculated the HTC from the other 20 homes using the monitored data (as collected by the TEST team)
- Participating organisations were asked to report the HTC of all 30 homes (TEST 4 and TEST 6), along with 95% confidence interval
- Results of TEST 4 and TEST 6 compared with the measured HTC by co-heating.

Measuring the HTC

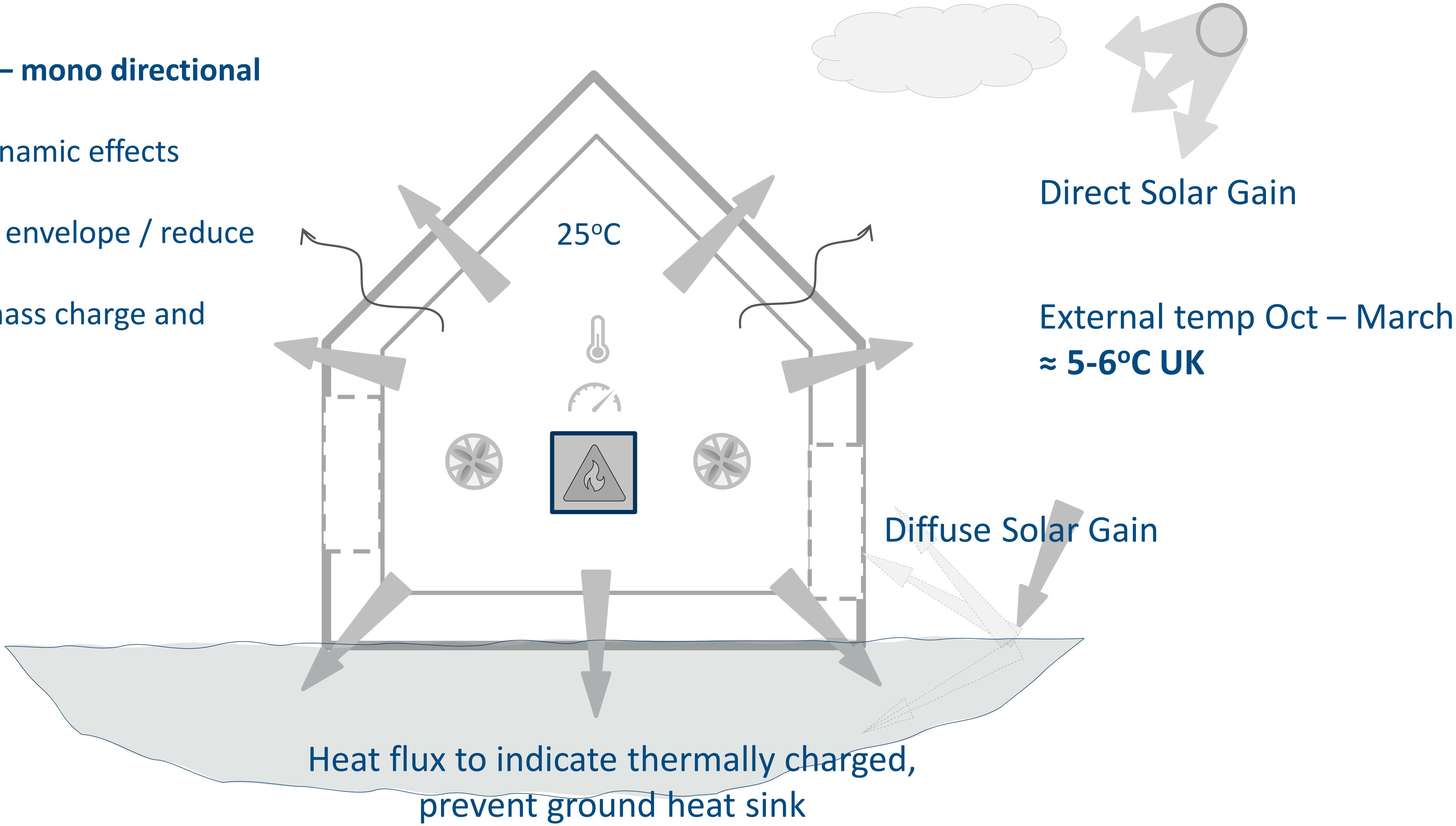
- 30 buildings Co-heating, QUB, blower door and Pulse

- Existing and calculated EPC using RdSAP mythology

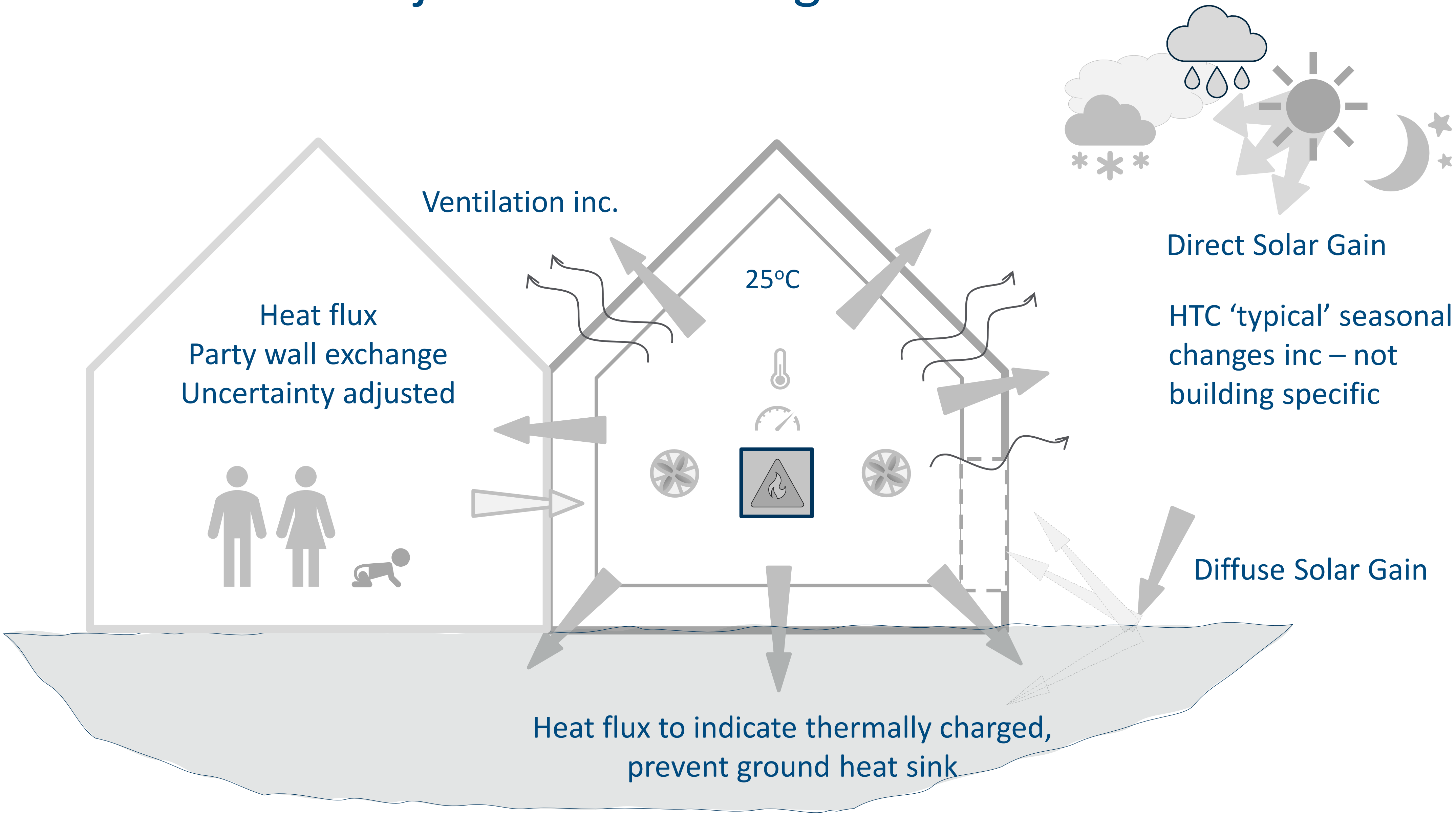
Coheating - HTC

ISO 52016:2017 HTC
one environment to the external – mono directional

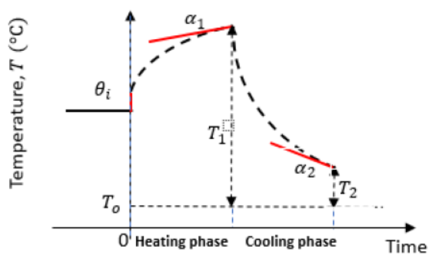
- Elevated heating - minimize dynamic effects
  Monodirectional heat flow
- Fans distribute heat across the envelope / reduce stratification
- Minimising dynamic effects : mass charge and discharge
- Infiltration measured

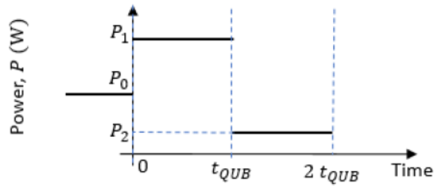


Adjusted Coheating - iHTC

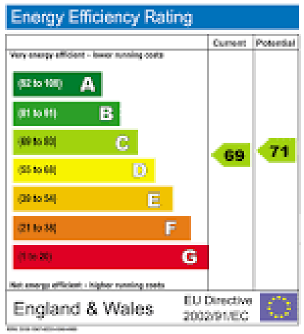


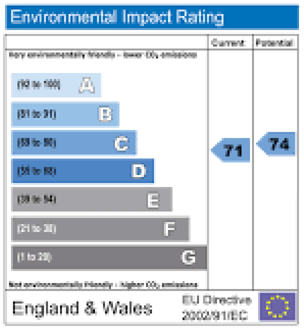
Baseline Performance Tests

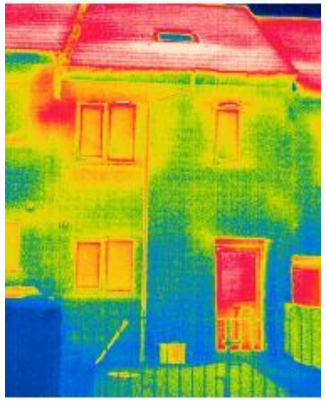




- Coheating = iHTC
  - Heatflux, temp, humidity, weather data
- QUB iHTC
- RdSAP HTC
- Blower door – air permeability and ventilation
- Pulse

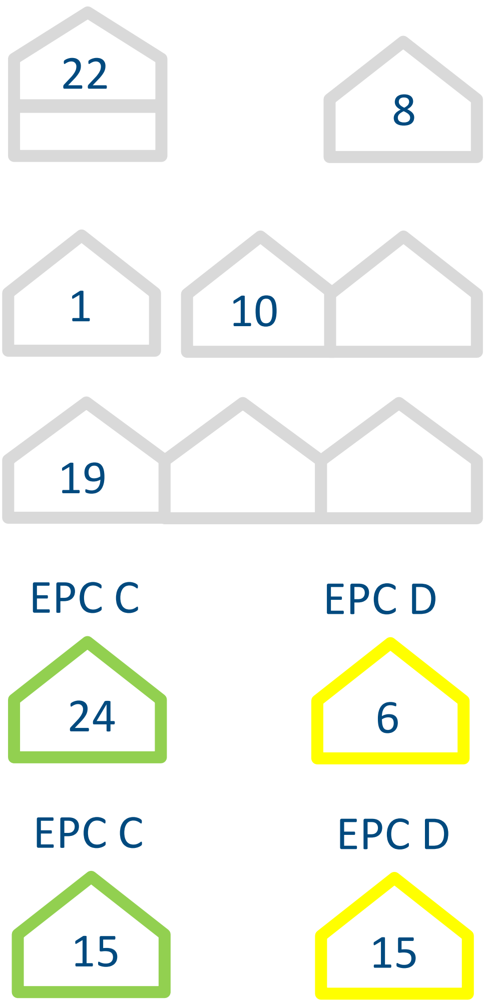






Building Context

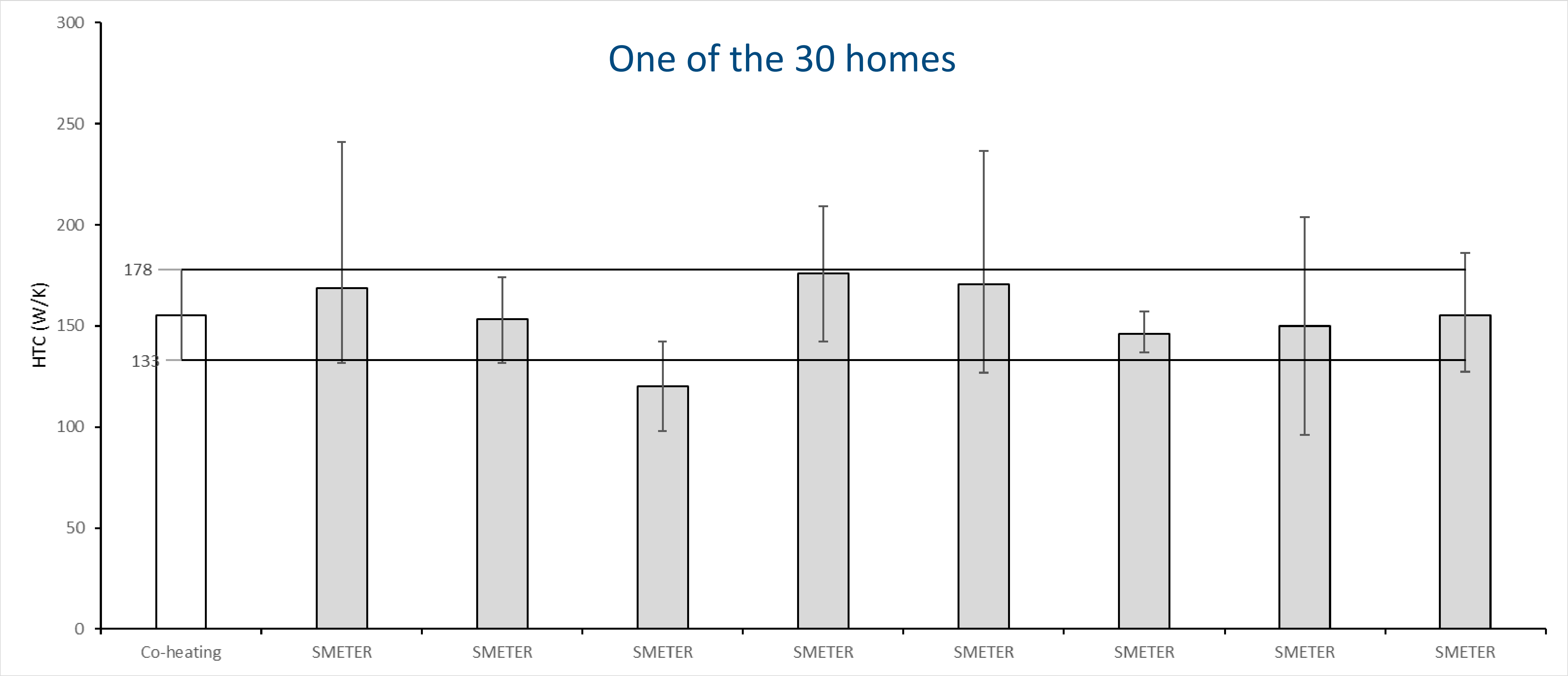
- 22 two-storey and 8 single-storey
- 1 detached, 10 semi-detached and 19 end-terrace
  - Circa 1927 to 1990
  - Floor areas 38m^2 to 83m^2 .
  - Within 6 km weather station



- EPC Test team
- EPC Commercial Assessor

External wall		Loft insulation				Ground floor		Windows	
Type (cavity, timber frame, concrete frame, or concrete no-fines)	Insulation	Type	Thickness (mm)	Location	Condition	Solid concrete or suspended timber?	Insulated?	Double glazed?	Total window area (m^2)
Cavity	Blown	MWF	200	Joists	Even cover	Solid	×	✓	11.08
Cavity	Blown	MWF	?	Joists	Unknown	Solid	×	✓	6.02
Cavity	Blown	MWF	300	Joists	Disturbed	Solid	×	✓	12.63
Cavity	Blown	MWF	300	Joists	Disturbed	Solid	×	✓	9.74
Cavity	Blown	MWF	300	Joists	Disturbed	Solid	×	✓	13.39
Concrete	?	MWF	300	Joists	Piled up	Solid	×	✓	13.28
Cavity	Blown	MWF	300	Joists	Even cover	Solid	×	✓	7.85
Cavity	Blown	MWF	300	Joists	Disturbed	Solid	×	✓	13.24
Cavity	Blown	MWF	100	Joists	Piled up	Suspended	×	✓	7.51
Cavity	Blown	MWF	100	Joists	Disturbed	Solid	×	✓	12.38
Cavity	Blown	MWF	100	Joists	Disturbed	Suspended	×	✓	9.98
Cavity	Blown	MWF	300	Joists	Even cover	Solid	×	✓	7.24
Cavity	Blown	MWF	100	Joists	Piled up	Suspended	×	✓	6.97
Timber	Frame	MWF	100	Joists	Even cover	Solid	×	✓	8.02
No-fines	EWI	MWF	300	Joists	Disturbed	Solid	×	✓	12.87
Cavity	Blown	MWF	300	Joists+ rafters	Even cover	Solid	×	✓	10.71
No-fines	EWI	MWF	300	Joists	Even cover	Solid	×	✓	11.90
Cavity	Blown	MWF	150	Joists	Piled up	Suspended	×	✓	7.49
No-fines	EWI	MWF	100	Joists	Piled up	Solid	×	✓	11.87
Cavity	Blown	MWF	100	Joists	Even cover	Solid	×	✓	13.30
Cavity	Blown	MWF	100	Joists	Boarded	Solid	×	✓	13.12
Cavity	Blown	MWF	300	Joists	Even cover	Solid	×	✓	11.16
Cavity	Blown	MWF	150	Joists	Disturbed	Solid	×	✓	14.20
Cavity	Blown	MWF	100	Joists	Unknown	Suspended	×	✓	7.29
Cavity	Blown	MWF	300	Joists	Disturbed	Solid	×	✓	13.28
Cavity	Blown	MWF	300	Joists	Unknown	Solid	×	✓	12.35
Cavity	Blown	MWF	300	Joists	Even cover	Solid	×	✓	14.65
Cavity	Blown	MWF	300	Joists	Even cover	Solid	×	✓	9.36
No-fines	EWI	MWF	200	Joists	Disturbed	Solid	×	✓	11.17
No-fines	EWI	MWF	100	Joists	Even cover	Solid	×	✓	11.17

TEST Project: Phase 2 Results



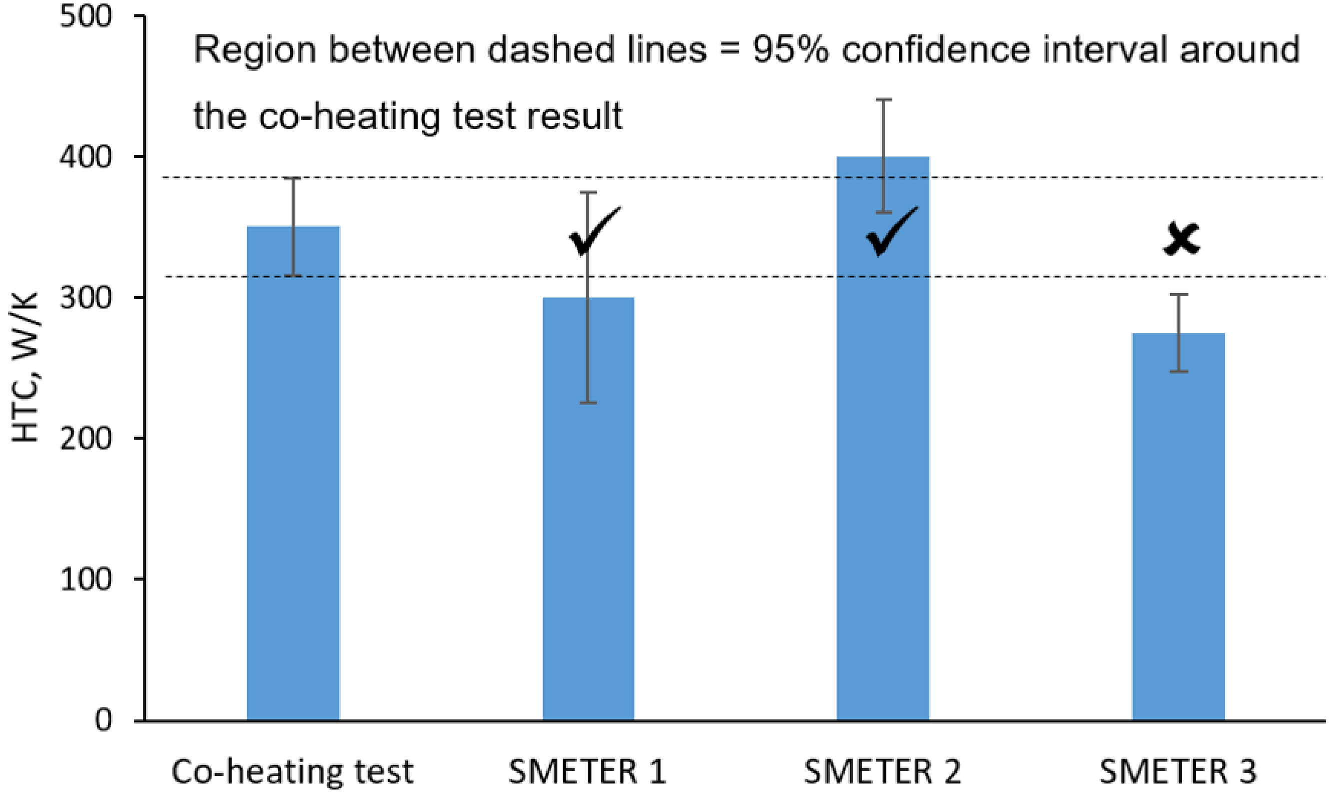
TEST Project: Evaluation of SMETER accuracy

1. Comparison of calculated HTC with measured HTC using confidence intervals
   - Do the confidence intervals overlap?

2. Analysis of the differences between the SMETER result and the measured HTC
   - Average difference: normalised mean bias error (NMBE)
   - Range of difference: coefficient of variation of root mean square error (CVRMSE)

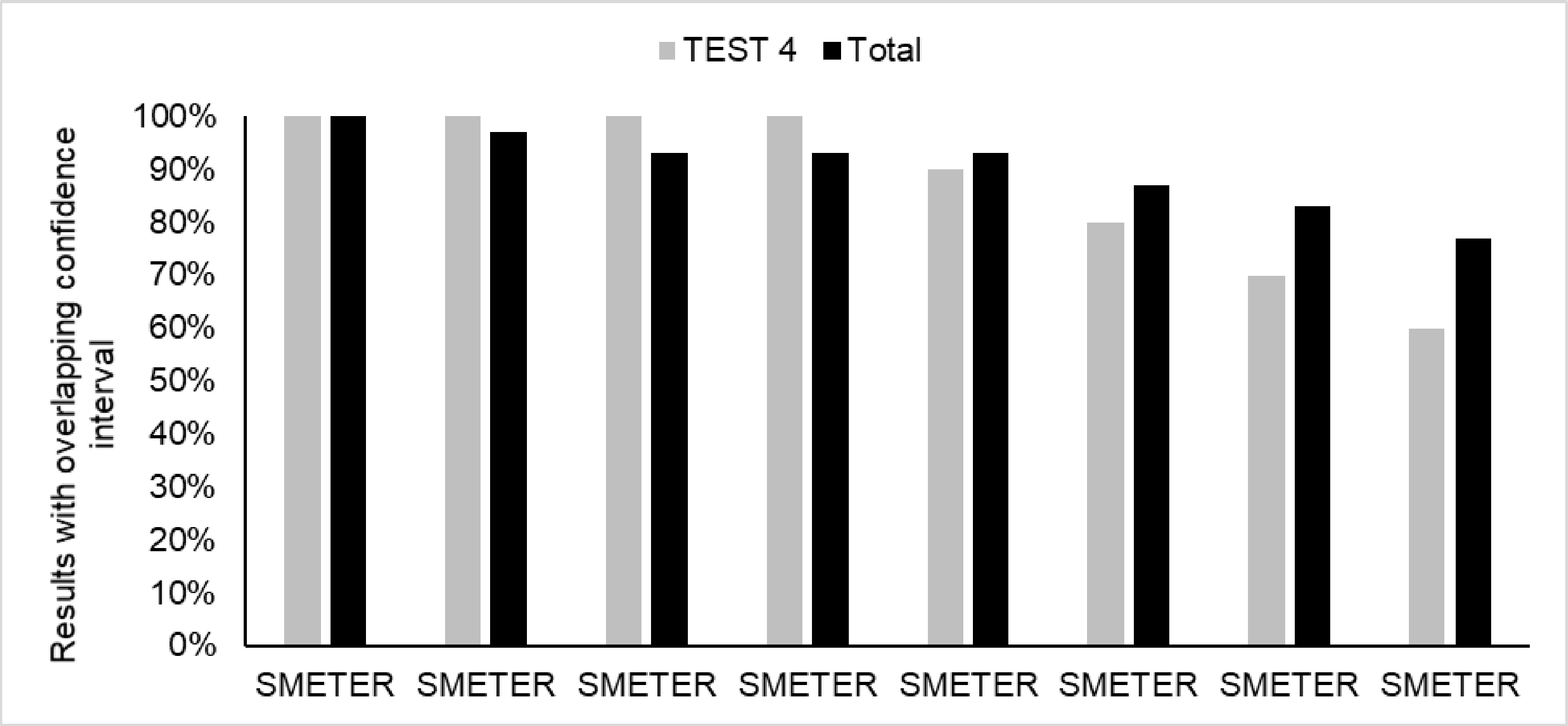
TEST Project: Evaluation of SMETER accuracy

1. Comparison of calculated HTC with measured HTC using confidence intervals
   – Example illustration



TEST Project: Evaluation of SMETER accuracy

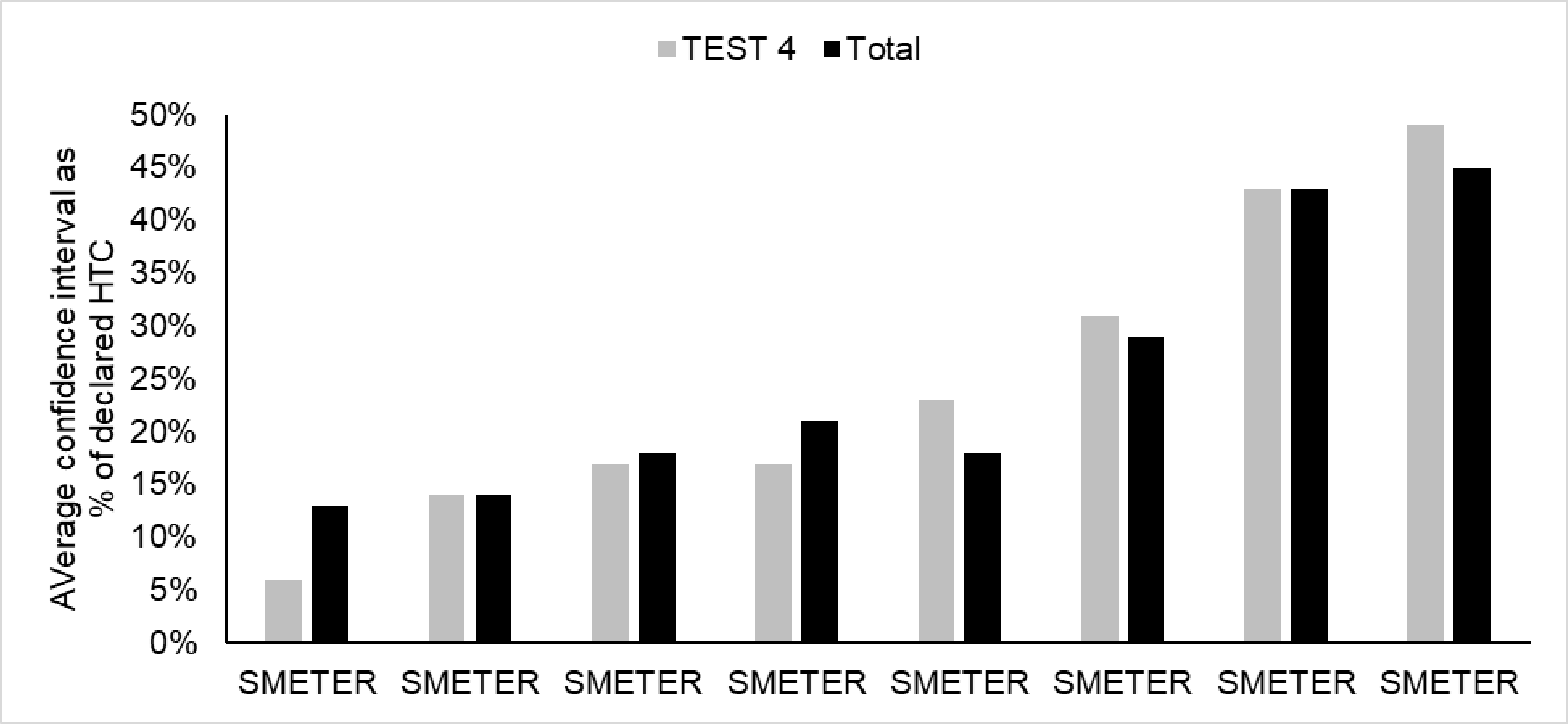
1. Comparison of calculated HTC with measured HTC using confidence intervals
   – Overlapping confidence intervals from 100% to 60% of declared results in TEST 4 and 100% to 77% in total (TEST 4 and TEST 6)



SMETERs in rank order

TEST Project: Evaluation of SMETER accuracy

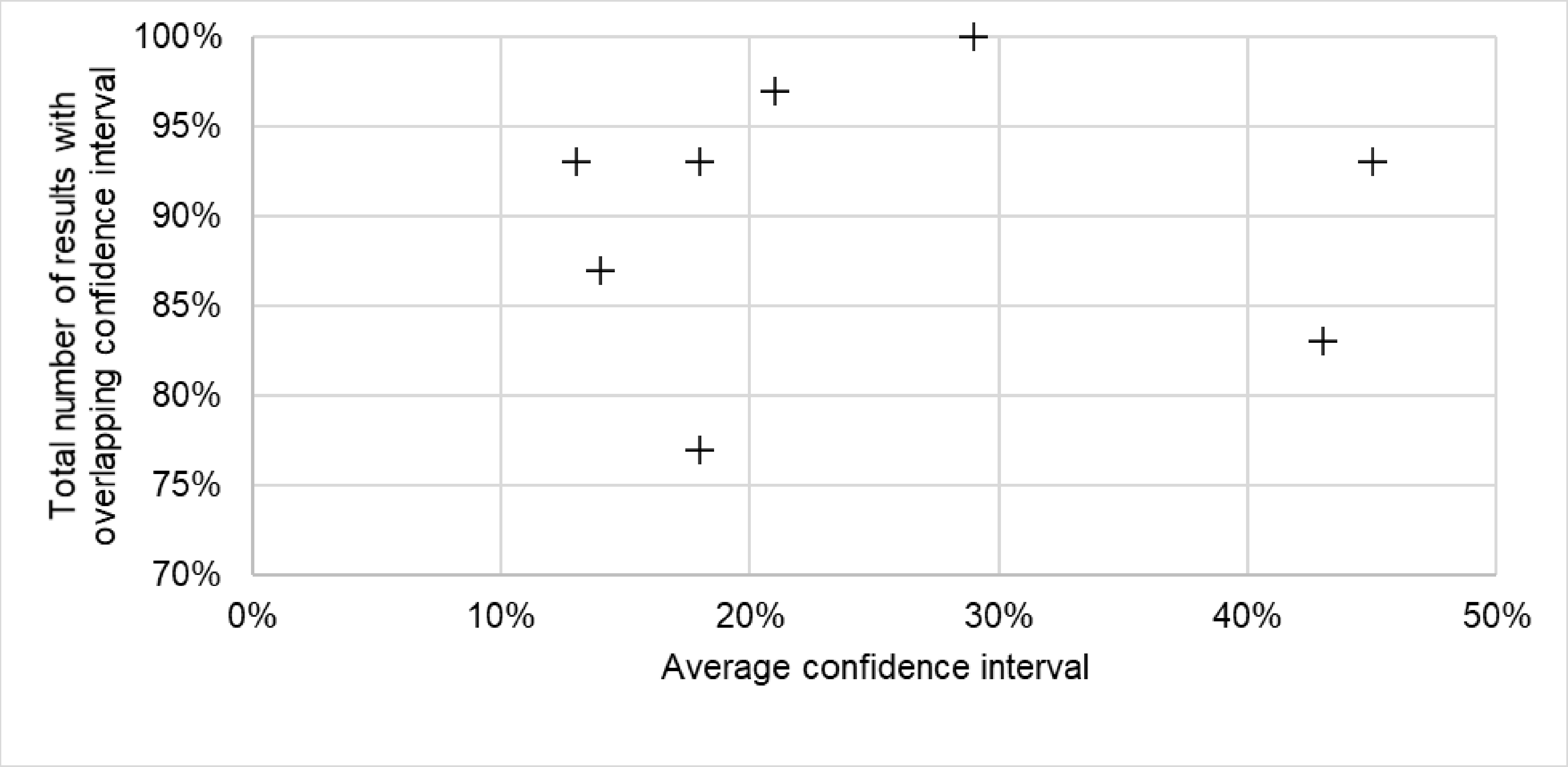
1. Comparison of calculated HTC with measured HTC using confidence intervals
   - Average confidence intervals from 6% to 49% in TEST 4 and 13% to 45% in total (TEST 4 and TEST 6)



SMETERs in rank order (different from previous slide)

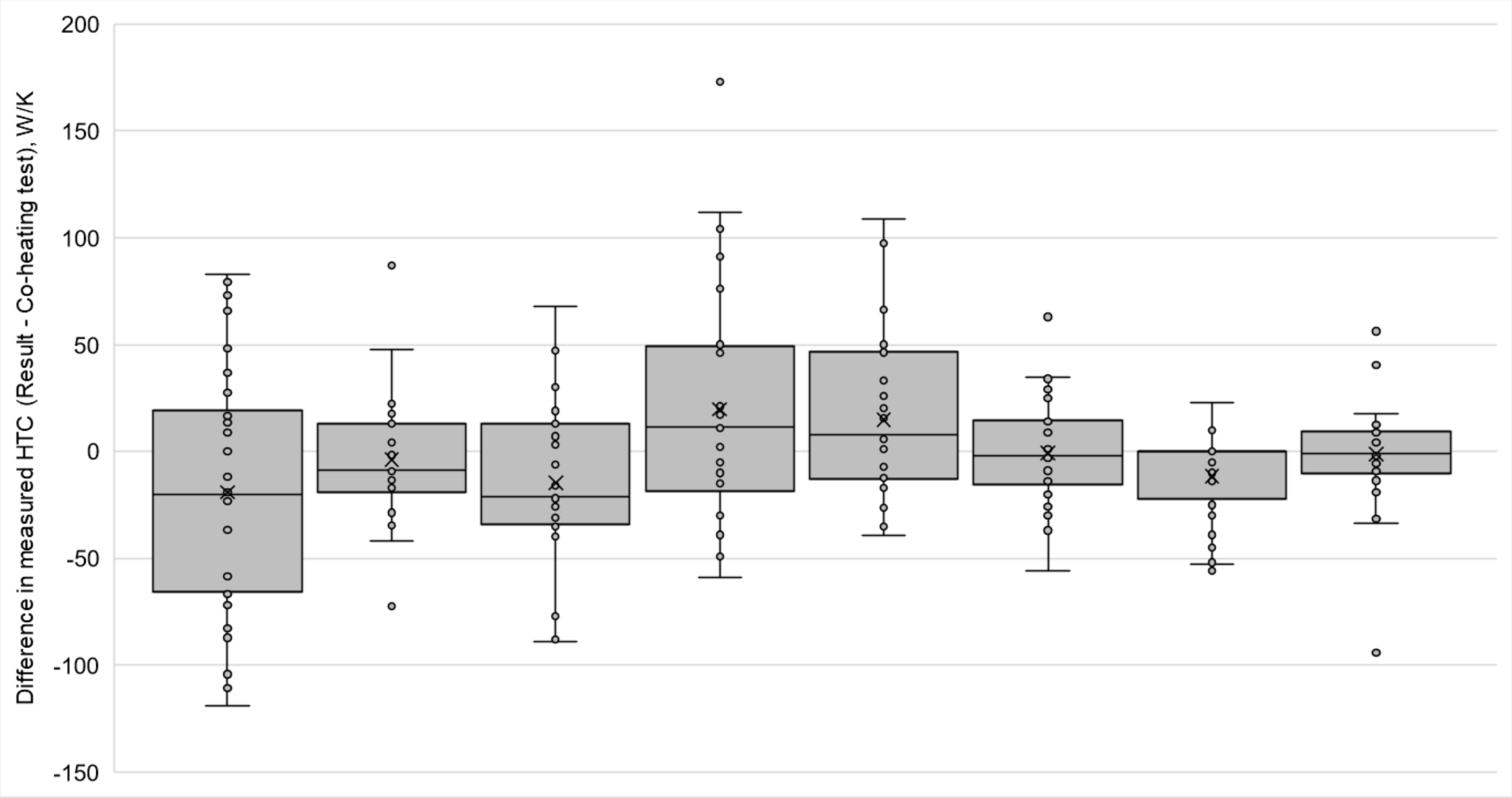
TEST Project: Evaluation of SMETER accuracy

1. Comparison of calculated HTC with measured HTC using confidence intervals
   – Risks with declaring a smaller confidence interval



TEST Project: Evaluation of SMETER accuracy

2. Analysis of the differences between the SMETER result and the measured HTC

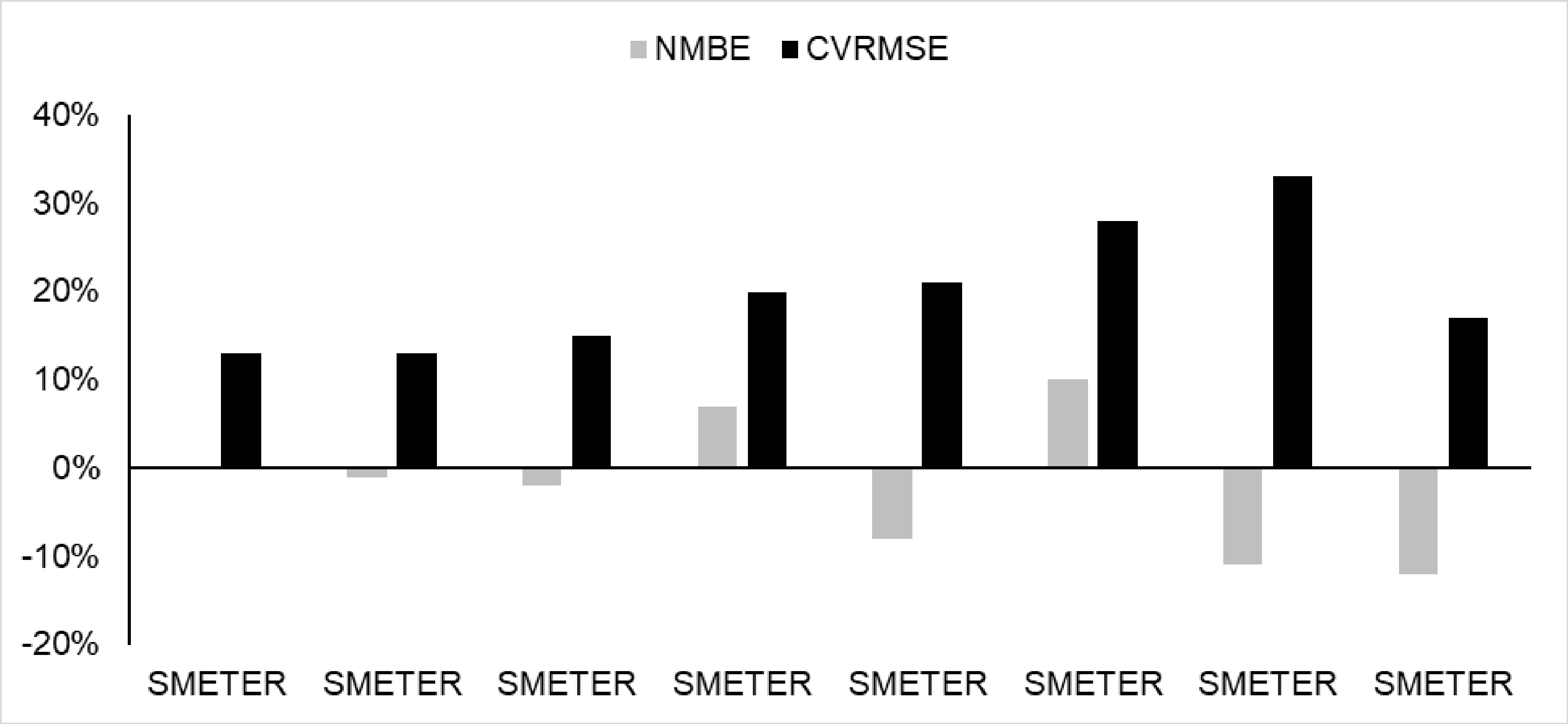


TEST Project: Evaluation of SMETER accuracy

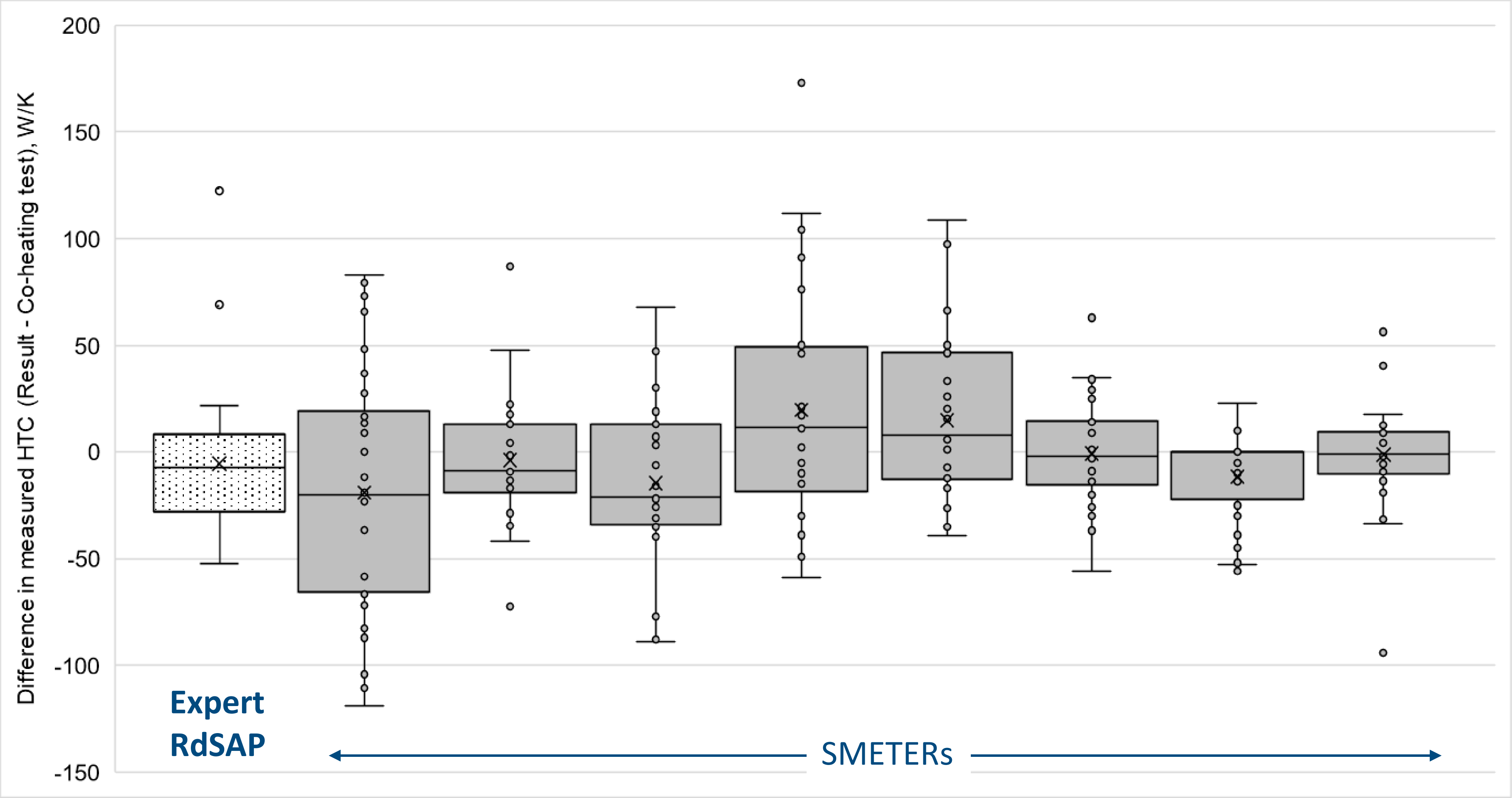
2. Analysis of the differences between the SMETER result and the measured HTC
   - Average difference: normalised mean bias error (NMBE)
     - quantifies the magnitude and direction of the average bias in the calculated HTC
     - This is a measure of the trueness, or systematic agreement, of the measurement and would ideally be zero.
   - Range of difference: coefficient of variation of root mean square error (CVRMSE)
     - a comparative measure of the precision of the calculated HTC
     - A lower CVRMSE is better.

TEST Project: Evaluation of SMETER accuracy

2. Analysis of the differences between the SMETER result and the measured HTC
   – For all results (TEST 4 and TEST 6): NMBE from 0% to -12%; CVRMSE from 13% to 33%

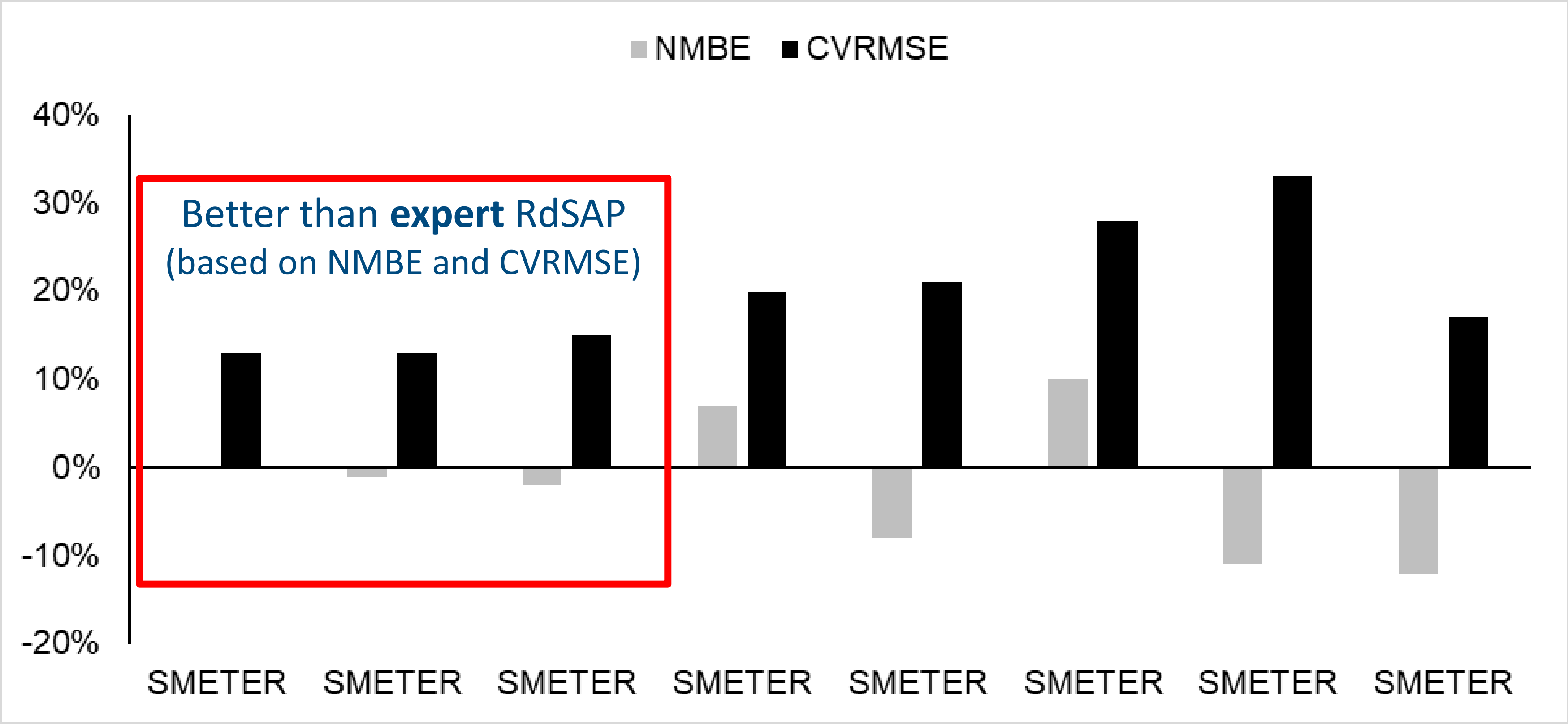


TEST Project: Comparison with **expert** RdSAP



TEST Project: Comparison with **expert** RdSAP

2. Analysis of the differences between the SMETER result and the measured HTC
   – Expert RdSAP: NMBE -3%; CVRMSE 18%



TEST Project: Summary of Phase 2 Field Trial

- Eight different SMETER Technologies were able to predict the HTC of 30 homes in a field trial
- The self-declared uncertainly ranged from an average of ±6% to ±49% (TEST 4)
- Compared with the measured HTC, trueness and precision varied:
  - NMBE ranged from 0% to -12%
  - CVRMSE ranged from 13% to 33%
- Three of the SMETER Technologies were more accurate than expert application of RdSAP survey and calculation
- A ninth SMETER technology joined the project part way through Phase 2. A trial comprising two separate dwellings was undertaken; the SMETER was able to successfully predict the HTCs with a self-reported uncertainty ±3% for one home and ± 8% for the other

TEST Project: Work in progress

- SMETER calculated HTC from further winter monitoring period
- Comparison with RdSAP HTC from commercial EPC assessment
- Annex 71 exercise using data from some of the homes

Limitations

- Representativeness vs the UK stock
  – All homes C or D
  – Semi- and detached: no flats or mid-terrace
    - Party wall heat losses.
  – Same boilers throughout, limited energy use outside the heated envelope
- Is the co-heating test derived HTC the “real” HTC of the property?
  – HTC varies
- Data issues
  – Additional data requirements of some participants
  – Data isn’t perfect (but issues such as energy use spikes are typical)

Future work

- GHG-SMETER project:
  - Voucher and LAD evaluation
  - Remote-only analysis
    - Smart meter data only
    - Sample target 2000
  - In-home temperature monitoring
    - 200 homes, occupant positioned sensors
    - Smart meter data
    - Airtightness testing for a sub-sample
  - April 2021 – October 2022
    - UCL (Smart Energy Research Lab plus Physical Characterisation of Buildings group)
    - Commercial SMETERs to be contracted to calculate HTCs

What is the change in HTC on installation of different measures? How does it compare to expectation?

How do different SMETERs compare? Do SMETERs support policy evaluation?

Provide publicly accessible data to support further research, including SMETER development.

SMETER Project-evaluation

Dennis Loveday
Emeritus Professor of Building Physics, Loughborough University

- Independent evaluator…and member of the TEST team
- Objective: …*'robust evaluation of to what extent, and how, the programme has achieved its objectives and contributed to longer-term desired outcomes'*
- Evidence from 17 project members (Participants, Monitoring Officers, TEST team, BEIS)
- Project Phase 1 (Jan-Oct 2019): Evaluation Report 1 approved June 2020…
  …one of its recommendations was today's workshop
- Project Phase 2 (Nov 2019-Oct 2020): Final Evaluation Report nearing completion
- Following slides present some pre-submission outcomes to support today's discussion…

SMETER Project-evaluation

- Questionnaires included a section **'Where to from here?'...**

- Comprised 3 questions relevant to today's workshop:
  - ***'In general, where do we go from here in relation to these technologies?'***
  - ***'How can BEIS be most effective, and what should they do next?'***
  - ***'If necessary, what other organisations or entities should become involved, and what should be their role(s)?'***

SMETER Project-evaluation

- Outcomes from: ***'Where do we go from here…?'*** categorised in terms of:

- **Policy, market, 'bigger picture' matters:**
  - HTC measurement should become routine part of asset management, new homes design, retrofit and QA of buildings
  - Allow SMETERS to provide the function of EPCs, recognise their value for giving forward-looking insights
  - Create SMETER market driven by policy, customer demand, or financing of products and services
  - Consider possible application areas, and compatibility with new technologies (heat-metering, electric vehicles, renewables)

SMETER Project-evaluation

- Outcomes from: ***'Where do we go from here…?'*** (continued):

- **Testing and related matters:**
  - More opportunities for testing – wider representation of stock, more complex properties/situations (e.g. effects of extensions, party wall heat flows), occupancy effects
  - Can SMETERS identify the effect of an energy efficiency retrofit?
  - Thorough understanding of uncertainties needed

- **Data and related matters:**
  - Facilitate lower cost and easier access to consumer smart meter data
  - Need more 'real' data (for technology development)

- **HTCs, EPCs and SAP:**
  - Compare measured HTCs with current EPCs and incorporate into SAP calculation

SMETER Project-evaluation

- Outcomes from: ***'How can BEIS be most effective…?'*** categorised in terms of:

- **Testing/monitoring, methods, remaining questions:**
  - Enable more monitoring of buildings in-use to widen evidence base
  - Establish performance required of SMETERS, reliability of tests, standardise methodology
  - Collaborate by publishing results to benefit all SMETER developers, and address remaining research questions

- **Policy, legislative, regulatory changes:**
  - Introduce an empirical basis to EPCs using measured HTCs, or require energy suppliers to advise customers on retrofit supported by SMETER data
  - Assist performance measurement of buildings to become the norm
  - Develop performance/testing standards, quality control and commissioning of new housing and assessment of existing stock

SMETER Project-evaluation

- Outcomes from: ***'How can BEIS be most effective…?'*** (continued):
  - Regulation to support policy-led development of markets
  - Examine incentives for acceptance and deployment of SMETERS
- **Data and related matters:**
  - Release all TEST data to further develop SMETER technology
  - Facilitate access to historic smart meter data, and to smart meter data for public interest purposes where consumer has consented
  - Facilitate collaboration across SMETER industry to create a large dataset as a resource
- **More immediate actions:**
  - More funding to build on advances made (utilisation of HTCs and SMETERS)
  - Discuss SMETER applications, align with wider BEIS programmes, de-carbonisation

SMETER Project-evaluation

- Outcomes from: ***'What other organisations should become involved…?'***

Activity	Organisations	Roles
Data supply	DCC, 3rd party data providers, energy suppliers, Ofgem, Public Interest Advisory Group	Access to smart meter data Requiring energy suppliers to act
Testing (field) and tool use	Social housing providers, housing developers, Test houses (eg BSRIA)	Testing at scale, customer/user input, access to tenants, users of the tools
Quality control	BRE or NPL	Relationship between SAP & SMETER; quality control, method-checking
Policy	DCLG/policy makers, Local Authorities, inspectors, planners	SMETER support for these, Building Regs, EPCs, verification

SMETER Project-evaluation

- Outcomes from: ***'What other organisations should become involved…?'*** (continued)

Activity	Organisations	Roles
Consumers / customers	Customer groups, marketing expertise, financiers	How to make data relevant, influence and trigger change in behaviour
Manufacturers/products	SMETER product developers (within & outside the project); makers of heat pumps, thermal-related building products;	To create the market Heat-metering and COP estimation
Further sources of funding (additional to BEIS)	IEA EBC Annex Innovate UK EPSRC MHCLG	Potential for further funding

SMETER Project-evaluation

In Summary

- A successful and effective project – delivered outputs to aid SMETER development and measurement-based evaluation of buildings performance…**'repeat!'**

- Generated a valuable resource of co-heating-based field data, that should be expanded to create a larger, more diverse, dataset for evaluating SMETER-type technologies

- Evaluate holistically to include:
  - Accuracy/fitness for purpose against specified criteria
  - Practicality
  - User acceptability
  - Cost-effectiveness

SMETER Project-evaluation

Selected quotes from project members:

'It is crucial to facilitate lower cost and easier access to consumer smart meter data (while of course maintaining privacy)' (Participant)

'…gather a greater understanding of our properties and a deeper insight into how they are performing rather than how they should perform' (TEST team member)

'HTC measurement is key to delivering on the expectations of energy efficiency improvements…it should be a routine part of asset management…' (Participant)

'It will be very hard to develop a market for these technologies…without Government intervention' (Participant)

Introduction to requirements for an effective UK system of in use performance metrics

Overview

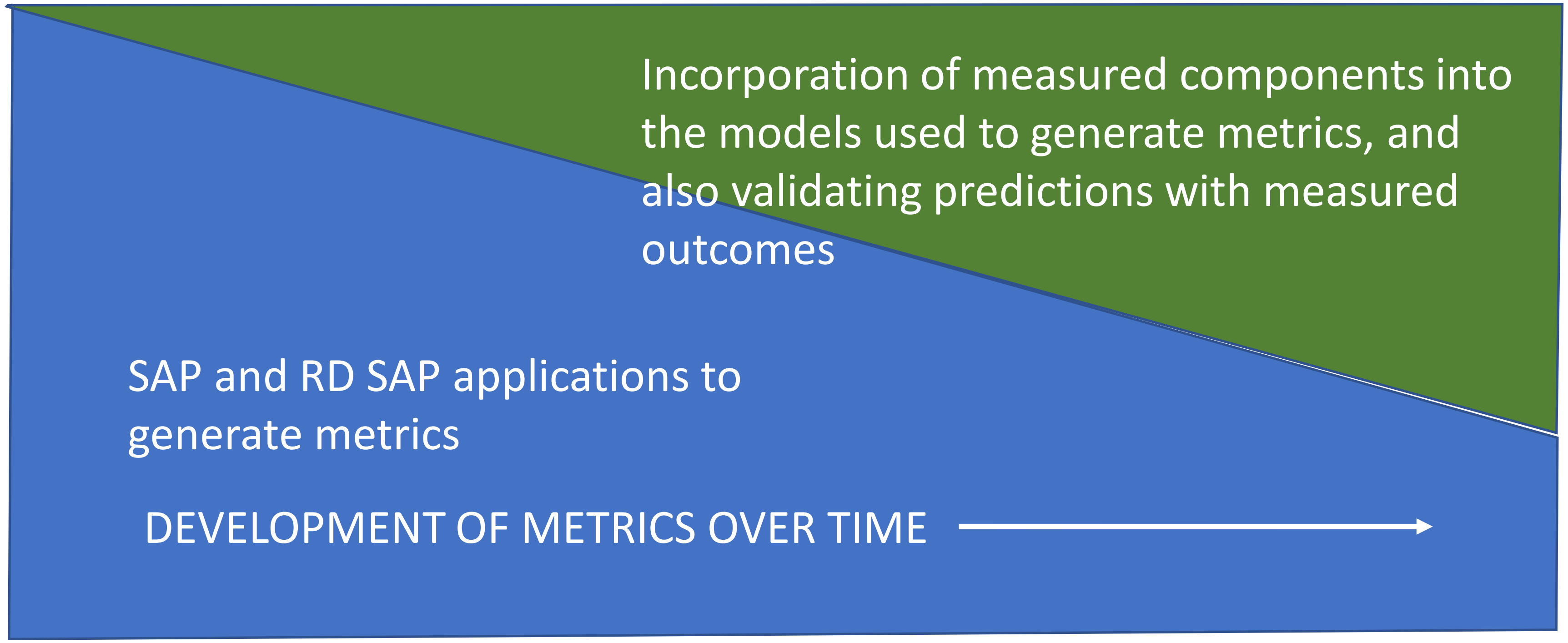
1. Accurate in use thermal performance metrics **create new possibilities for supporting the delivery of Net Zero**
2. Measured heat loss could be **incorporated into the existing models and metrics** which underpin our current policies
3. Designing as useful a system as possible will involve being clear about what functions we want to deliver, and therefore the **criteria we need to satisfy**

> **The importance of SAP/RdSAP is colossal**
>
> SAP/RdSAP is not just a calculation methodology: it is integral to the delivery of UK policies associated with the energy performance of new homes and the whole UK housing stock. It is used throughout the housing sector, from small works to large new developments. While regulations set the requirements, it is in large part SAP which defines the target and the assessment of the performance and effectiveness of the measures proposed.
>
> SAP is a central tool for those in charge of developing, implementing and tracking policies (e.g. BEIS, MHCLG, Ofgem, Climate Change Committee, Local Authorities), for the whole building industry (housebuilders, supply chain, manufacturers, energy assessors, engineers, architects etc), and for residents.
>
> Its importance cannot be overstated.

(Extract from SAP 11 scoping study report, 2021)

Incorporating in use measurements into models

Key metrics that are currently derived from SAP and RD SAP could be made more accurate over time, by the incorporation of real data. For example, EPC ratings could be enhanced by incorporating in-use measurements of the Heat Transfer Coefficient (HTC), as could additional EPC metrics being considered as part of SAP 11 scoping.



Department for Business, Energy & Industrial Strategy

Improving the impacts of metrics

Metrics are measures of quantitative assessment commonly used for comparing, and tracking performance or production (as distinct from data, which are inputs to such assessment).

Metrics for net zero housing (and other aspects of net zero) can serve a number of functions[1]:

- **Diagnosis**: keeping track of methods and procedures and comparing outcomes, to identify and replicate successful approaches
- **Public information**: providing transparency to consumers, and a basis for comparison and competition among providers
- **Pay for performance**: accountability is backed up by monetary rewards or penalties

"Effective" metrics ought to facilitate all of the above.

[1]*Based on framing in "The Tyranny of Metrics" by Jerry Z Muller*

Questions for this session

1. What are the **most important criteria** for “effective” metrics?
   - E.g.: accuracy & robustness, cost effectiveness, usefulness and relevance to the householder, ditto to markets / supply chains, ease of visibility & disclosure, proof against bias/gaming, value to policy and strategy, balance between current & future applications?
2. Who are the **key stakeholders** in developing a UK system of in use performance metrics?
3. What **wider developments** would developing such a system need to take into account?