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Built2Spec

Built to Specifications – Tools for the 21st Century Construction Site

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D1.2 Performance gap and its assessment methodology in Built2Spec project

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Executive summary

The **Deliverable D1.2** titled "**Energy Performance Gap and its assessment in Built2Spec project**" is a public document delivered in the context of WP1, Task 1.4: Methodology to assess change to the design/commissioning performance gap.

This work is part of the project on Tools for the 21st Century Construction Worksite (BUIL2SPEC) and is financed by the European Union under the Horizon 2020 Programme.

This Deliverable D1.2 aims to better understand the causes of the performance gap, to try to quantify how big it is, to know as some constructive aspects influences in energy efficiency, to determine an assessment method of the gap from design to commissioning, and to provide guidelines to minimize the energy gap.

This document is structured as follows: After a short general introduction (chapter 1), are presented more relevant sources and literature studied (chapter 2), from all these sources are extracted most common causes of performance gap (chapter 3), how big is the gap is explained using also these sources (chapter 4); How some characteristics thermal characteristics impacts in energy performance is explained in chapter5; and how to assess the change to the design/commissioning performance gap in chapter 6. Finally a recommendation to get close the gap is described in chapter 7.

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Abbreviations

B2S = Built to Specifications

DOA = Description of Action;

CS = Communication Strategy;

WP = Work Package.

VCMP= Virtual Construction Management Platform

BER: building emission rate for buildings other than dwellings.

DER: dwelling emission rate. For self-contained dwellings and individual flats (excluding common areas). This is the annual CO2 emissions of the proposed dwelling expressed in kg/m2.

EPC: energy performance certificate (A to G rating)

DEC: display energy certificate (A to G rating representing the use of the building, calculated after measuring 12 month use and taking into account all energy uses).

SAP: Standard Assessment Procedure

RIBA: Royal Institute of British Architects

BMS: Building Management System

1 Introduction

Task 1.4 is titled "Methodology to assess change to the design/commissioning performance gap". The main objective of this task is to develop a methodology to assess the energy performance gap due to the construction process itself. The key to achieve this objective is to have a deep knowledge about what is performance gap, why it happens and how it can be solved.

The performance gap is a relatively new concept that can be defined as the difference between the energy consumption anticipated in the design phase and the current consumption during in-use stage[1]. There are several causes yielding the gap which occur on the whole construction process. This document aims to better understand the causes of the performance gap, to try to quantify how big it is, to known as some constructive aspects influences in energy efficiency and to provide guides to minimize the energy gap.

In chapter 2 "Understanding the performance gap" the main sources are presented studied to understand the Energy Performance Gap from several points of view. These sources give a complete overview of this phenomenon.

As mentioned above, the energy performance gap causes are many and varied. These causes range from an inaccurate energy simulation during the design phase, through poor quality control during the construction. At chapter 3 the main causes for each construction stage are presented.

The performance gap could also be defined as a sum of mistakes during the construction process that widening the gap between energy planned and actual energy consumed. Figure 1 shows how increases the energy consumed in each stage (for non-residential buildings):

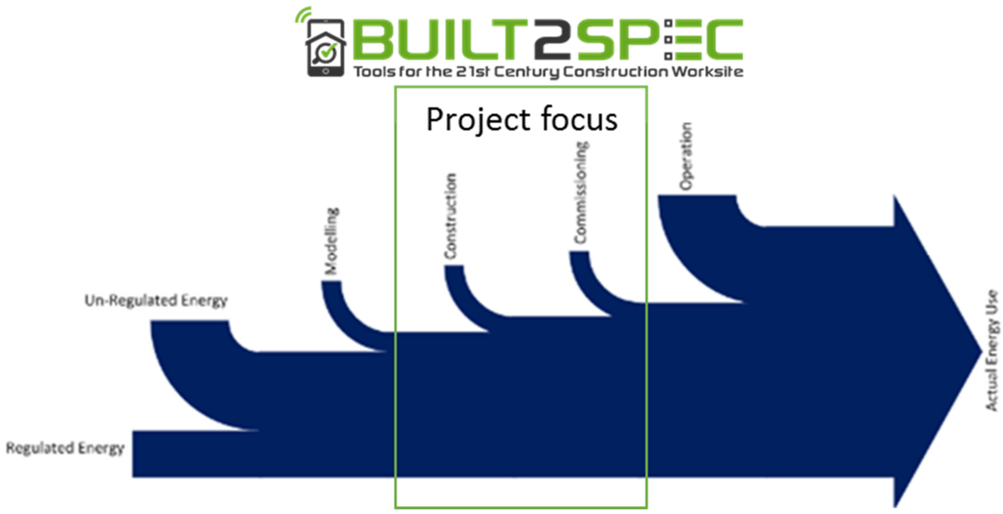


Figure 1 The Performance Gap Growth from Design to Operation (The Green Construction Board, 2013).

The performance gap can be more or less big depending on multiple factors. The point 4 "How big is the gap?" shows several studies that have measured this gap. Very interesting initiative is the "carbon Buzz", an online platform of RIBA, where building owners voluntarily upload energy consumption of their

1 "the difference between the initial calculations carried out in the design of a building compared to the actual energy recorded on utility meters can be several times greater; this is referred to as the 'Performance Gap'" (The Green Construction Board, 2013, p. 3)

buildings (real and planned). This tool allows benchmarking of current consumption sector-by-sector. In some sectors, such as Health, gap is more than double.

Another interesting information to take into account is the performance of Passivhaus buildings in Germany and Switzerland (see studies carried out by PHI in point 4.2). These studies show another side of the performance gap: buildings constructed following the Passivhaus standard (or similar) used to have negligible difference between the planned energy to the real energy consumption, or even they consume less energy. This fact is corroborated by other studies in the UK[2 3]. Therefore, it is possible to reduce the performance gap, designing and building in the right way.

On the other hand, it's wanted to quantify the impact of some of the most important thermal properties of the envelope in energy performance (wall U-value , air-tightness and thermal bridges). This information is obtained from different sources. First, a interesting study conducted by the Zero Carbon Hub on the impact of these thermal properties on DER (dwelling emission rate). Second, some simulations done by PHI specifically for this project measuring the impact in heating demand of changing the air-tightness factor for different geographical situations. These studies aims to relate variations in thermal properties during construction process with the energy performance of the building. For example, the figure 2 shows how air permeability of the buildings affects in the energy performance (Figure 2a on DER and figure 2b in heating demand).

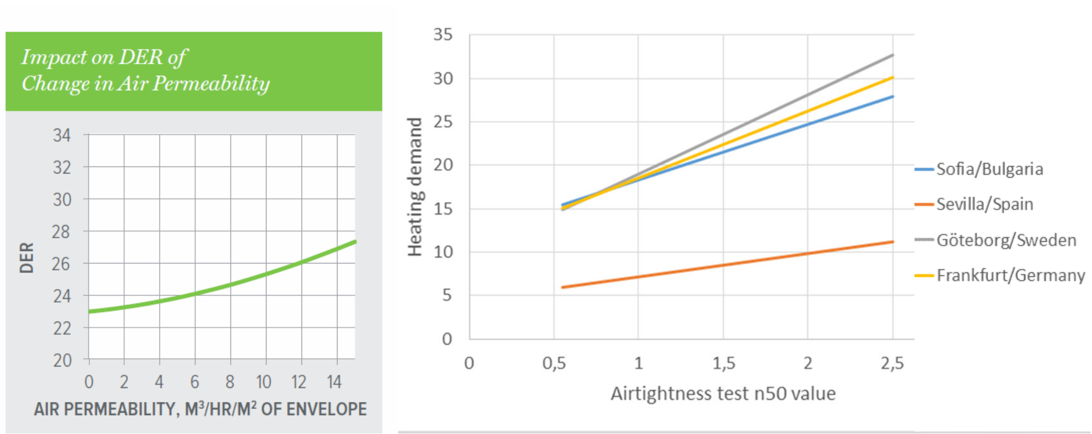


Figure 2 (a)Impact on DER of Change in Air Permeability compared to (b) Impact on Heating Demand of change airtightness test n50 value.

A detailed study of all the main parameters that impact the energy performance gap during construction (from design to commissioning stage) will be evaluated in WP7 in a similar way than the above example on air tightness and cross-compared to understand which are the most relevant and how they relate to each other also depending on the different countries and pilot buildings. In Chapter 6 is described the methodology and also explained how the Built2Spec tool PULSE can do the quality check of the air tightness.

2 A new build regulatory mandate at or near to the passivhaus standard is essential for the successful delivery of new low-energy buildings across the EU. Only with a new build standard of this nature can supply chains be developed and high quality practices become standard. (Tofield, 2012, p. v)

3 This paper presents the results of a number of in-depth building fabric thermal performance tests undertaken on three case study dwellings located on two separate Passivhaus developments in the UK".." The results from the tests revealed that all the case study dwellings performed very close to that predicted.. (Johnson, Farmer, Brooke-Peal, & Miles-Shenton, 2014, p. abstract)

Finally, this document also wants to give some guidelines for "closing the gap". The diversity of sources studied are drawn some general recommendations explained in chapter 7.

Closing the gap". These recommendations encompass the whole construction process focusing on the most critical points of each part. For example, doing more accurate simulations including unregulated energy, reducing design complexity, performing a good strategy for monitoring and control facilities (BEMS), doing a good commissioning, etc. In this point is also exhibited the concept of "Soft Landings" used in the UK which allows a better commissioning involving the design during the initial in-use stage.

2 Understanding the performance gap

The performance gap is a complex phenomenon which is influenced by different factors. This chapter explores different sources to better understand this phenomenon. First section reviews the existing literature inputs. This search was carried out by the different partners within their linguistic circle. Second sections presents the conclusions provided by B2S partners in a questionnaire.

2.1Inputs from literature:

2.1.1 Relevant information from UK

To understand what the performance gap is, several documents and initiatives were studied. Most representative and interesting sources used are as follow:

1) Document written by BSRIA: a very interesting document with a complete information about performance gap and soft landings. Is a document done specifically for this task (the entire document can be found in Annex C - UK input for T1.4).
2) Carbon Buzz is an RIBA CIBSE platform for benchmarking and tracking energy use in projects from design to operation. It is intended to encourage users to go beyond compliance of mandatory Building Regulations calculations and refine estimates to account for additional energy loads in-use. The platform allows users to compare design energy use with actual energy use side by side to help users close the design and operational energy performance gap in buildings.
3) Closing the gap. This document is made from Carbon Trust an organization that defines their mission as "Our mission is to accelerate the move to a sustainable, low carbon economy. To have real impact we act as a catalyst, making the case for change to businesses, governments and civil society worldwide" (Carbon Trust, 2011). The document Closing the Gap is oriented to investors and final users of buildings. This document explains where and why performance gap occurs today and some guidelines to minimize it. The insights presented are based on real data from 28 case studies from Department of Energy and Climate Change's Low Carbon Buildings Programme and their work on refurbishments.
4) The Performance Gap: Causes and Solutions. This document is made from Green construction board. The Green Construction Board was established in October 2011 as a consultative forum for government and the UK design, construction, property and infrastructure industry. The Board is the sustainability work stream of the Construction Leadership Council. This document gives some interesting data about how important is the gap in each stage of construction process (for non-domestic buildings). It shows that in-use stage has the highest impact in energy performance because un-regulated energy is not taken into account during design process. The document also presents some guidelines to "closing the gap".
5) Zero Carbon Hub. Is about house-building process and measure the gap between conception through to completion site, beyond handover.
6) Delivering a low-energy building. Making quality commonplace is a document made by Adap Low Carbon Group within Build With Care European founded project.

2.1.2 Relevant information and literature from France

In France, we don't find a lot of reference studies about performance gap through the all construction process. Nevertheless, the subject is treated through different topics and a lot of research studies and projects have been conducted about:

- Commissioning,

- Improvement of simulation tools,
- Air tightness measurement,
- Impact of users on predicted energy consumption,
- Monitoring of buildings,
- Etc[4].

The energy performance contracts are another solution to limit the gap between design studies and real consumption. Numerous guides have been edited about this kind of contracts and how to control and maintain energy performance from briefing to in-use stage[5].

Some studies are more detailed and very interesting.

1) *Energy consumption practices in efficient buildings: Theoretical consumption and actual consumption. The case of* Patio Lumière*: a modern building located in an eco-district*(Etude réalisée par Gaëtan Brisepierre, 2012, financement ADEME et Leroy Merlin Source) The Patio Lumière building has a consumption of 70% compared to the target of 70 kWh /m² /yr. But consumption of 120 is the best among 8 instrumented buildings, the worst value is 177 for identical objectives whether overconsumption of 150%. The main lesson is that users are far from being the main cause of over-consumption of low-energy buildings. These differences are first explained by the inevitable imprecision of consumption forecasting models that take into account multiple parameters difficult to control such as weather or internal heat inputs data (electricity consumption, presence of occupants ...). The second factor of overconsumption is related to the professional practices of the actors of the building, and not from users' practices. In terms of design, oversizing for example; at the execution, poor workmanship during installation; at the operation, the defects of maintenance and adjustment.
2) Nursery of Montrevel en Bresse, energy and environmental performance evaluation demonstrator buildings with high energy performance in Rhône Alpes region - results of the first year of measurements (ADEME / Enertech, February 2012). In the following diagram, the regulatory calculation (RT 2005) and the real consumption are close but if we look in details,
    - Measured heating consumption is greater than 21% to the value of calculation,
    - The hot water (ECS) was not taken in account in the regulatory calculation,
    - Lighting and auxiliary have been largely oversized in the regulatory calculation.

[4] Some examples : L'instrumentaion des bâtiments pour un suivi des consommations énegétiques , technical guide ADEME - January 2015. Memento_commissionnement,_Costic_2008. STD+ research project, Nobatek 2015. Etanchéité à l'air des bâtiments, guide à l'usage des professionnels, ADEME- Novembre 2011.

[5] Some exemples : Guide énergie-carbone pour le patrimoine immobilier universitaire, MENESR – February 2013. Memento contrat de performance énergétique, COSTIC – 2012. Guide du contrat de performance énergétique, MEEDDM – July 2010.

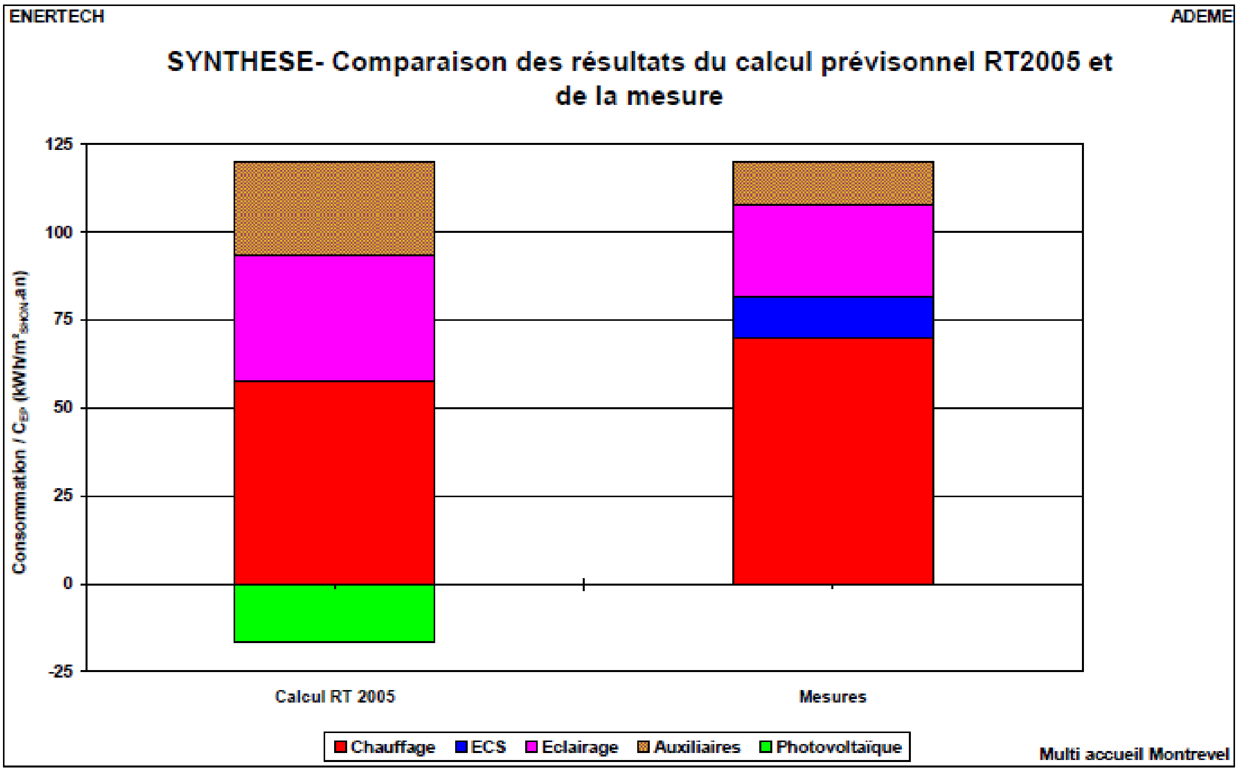


Fig. Regulatory calculation (RT 2005) and measured consumption for Montrevels's building

More recently, some European and French research projects (e.g. H2020 project Hit2gap, or French INEF4 project SIBEX have the performance gap for main subject to explore. As they are just about to start, the results are not available yet.

2.1.3 Relevant information and literature from Netherlands and Belgium

In The Netherlands many studies have been performed on the energy performance gap. And rightly so, since in many studies, such as in Macjen et al (2013) it has been demonstrated that the actual energy performance can be quite far from the theoretical energy performance for energy simulations.[6] For buildings with a low (theoretical) energy performance the actual performance is not as bad as might be expected. For buildings with a high energy performance the opposite is true. For utility buildings similar results have been obtained by Hoes-Van Oeffelen et al (2013)[7]. In section 4.3 The gap in Netherlands and Belgium are shown more details.

2.1.4 Relevant information and literature from Italy

Quality checks from the construction side are one the most important activities to carry out in order to reduce the performance gap of buildings between designed and as built; on the other side, designers have the ability to contribute to the reduction of this gap by capitalising on the powerful tools they are provided which, namely the calculation methods and the codes, laws, standards.

[6] Majcen D., Itard L. and Visscher H., Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: discrepancies and policy implications, Energy Policy 54, March 2013, 125–136.

[7] Hoes-van Oeffelen, E.C.M., Spiekman, M.E., Bulavskaya, T., TNO 2013 R10916. Energielabels en het gemeten energiegebruik van utiliteitsgebouwen, 2013

In the last years standards evolved to take into account the new developments and improve design methods. Thanks also to the development of new and more sophisticated numerical calculation procedures the ability to reduce the performance gap has improved.

In Italy in October 2015 was adopted a "review" of the UNI TS 11300:2008 code (here in after "OLD"), i.e. UNI/TS 11300:2014 (here in after "NEW") code, in which some aspects have been updated. The main reviews regard:

- **thermal bridges evaluation**;
- natural and mechanical ventilation evaluation;
- building and technical system energetic balance;
- latent and humidification energy request;
- cooling and heating season duration.

These updates introduced new, more accurate and closer to reality approaches that allow to reduce the building energy performance gap. In particular in this review great importance was given to the assessment of thermal bridges; in fact the increase of the total **heat loss** due to the presence of thermal bridges can undergo account for **10-20% up to 40%**[8]. A detailed focus on thermal bridges is provided in the next section.

As an example, with the "OLD" standard to evaluate the Energy Performance Certificate (EPC) in existing buildings, a simplified methodology allowed designer to evaluate thermal bridges *as a percentage of the whole thermal transmittance*, therefore possibly introducing several errors in the evaluation of the energetic behavior of the structure under study. The "NEW" review of the code, introduces more accurate approaches (as described above) allow to evaluate performances closer to the real behaviour (see figure 13).

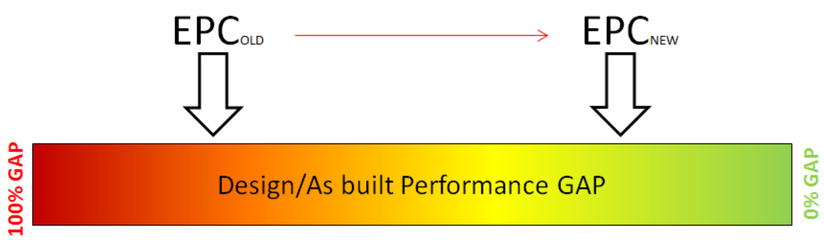


Figure 1 Schematic representation - reducing performance gap due to the evolvement of codes, standards, etc. Italian example.

In Annex B is presented a complete information focus on thermal bridges.

2.1.5 Relevant information and literature from Germany and Switzerland

The Passive House Institute has carried out several monitoring studies. The results of two of these studies will be mentioned in section 4.2 The gap in Germany and Switzerland best practices. In this section is also shown a detailed analysis carried out for 7 buildings in a Swiss study on the 'Performance Gap' in

[8] http://www.cened.it/06_10_11 – Esempio best practice edilizia.pdf (in Italian).

Switzerland[9]. This study investigated for each of the 7 buildings the reasons why more energy than planned is used.

Summarizing; the most important findings are: different building uses (other than planned) and different user behavior lead to a difference between the planned and actual performance. Use of appropriate simulation software during design phase and maintaining a high quality of workmanship are essential to prevent performance gaps. Additional factors are HVAC units which do not work according to the user profile (e.g. heating during the time of non-utilisation) or which are not correctly controlled and balanced, therefore continuous monitoring of the energy use and its assessment can detect and avoid errors.

2.1.6 Relevant information and literature from Spain

No relevant literature is found in Spain related to energy performance gap. It seems that this phenomenon is not yet taken into account for Spanish Energy Experts.

2.2 Inputs from questionnaire answered by B2S partners

Some partners have answered a detailed questionnaire regarding the performance gap (see Annex A Questionnaire part V **Performance gap).** In this questionnaire most common causes of performance gap were listed. In most points, the partners agree that these causes also happen in their countries therefore it can be extracted that all countries needs to improve their construction process to avoid the gap.

[9] (Struck, et al., 2014)

3 Causes of performance gap throughout whole construction process

As said above, several documents has been reviewed to understand better what the performance gap is and which are their causes. The most common causes of performance gap are explained here divided in the stages of construction progress:

Briefing stage

Poor briefing and bad definition about energy performance is a common cause in this stage e.g. clients fail to inform the design team about what they want or how they want to use their building, number of users, etc. No control of concordance between operation budget and energy performance desired.

Design stage

Basic design (firsts drafts)

- Lack of concept design team understanding of the impacts of their decisions on energy performance or their potential to contribute to the Performance Gap.
- Limited understanding by funders of the impact of aesthetics requirements on energy performances targets.
- Limited understanding by concept design team of impact of early decisions of energy performance targets.
- Absences of SAP specialists in this stage, indicating a possible lack of consideration for the energy performance of the sites (detected in UK).
- Complex design with difficult buildability makes Energy Performance Gap arising.
- Government doesn’t lead the way to try to improve as-built energy performance.

Detailed design

- Inadequate understanding and poor knowledge within design team (buildability, thermal detailing [junctions], Psi-values, tolerances, construction systems and materials, site conditions, SAP and energy issues, performance).
- Incorrect specification of building materials in design (poor specification); incorrect data used in design.
- Lack of communication regarding critical energy performance criteria of components from design team to procurement team.
- Construction details inadequately specified in design, or not well enough communicated to site.
- Lack integrated design, e.g.: services designed by the supplier.
- Design weaknesses not recognized by compliance model.
- The unregulated energy is not included e.g. servers, lifts, etc. In case of UK is used to include in simulation energy only based in part L building regulation.

- Inaccurate assumptions which will create unrealistic baselines for expected performance. Concerns about accuracy of aspects energy calculation model and assumptions, e.g. thermal mass, hot water, ventilation, cooling, lighting, thermal bridging.
- Issues surrounding use of calculation procedures related to U-values and Psi-values. E.g.: use U-Values and Psi values from suppliers instead of calculate them.
- Limited ability to include new technologies in standard calculation methodologies.

Construction stage (tendering and contracting, implementation and its supervision)

- Procurement and construction team lack of understanding of critical energy-performance related criteria.
- Construction details inadequately specified in design, or not well enough communicated to site. Full design information or installation guidance produced but not available on site. Lack of designer input available to site if issues arise.
- Construction teams not sufficiently involved at the design stage.
- Tender documentation not containing up-to-date requirements or trade specifications.
- Building materials not conforming to specification or not performing *in situ* as expected. Inappropriate substitution of one material (or supplier) without due regard for performance criteria.
- Construction responsibilities for energy performance unclear, lack of collaborative working
- On-site construction not conforming to design.
- Poor installation or commissioning of services, short term fixes and improvisations on site without understanding of long-term impact.
- Lack of adequate quality assurance on site and responsibility for QA,
- Existing quality checks were limited and did not focus strongly enough on energy-related performance.
- Lack of robust verification of planning requirements and standards at completion. Lack of robust energy-performance related verification.

Handover and close-up stages (commissioning)

- Poor communication to the client how best to operate their new building.
- Handover should be on guides, manuals, walkthroughs, support, etc. But sometimes is rushed and incomplete.
- Bad Metering strategy, poor training of building users

In-use stage

- No widespread culture of reviewing what has been constructed and then using that knowledge to inform future projects.

4 How big is the gap?

The energy performance gap can vary widely from the most good practice (which is almost negligible) to worst experiences. According to Carbon Trust: Gap can very within 16% in best practices to five time in worst one (Carbon Trust, 2011). In this point are described the results of some studies to try to understand better the energy performance gap.

The energy performance gap has been mostly studied in the UK (the majority of literature comes from there) with a boost from government[10] to achieve closing the gap in 2020. In point 4.1 are presented some data from this studies.

Another interesting information to take into account is the performance of energy efficient buildings in Germany and Switzerland (see 4.2). These studies shows another side of the performance gap: the buildings constructed following the Passivhaus standard use to have no difference between the planned energy with the real energy consumption or even consume less energy. This fact is corroborated by other studies in the UK[11] [12]. Therefore, it is possible to reduce the performance gap, designing and building in the right way.

The literature from Netherlands and Belgium also shows another interesting fact: when worst is the EPC rate of the building planned, bigger is the gap (see point 4.3). But at the same time, buildings with worst EPC rating consumes less than expected (it could be said "negative gap") and buildings with best EPC rating consumes more than expected ("positive gap").

All of this studies show that constructing without gap is possible, but not easy, and needs to be addressed since the project's beginning. If there isn't a real will to achieve planned energy performance, the gap can be very big.

4.1 The gap in non-domestics buildings (UK information)

In UK, different stakeholders have conducted several studies to better understand the importance of the gap and try to quantify it.

Very interesting is the initiative of the Carbon Buzz, an online platform of RIBA, where building owners voluntarily upload energy consumption of their buildings (real and planned). This tool allows benchmarking of actual consumption sector-by-sector. The table below shows the actual consumption in

10 "...the Government has had concerns about the potential gap between design and as-built energy performance, following research into this issue by several universities and specialist project.." (Zero Carbon Hub, 2014, p. 3)

11 A new build regulatory mandate at or near to the passivhaus standard is essential for the successful delivery of new low-energy buildings across the EU. Only with a new build standard of this nature can supply chains be developed and high quality practices become standard. (Tofield, 2012, p. v)

12 This paper presents the results of a number of in-depth building fabric thermal performance tests undertaken on three case study dwellings located on two separate Passivhaus developments in the UK: one masonry cavity and the other two timber-frame. The results from the tests revealed that all the case study dwellings performed very close to that predicted. This is in contrast with other work that has been undertaken regarding the performance of the building fabric, which indicates that a very wide range of performance exists in new-build dwellings in the UK, and that the difference between the measured and predicted fabric performance can be greater than 100%. (Johnson, Farmer, Brooke-Peal, & Miles-Shenton, 2014, p. abstract)

relation to the provisions for different sectors. It can be seen as in some sectors (Health, Education, offices and hospitality) is where there are most gap.

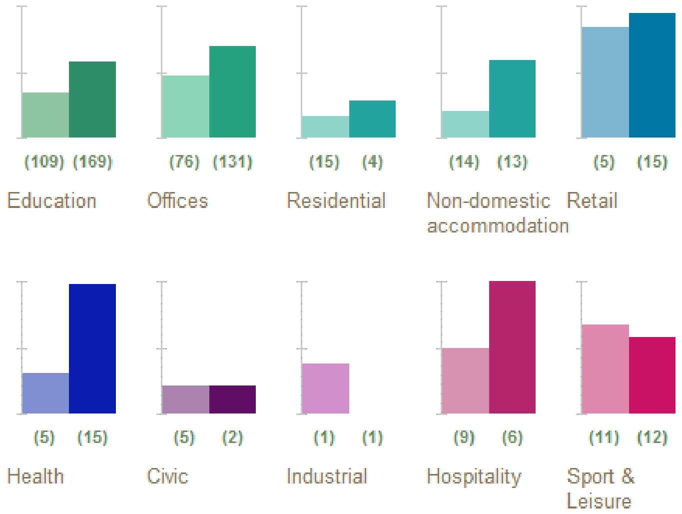


Figure 4 Energy consumption sector-by-sector, (Carbon Buzz, s.f.)

Going into more detail in how offices and schools perform, we see that the average of the exchange factor is 1.59 and 1:48 respectively:

Category	Mean Design Total Heat Consumption (kWh/m²/yr)	Mean Actual Total Heat Consumption (kWh/m²/yr)	Factor Change Design to Actual - 'Performance Gap'	Mean Design Total Electricity Use (kWh/m²/yr)	Mean Actual Total Electricity Use (kWh/m²/yr)	Factor Change Design to Actual - 'Performance Gap'
Office	46	73	1.59	71	121	1.71
Education	57	84	1.48	56	106	1.90

Figure 5 Energy consumption office and education (Carbon Buzz, s.f.)

The following image made by the Green Construction Board for non-domestic buildings shows how this gap grows during the different stages of construction. It can be seen how the use stage can have the greatest impact (30 to 120%) if the systems are too complex or BMS are not used properly.

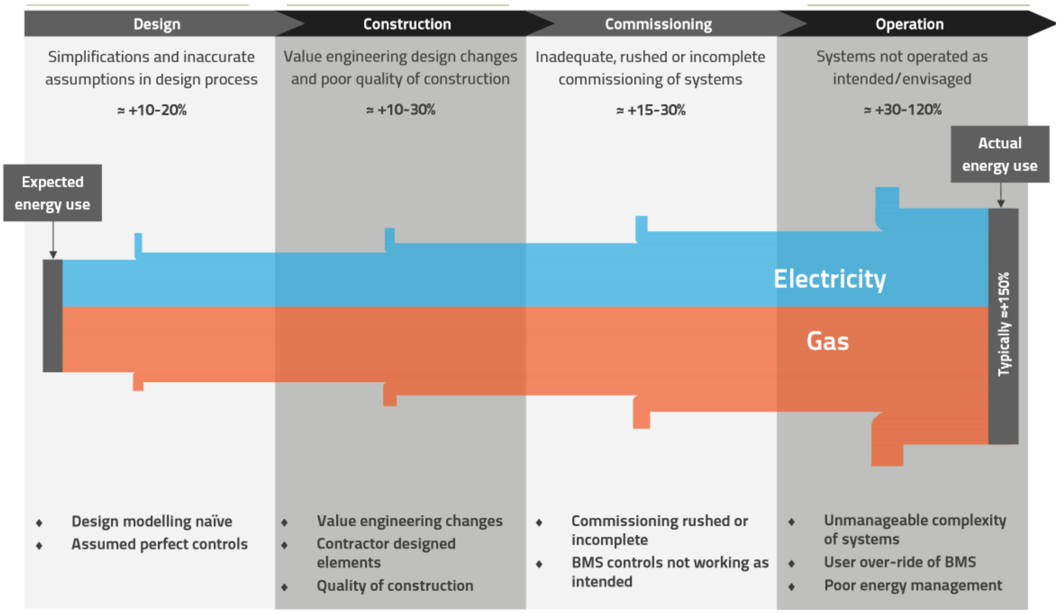


Figure 6. The gap throughout the whole construction process, (The Green Construction Board)

Green Construction Board has also made some case studies to better understand what will happen at each stage. For example, during the Design stage energy can be predicted much lower than reality because now only it's taken into account the energy regulated by compliance regulations (Part L in the UK). In the chart below you can see how the unregulated energy can mean a 69% of total consumption.

Table 1 Summary of electricity consumption for case study 1

Electricity Af = 9144m²	Loads	Annual Energy kWh/m²	% of Total
	Lighting	26.4	
	Fans, Pumps and Cooling	52.8	
Regulated Electricity		79.2	31%
	Small Power	45.6	
	IT and Comms	23.2	
	Lifts + Miscellaneous	3.5	
	Servers & Server AC	102.9	
Unregulated Electricity		175.2	69%
Total Electricity		254.4	100%

Figure 5 Summary of electricity consumption for case study 1

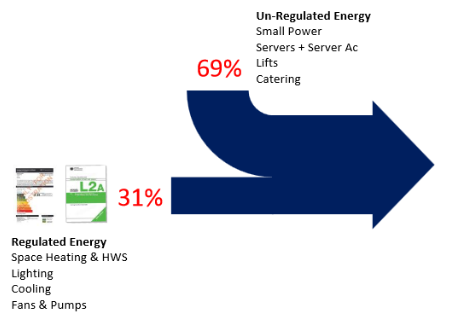


Figure 7. Case study: performance gap between regulated vs unregulated energy, (The Green Construction Board)

The impact of the unregulated energy in the performance gap is also studied by Carbon Trust:

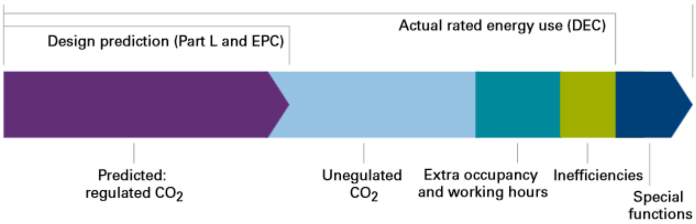


Figure 8. Design predictions for regulatory compliance don't account for all energy used in a building (adapted from Carbon Buzz) (Carbon Trust, 2011, p. 3)

4.2 The gap in Germany and Switzerland best practices

The Passive House Institute has carried out several monitoring studies. The results of two of these studies will be mentioned here:

The monitoring of the Kronsberg Passive Houses[13] showed an average measured heating consumption of 13.3 kwh/(m²a) in the second heating period (14.9 kWh/m²y in the first period), in relation to the 11.8 kWh/(m² year) projected in the PHPP.

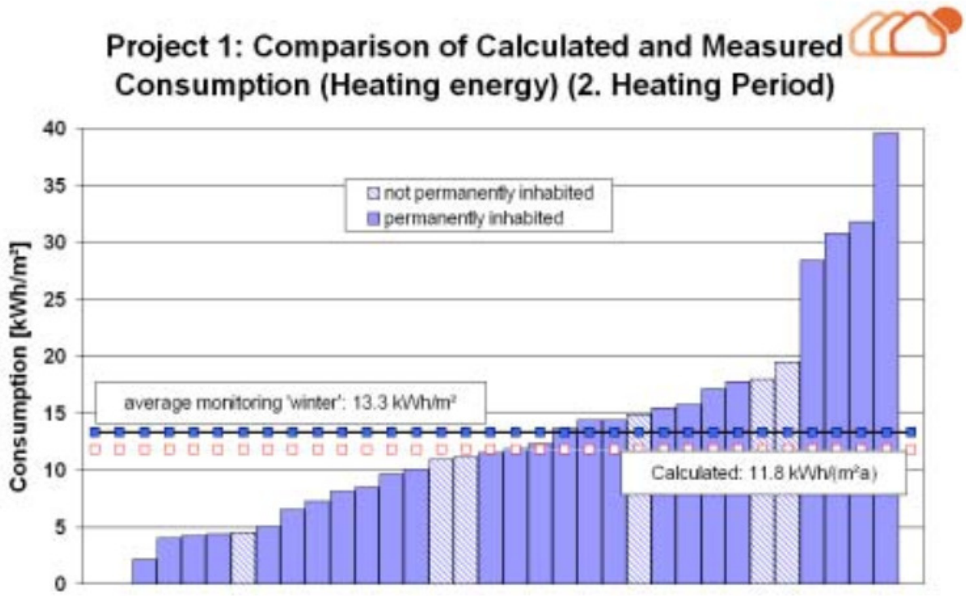


Figure 9. Comparison of the measured heating consumption and the projected heating requirement values (calculated) in the second heating period (1.10.2000 to 30.4.2001).

The diagram also shows a large variance between the single buildings. The reason for the variance could be the different user behaviour, but this was not investigated in this study.

The second study is the interim report of the simplified monitoring (heating demand only) of the Bahnstadt Heidelberg settlement with 1260 appartments and a floor area of around 75000 m². This shows an average heating energy consumption of 14.9 kWh/(m²a)[14],[15]. The use of the PHPP as a design tool was compulsory for those buildings.

[13] http://passivehouse.com/05_service/03_literature/030101_new-builds_residential.htm

[14] (Peper, Soren; Passivhaus Institut, Darmstadt, 2014) (currently only in German language)

[15] (Peper, Soren; Theumer, Susanne; Passive House Institute and Pietrobon, Marco; Pagliano, Lorenzo; eERG Politecnico di Milano, 2015)

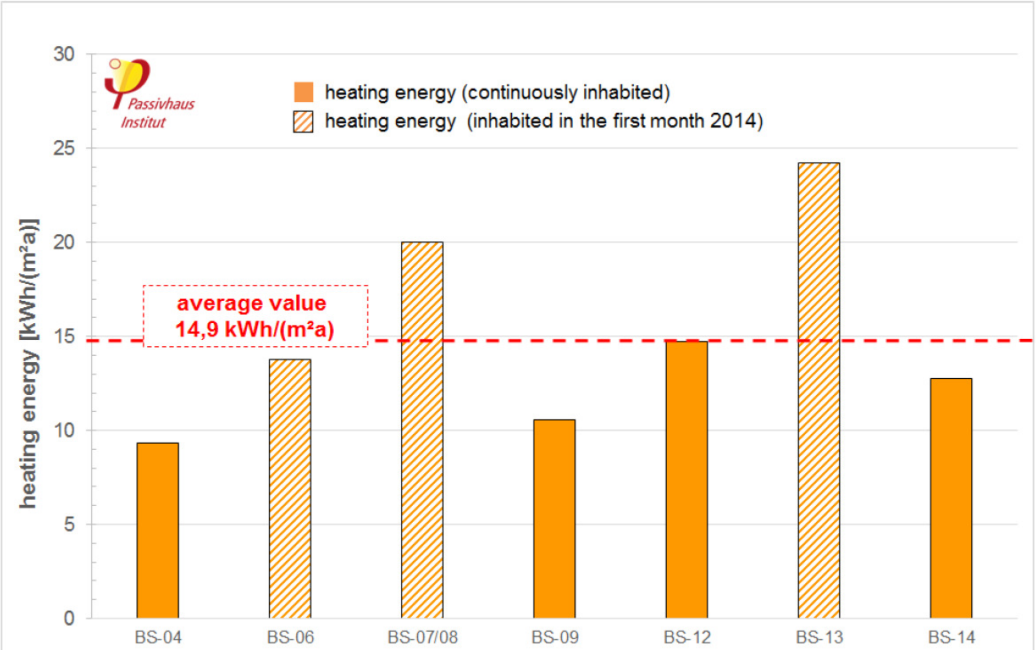


Figure 10. Annual heating consumption values for residential utilization (incl. hostels) according to development blocks.

A general investigation of the performance gap has been carried out by the German Energy Agency 'dena'.

In 2013, Christian Stolte et al. of 'dena' evaluated 63 of the 'dena' pilot buildings[16]. On average the targeted building performance was met, the deviation was mostly in the range of +/- 10%.

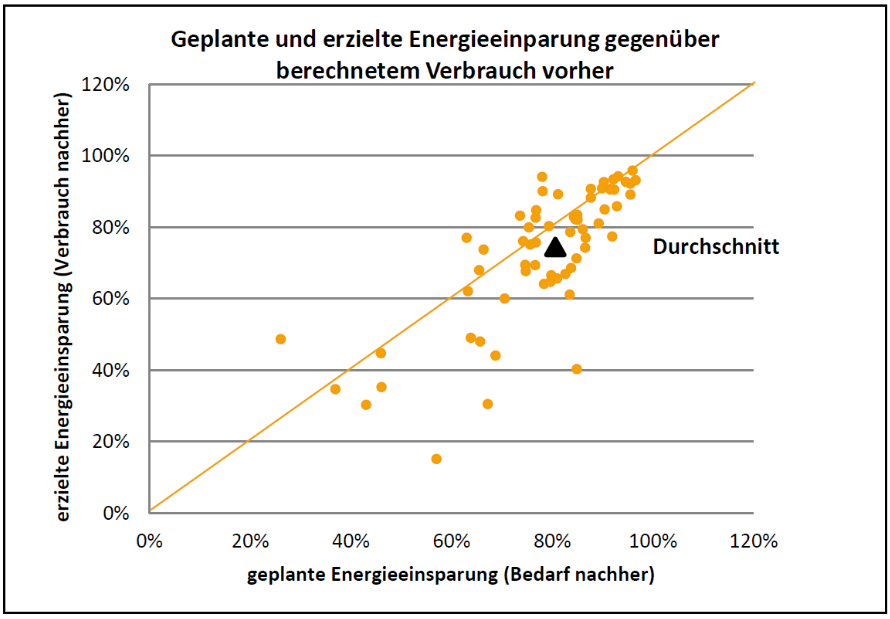


Fig. 11: Planned and achieved saving in the evaluated dena Projects as percentage

(Stolte, Marcinek, Bigalke, & Zeng, 2013)

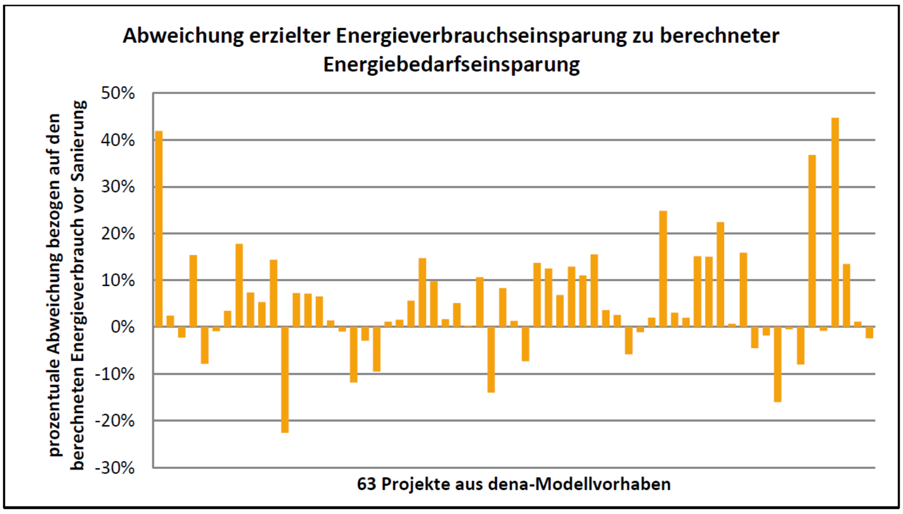


Fig. 12: Deviations in the achieved energy consumption savings and the calculated energy demand savings

Although the target was met on average, the authors concluded that in order to identify the reasons for the variance it is necessary to investigate the specific individual buildings, their properties, usage profile and their performance. This study is not available yet.

A detailed analysis carried out for 7 buildings in a Swiss study on the 'Performance Gap' in Switzerland[17]. This study investigated for each of the 7 buildings the reasons why more energy than planned is used. To cite the abstract of the study done by Christian Struck, of the Hochschule Luzern, et al.[18]:

> The performance gap traditionally describes the difference between key performance indicators during design and operation of a building. The observed differences can be significantly. The observed phenomenon becomes particularly important when designing and operating net-zero or energy positive buildings. This conference discusses the performance-page using seven case studies from Switzerland. The presented data shows that the causes for performance-gap lie predominantly in the building and system use, system controls and degree of simulation model abstraction. The authors conclude that it needs three things to maintain the design to enery balance during building operation: (1) consideration of the variability of the building use, building specification, quality of craftsmanship already during design; (2) an extendable model of the building and its systems and (3) continuous performance monitoring.

Summarizing; the most important findings are:

- Different building uses (other than planned) and different user behavior lead to a difference between the planned and actual performance
- Use of appropriate simulation software during design phase and
- Maintaining a high quality of workmanship are essential to prevent performance gaps.
- Additional factors are HVAC units which do not work according to the user profile (e.g. heating during the time of non-utilization) or which are not correctly controlled and balanced, therefore continuous monitoring of the energy use and its assessment can detect and avoid errors.

[17] (Struck, et al., 2014)

[18] Ref. previous footnote

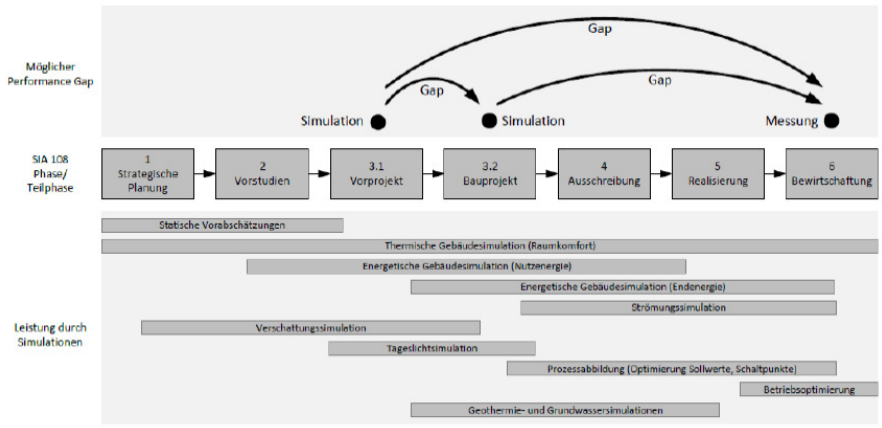


Fig. 13: Deviations in the achieved energy consumption savings and the calculated energy demand savings

The authors of the two studies mention in addition that describing the performance gap in % could mislead the reader, particularly if the energy consumption is very low. According to the study one extreme example is the Monte Rosa building: it was designed for 1 kWh/m2a and now uses 3 kwh/m2a. Everybody will agree that a building with 3 kWh/m² is an excellent building. However, the performance gap is 300%!!![19]

4.3 The gap in Netherlands and Belgium

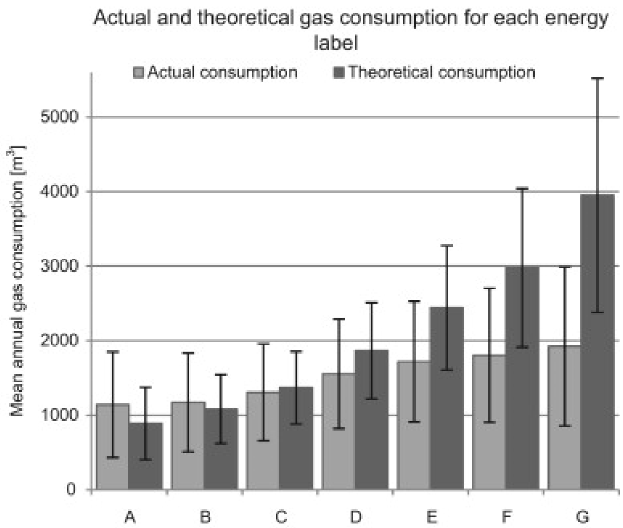


Figure 14 : Actual and theoretical gas consumption for each energy label (Macjen et al (2013))

In The Netherlands many studies have been performed on the energy performance gap. And rightly so, since in many studies, such as in Macjen et al (2013) it has been demonstrated that the actual energy performance can be quite far from the theoretical energy performance for energy simulations.[20] For buildings with a low (theoretical) energy performance the actual performance is

[19] (Struck, et al.,2014)

[20] Majcen D., Itard L. and Visscher H., Theoretical vs. actual energy consumption of labelled dwellings in the Netherlands: discrepancies and policy implications, Energy Policy 54, March 2013, 125–136.

not as bad as might be expected. For buildings with a high energy performance the opposite is true. For utility buildings similar results have been obtained by Hoes-Van Oeffelen et al (2013)[21].

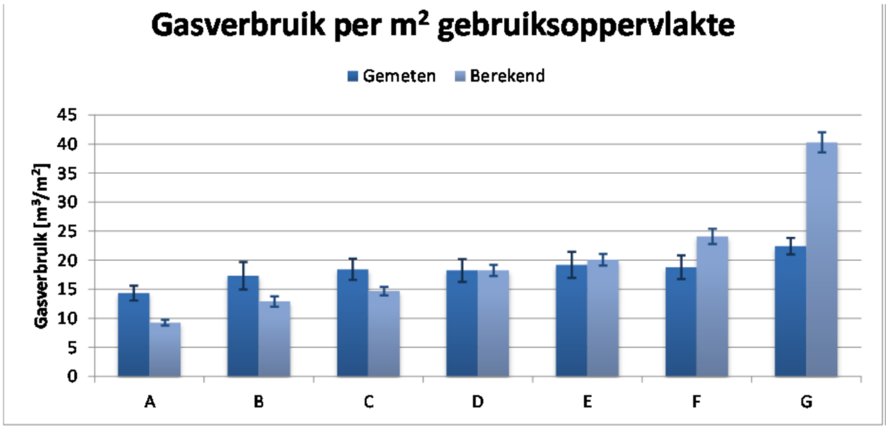


Figure 15: Gas consumption per m2 floor area in m3 of utility buildings (Hoes-Van Oeffelen et al (2013))

Since Built2Spec is mostly focused on new buildings, the fact that the actual energy consumption in high-energy building is higher than predicted is interesting. A study into the energy performance gap in high-performance buildings has been conducted in Belgium by Delghust et al (2015).[22] There it is argued that the technical parameters (i.e. on-site execution, system efficiencies etc.) prevail in explaining the prediction error. In order to have an accurate prediction of the energy use, the input on occupant behaviour and building properties need to be determined more accurately. An example is provided on air tightness. The default value for air tightness (V_{50}) of high performance buildings in the energy calculation is 12 $m^3/(h.m^3)$, whereas the median value of the sample where the air tightness was measured turned out to be 2,6 $m^3/(h.m^3)$. This illustrates that using measured building properties as input for the energy calculations lead to a smaller energy performance gap.

[21] Hoes-van Oeffelen, E.C.M., Spiekman, M.E., Bulavskaya, T., TNO 2013 R10916. Energielabels en het gemeten energiegebruik van utiliteitsgebouwen, 2013

[22] Marc Delghust, Wina Roelens, Tine Tanghe, Yves De Weerdt & Arnold Janssens (2015): Regulatory energy calculations versus real energy use in high-performance houses, Building Research & Information, DOI:10.1080/09613218.2015.1033874

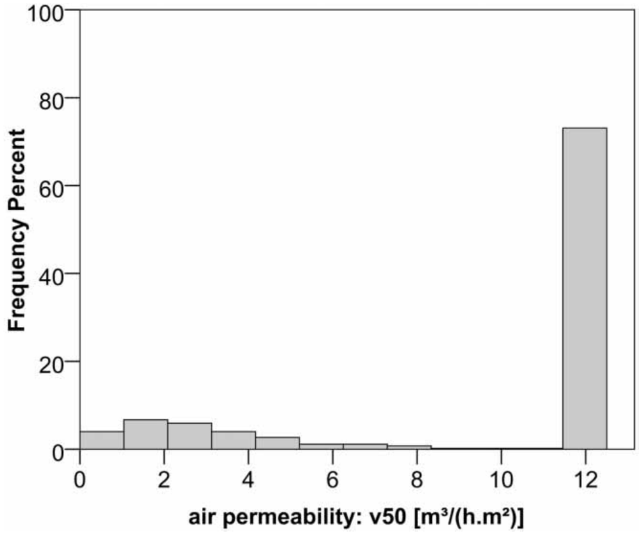


Figure 16: Air permeability (v50) of the subsample (N=75); 12 is the default value; measured values are all far lower than the default

5 How some thermal characteristics impacts on energy performance

5.1 Impact on DER

Zero Carbo Hub did a very interesting study about the impact in DER (Dwelling CO2 Emission Rate) if the input used in SAP does not match what is built. Related to constructive details: DER: SAP 2009 software was used to calculate the DER (kgCO/m2 per year) for a semi-detached archetype dwelling, using specifications chosen to represent a Part L 2013 compliant dwelling.

In this point results are only presented related to wall U-values, thermal bridges and air permeability. The complete information can be found in Closing the Gap Between Design and As-built Performance: End of Term Report – Appendix H.

5.1.1 Wall U-values:

Discrepancies relating to wall U-values were also found to be very important. DER is very sensitive to wall U-value and there was judged to be a high chance of a discrepancy between the wall U-value input and the as-built value. If gaps large enough to allow cold air to circulate behind insulation are present, a nominally insulated wall would perform similarly to an uninsulated one, potentially resulting in a rate of heat loss several times worse than calculated.

The example modelled 'only' assumed the U-value was doubled from 0.2 to 0.4, so the DER impact would be much greater in the worst cases. (Zero Carbon Hub, 2014, p. 4).

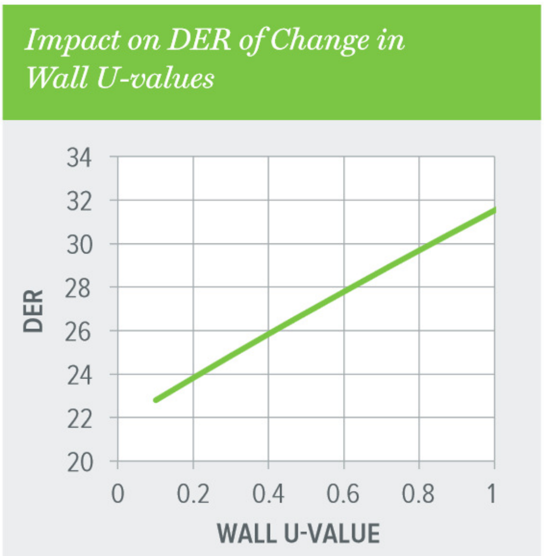


Figure 17: Impact on DER of Change in Wall U-values

5.1.2 Thermal bridges

Numerous issues relating to thermal bridge heat losses were raised by group members. A number of these were looked at with example calculations (see table below). Individually some of these have a significant effect on DER (lintels appear to be the most important), but in the opinion of work group members thermal bridge input discrepancies are likely to be both multiple and very common; for example, accredited values may tend to be used where default values should be. For this reason the importance of this item is best represented for comparison with others as an adjustment to the 'y-value', as a proxy for a range of individual Psi-value and bridge length input discrepancies. In combination these can make a significant difference to the DER and therefore this is seen as another important area of potential discrepancy (Zero Carbon Hub, 2014, p. 4).

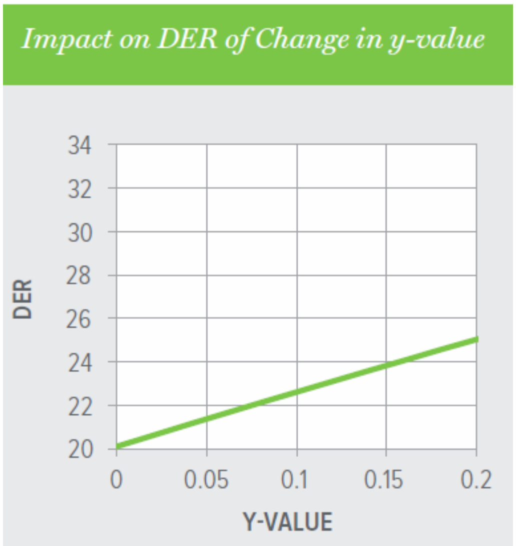


Figure 18: Impact on DER of Change Y-values

5.1.3 Air permeability

Work Group members believed there was a medium likelihood of a discrepancy between the inputted and actual value for air-permeability. This item has a relatively large impact on the DER. In theory this is a well-controlled input since it is one of the few tested features of new dwellings (at least in a sample of cases). However doubts were expressed by some group members as to the consistency of achieved values in non-tested homes. It is worth noting that sensitivity to air permeability is non-linear – at higher levels the result is more sensitive to input changes. (Zero Carbon Hub, 2014, p. 6).

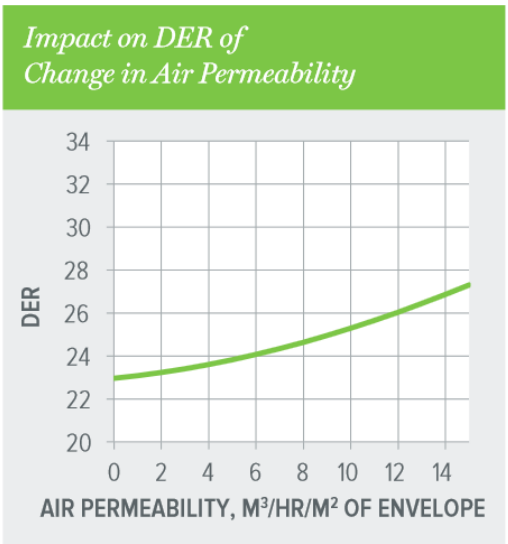


Figure 19: Impact on DER of Change in Air Permeability

5.2 Impact of air-tightness on heating demand

Some simulations have been carried using the PHPP, the energy balance simulation program of Passive House Institute which is known to be precise and reliable. The intention of this simulations is to know the impact of air-tightness on heating demand.

We take the building data of a very well-constructed kindergarten with an area of 735 m² which is a certified Passive House in Sofia/Bulgaria. In reality the achieved level of airtightness was n50 = 0.55 h-1.

We will suppose that the airtightness test showed a result of n50 = 2.5 h-1. This could happen if leaks arose during construction, but after completion they could not be repaired because the leaks were located in areas which are no longer accessible and/or joints are not taped as they should be or if infiltration barriers are missing at entrance doors or windows.

The tables below show the impact on energy consumption for heating and cooling when the airtightness test results increase from n50 = 0.55 h-1 to 2.5 h-1In addition, we will apply different climate zones for this kindergarten. Technical characteristics are adapted for the fictive locations.

Kindergarten, located in Sofia/Bulgaria

Technical data	**as built**	ficitively
Location	Sofia/Bulgaria	Sofia/Bulgaria
Glazing	Ug = 0.8 W/m²	Ug = 0.8 W/m²
Window frames	Uf = 0.97 W/m²	Uf = 0.97 W/m²
Wall insulation EPS 0.031	200 mm	200 mm
Roof insulation Mineral wool 0.04 between beams	300 mm	300 mm
Floor insulation XPS	200 mm	200 mm
Heating demand	15.47 kWh/(m²a)	27.94 kWh/(m²a)
Heating load	14 W/m²	28 W/m²
Cooling demand	-	-
Cooling load	-	-
Heat recovery efficiency	72%	72%
Electric efficiency	60%	60%
Airtightness test n50 value	0.55 h-1	2.5 h-1 (fictive)

Fictive: same kindergarten, but located in Sevilla/Spain

Technical data		
Fictive Location	Sevilla/Spain	Sevilla/Spain
Glazing	Ug = 1.3 W/m²	Ug = 1.3 W/m²
Window frames	Uf = 1.5 W/m²	Uf = 1.5 W/m²
Wall insulation EPS 0.031	100 mm	100 mm
Roof insulation Mineral wool 0.04 between beams	100 mm	100 mm
Floor insulation XPS	-	-
Heating demand	5.97 kWh/(m²a)	11.21 kWh/(m²a)
Heating load	8 W/m²	15 W/m²
Cooling demand	13 kWh/(m²a)	13 kWh/(m²a)
Cooling load	17 W/m²	18 W/m²
Heat recovery efficiency	72%	72%
Electric efficiency	60%	60%
Airtightness test n50 value	0.55 h-1	2.5 h-1 (fictive)

Fictive: same kindergarten, but located in Göteborg/Sweden

Technical data		
Fictive Location	Göteborg/Sweden	Göteborg/Sweden
Glazing	Ug = 0.6 W/m²	Ug = 0.6 W/m²
Window frames	Uf = 0.8 W/m²	Uf = 0.8 W/m²
Wall insulation EPS 0.031	400 mm	400 mm
Roof insulation Mineral wool 0.04 between beams	500 mm	500 mm
Floor insulation XPS	270 mm	270 mm
Heating demand	14.91 kWh/(m²a)	32.72 kWh/(m²a)

Heating load	14 W/m²	30 W/m²
Cooling demand	-	-
Cooling load	-	-
Heat recovery efficiency	85%	85%
Electric efficiency	60%	60%
Airtightness test n50 value	0.55 h-1	2.5 h-1 (fictive)

Fictive: same kindergarten, but located in Frankfurt/Germany

Technical data		
Fictive Location	Frankfurt/Germany	Frankfurt/Germany
Glazing	Ug = 0.7 W/m²	Ug = 0.7 W/m²
Window frames	Uf = 0.85 W/m²	Uf = 0.85 W/m²
Wall insulation EPS 0.031	300 mm	300 mm
Roof insulation Mineral wool 0.04 between beams	350 mm	350 mm
Floor insulation XPS	200 mm	200 mm
Heating demand	15.08 kWh/(m²a)	30.14 kWh/(m²a)
Heating load	12 W/m²	26 W/m²
Cooling demand	-	-
Cooling load	-	-
Heat recovery efficiency	85%	85%
Electric efficiency	60%	60%
Airtightness test n50 value	0.55 h-1	2.5 h-1 (fictive)

The chart below summarizes how the increase of airtightness test n50 value impacts on the heating demand for each location.

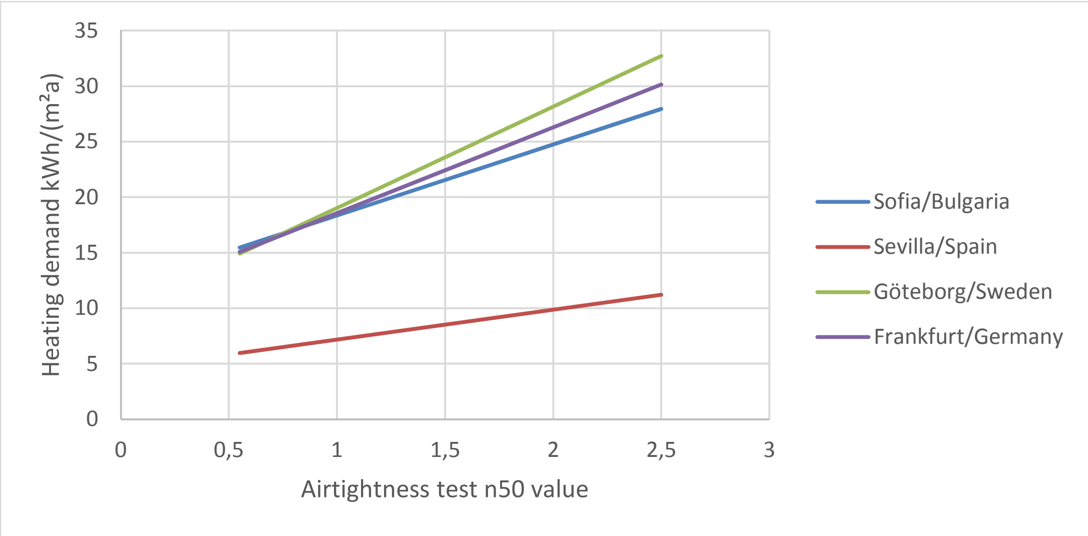


Figure 20: Impact on Heating Demand of Airtightness test n50 value

6 How assess the design/commissioning performance gap

The aim of this point is study how to assess the performance gap from design to commissioning. However before this stage, some quality checks can be done to assess if the real energy performance of the building will be as well as planned.

First it is important to define how is the gap assessed and quantified. In Buil2Spec the gap will be the considered as the difference between the Energy Performance Certificate (EPC) carried out at design and the one carried out after commissioning with as built parameters values. The calculation will use the start EPC calculation method in each country and also the internationally recognised PHPP calculation provided by the Passive House Institute.

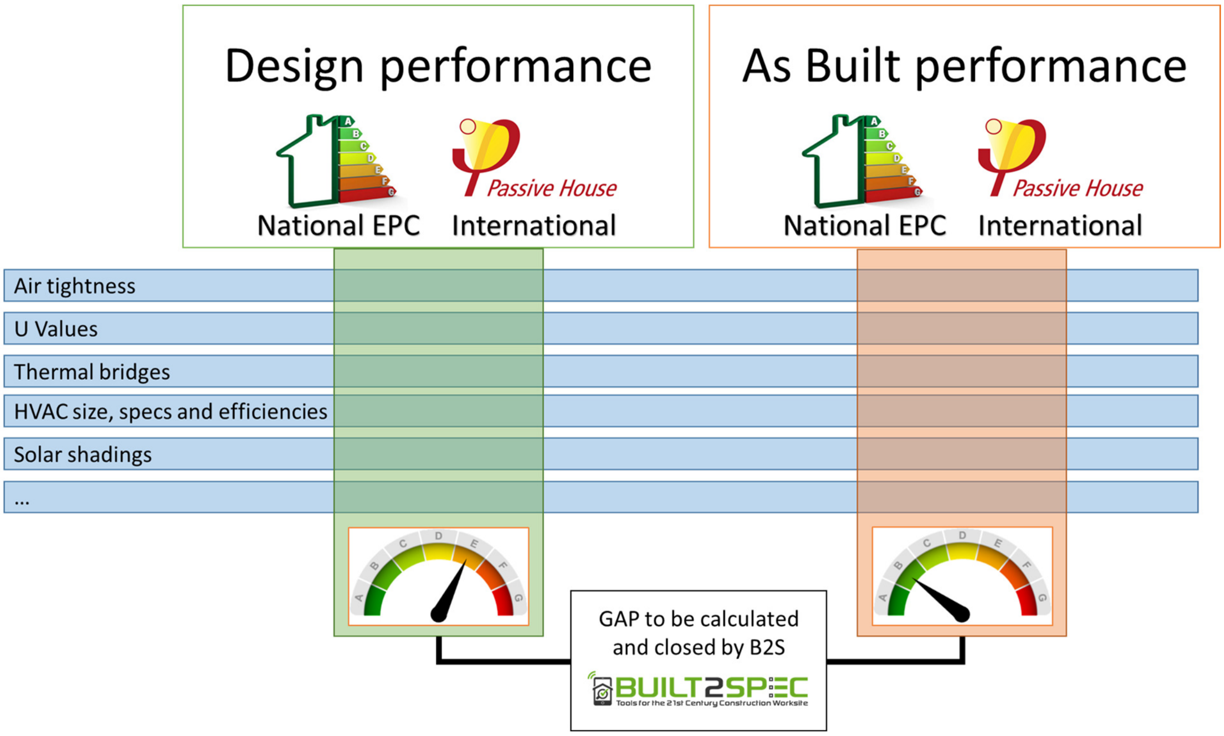


Figure 2 Energy Performance gap calculation in B2S

This methodology can help to assess the energy performance gap from design to commissioning:

STEP 1: Design stage:

Identify in the project the most critical thermal parameters for energy performance (air-tightness, thermal bridges, walls and windows U-values) and compile them in a datasheet (see an example of datasheet in the image below). This step consist in a desk study of the impact of different paramenters that can impact construcion quality and affect EPC calculation results. This study will be done using both the EPC national calculation tools for each pilot and also the PHPP tool. This study will also to set priorities in terms of quality checks during construction.

FABRIC

EXTERNAL WALL 1

Build Up *(description of Wall layers)*

Area: m² | U-value: W/m²K

EXTERNAL WALL 2

INTERNAL WALL 1

ROOF 1

FLOOR 1

WINDOWS 1

Number of windows | Frame and Glass U-value: W/m²K

Total area: m² | Description

Orientation | Overshading

AIR PERMEABILITY

Target at design stage: m³/h.m² at 50 Pa

THERMAL BRIDGING JUNCTION DETAILS

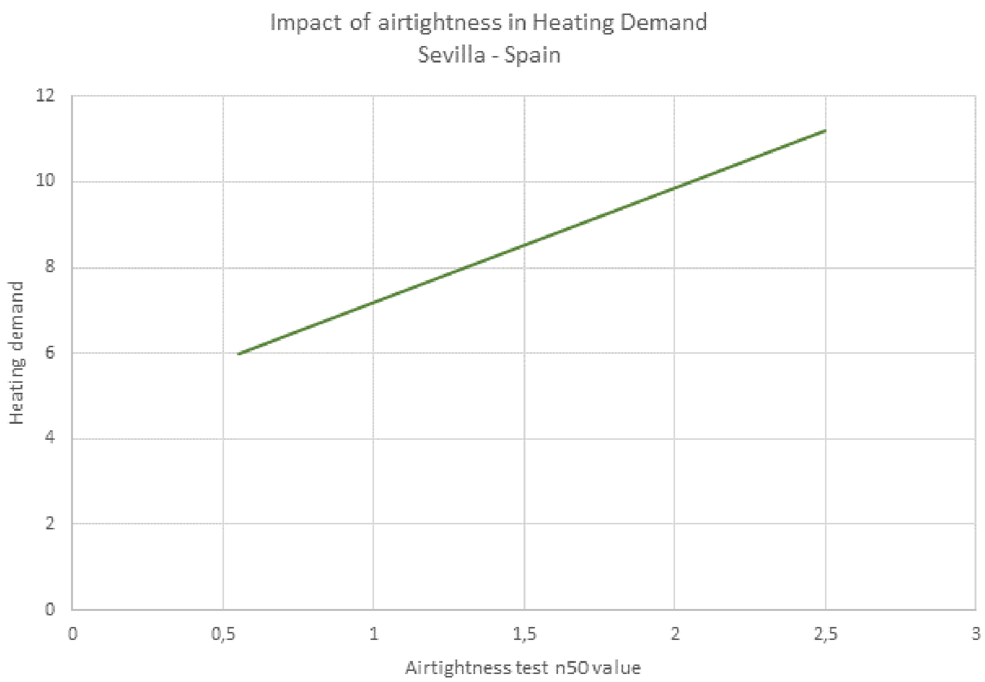
THERMAL BRIDGE 1

Detail

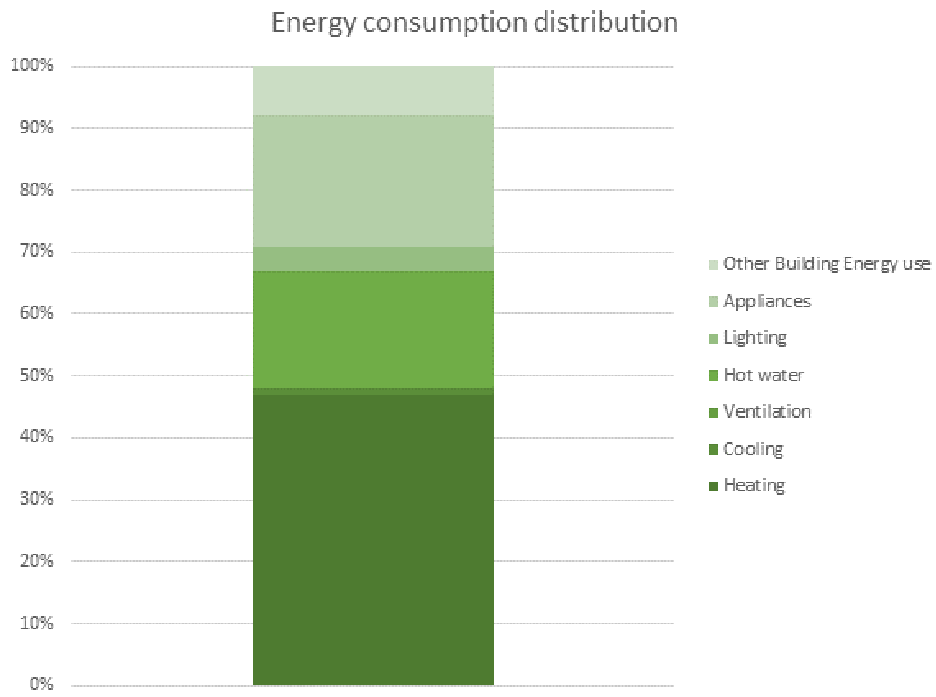
Psi-value: W/mK

THERMAL BRIDGE 2

During energy simulations define how each parameter affects the heating and cooling demand (see point 5.2). **Example: Defining airtightness impact in heating demand.**



Identify also building energy consumption distribution:



Source: Analysis of energy consumption in the residential sector in Spain – IDAE

During design process identify and define a robust strategy for checking these parameters. In deliverable 1.1 and 1.3, quality checks strategy is developed for Buil2Spec project.

STEP 2: Construction stage:

Use the B2S tools to check defined parameters during construction process (e.g. air tightness with PULSE, thermal bridges, U-value with infrared camera, etc.). This parameters must be compared with datasheet from the design stage. The intent is that by using the B2S tools the difference will be minimised and therefore also the resulting GAP.

STEP 3. Commissioning stage. Testing final parameters of building envelope (air tightness, U-values).

Test final parameters and collect them in the datasheet. For example to collect Wall U-values use heat flux sensor. To test airtightness use PULSE tool (described below). To collect information about thermal bridges use the special IR camera developed in Built2spec project.

FABRIC

EXTERNAL WALL 1

Build Up (description of Wall layers)

Area m²

U-value W/m²K

Measured U-value

EXTERNAL WALL 2

INTERNAL WALL 1

ROOF 1

FLOOR 1

WINDOWS 1

Number of windows

Frame and Glass U-value W/m²K

Measured U-value

Total area m²

Description

Orientation

Overshading

AIR PERMEABILITY

Target at design stage m³/h.m² at 50 Pa

Measured

THERMAL BRIDGING JUNCTION DETAILS

THERMAL BRIDGE 1

Detail

Psi-value W/mK

Image of IR camera

THERMAL BRIDGE 2

6.1 Built2Spec tools

Buil2spec tools can help to avoid the energy gap during construction process. This tools can facilitate testing some thermal parameters and ensuring the expected performance of them. The chart below shows which tools developed within B2S project can assess the energy performance of the building (IR analysis methods and innovative low pressure air tightness technique).

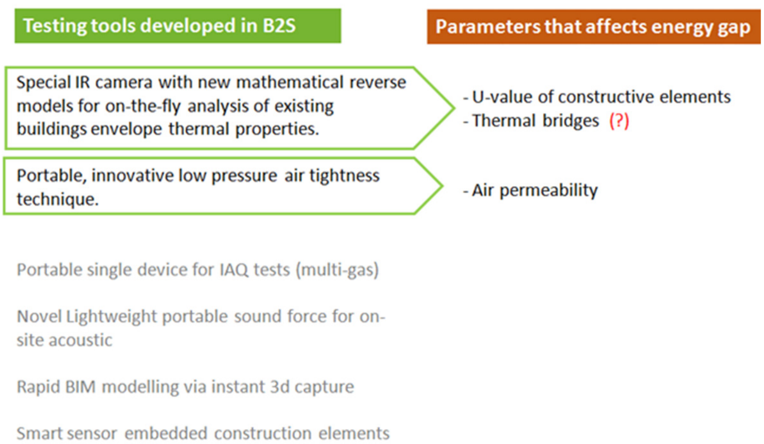


Figure 21: Buil2Spec tools to assess energy performance

6.1.1 PULSE: portable, innovative low pressure air tightness technique

The B2S testing tool for measuring building air permeability is called "PULSE" unit, which releases compressed air into the test space over a short period of time (1.5 second) to create an instant pressure rise. The pressure decay and air leakage rate through building envelope are measured and related to obtain the air characteristics under 4 Pa pressure difference. The existing tool in market for measuring the air permeability is blower door unit.

The installation and testing procedures of these two tools are listed in Table 1.

Table 1 Installation and test procedures of B2S airtightness testing tool (PULSE) and blower door unit (BD)

Technique	Installation	Test and analysis
BD	• Set up the blower door panel in the existing doorway (door removal if necessary, or utilisation of wedges for filling gaps between panel and door frame when the shape of door frame is irregular); • Mount the gauge on the blower door panel or door; • Connect red tube between fan and gauge, green tube between outdoor and gauge; • Connect the speed control cable from fan to gauge; • Install the fan and cover it; • Connect the fan power plug to a wall outlet;	• Press **[On]** to power up the gauge; • Take three time-averaged (typical 5 seconds, 10 seconds if it is windy) zero flow readings of building pressure; record the indoor temperature, barometric pressure and outdoor wind speed. • Remove the fan cover, choose the right ring for measurement and switch on the fan to adjust the building pressure. • Take 7-10 readings starting from 10 Pa or 5 times of zero flow reading, up to 60-70 Pa, with an interval between adjacetn building pressure smaller than 10 Pa. • Switch off the fan and cover it. • Repeat step 2 to record three zero flow readings and environmental conditions after the test. • Input the data to blower door data analysis software such as TECTITE, to analyse the data.
PULSE	• Place the PULSE unit in an unconstrained space; • Connect the pressure transducer and solenoid valve to the ATT box, connect the pressure tube from reference tank to "-" port of differential pressure transducer on the front of ATT box; • Connect the unit to the wall outlet;	• Turn on motor to charge the air tank. • Change the switch from "auto" to "off" mode when it stops chargeing automatically or when the desired pressure level is achieved. • Switch on ATT box, input the tank size, and building parameters (which can also be obtained from VCMP). Press the "start" button to commence the test, the test data is taken and building leakage parameters are calculated, displayed and then stored in the unit; (In the MK3 prototype, the unit opertion will be automated and can be remotely controlled via mobile phone)

For the PULSE technique, the installation is simple and quick, not needing to block existing doorway and the pressure tube doesn't have to go through the building envelope. Hence the building integrity is maintained. The test duration of PULSE is 6 seconds which makes the test less affected by the wind. The PULSE test is more representative of building permeability in reality due to the fact that it is done at 4Pa, close to natural condition. To summarize it, B2S testing tool has the following features:

- ✔ Accurate results at typical infiltration pressures
- ✔ Measurement of the *whole* building envelope
- ✔ Quick, easy and portable
- ✔ Ability to tether units for large buildings
- ✔ Instant and repeatable results
- ✔ Effects of the wind are accounted for

It has to be admitted that the current disadvantage of PULSE technique lies in the inability of identifying the location of leakage pathways on its own. However, with the assistance of a simple and cheap door fan, the detection of leakage pathways can be done. At a later stage of this project, further work will be carried out on the development of detecting leakage pathways using PULSE technique.

Compared to the blower door test which needs to analyze the test data separately either manually in the spreadsheet or in a commercial software such as TECTITE, the ATT box records the measured data, analyses it and displays the results instantly. This allows the operative, either construction worker or craftsman, to do quick-checks, evaluate the effect of the measures on airtightness improvement and the leakage level, and decide whether remedial work is required before moving forward.

The workflow of measuring building airtightness using the PULSE technique, which is currently at MK2 stage, is shown in Figure 22.The workflow for MK3 unit, which will be used in B2S, will be simpler than this and can be remotely controlled on devices such as mobile phone.

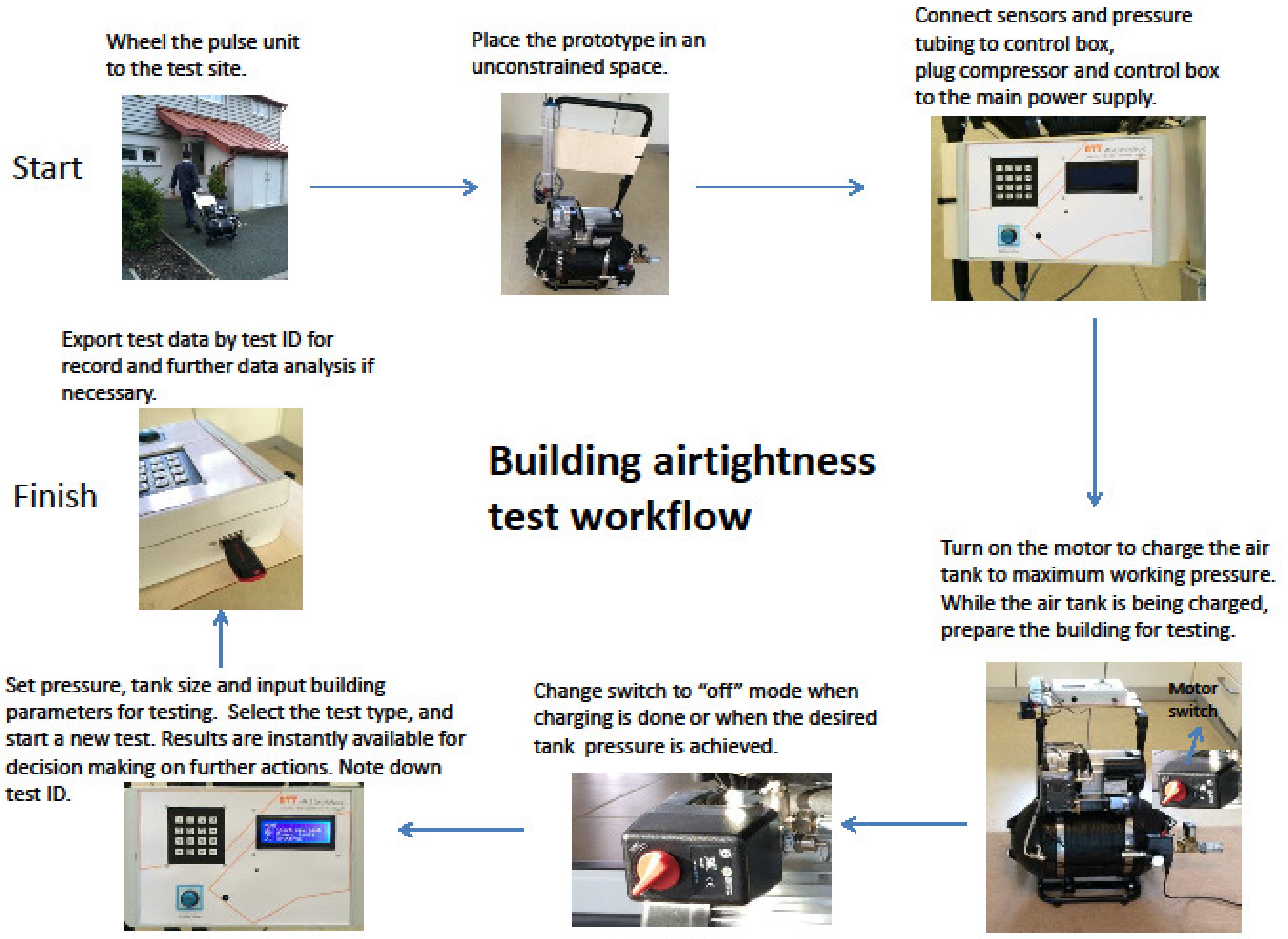


Figure 22 Workflow of building airtightness test using the PULSE technique

In order to minimize the energy gap caused by the building airtightness, the PULSE technique can be used to monitor it during construction to make sure construction work and any measures taken for improving airtightness achieve the goal and eventually meet the target. A case example is given below.

Use Case Example: B2S VCMP quality check for airtightness

- During construction, the site operative receives the confirmation of delivery of envelope airtightness improvement measures (including wall insulation, building envelope seals, etc.)
- The PULSE unit is used to do quick-checks to building airtightness, before and after the measures is taken, to evaluate the effect of the measures on airtightness improvement and the leakage level. Decisions are made on whether a remediation is required to eliminate the reprocess and make sure the building airtightness meets the benchmark values before handed over to quality control.

Airtightness test results of buildings during construction are uploaded to the cloud database for storage and data sharing within the platform for quality control and evaluations such as energy demand and possibly acoustic performance and indoor air quality.

7 Closing the gap

7.1 General approach

The performance gap could be defined as “the difference between the initial calculations carried out in the design of a building compared to the actual energy recorded on utility meters can be several times greater” (The Green Construction Board, 2013, p. 3). As could be seen in Figure 6: the gap can vary from +10 to +20% in design stag, from +10 to+30% in construction stage, from +15 to +30% in commissioning stage and from +30 to +120% in use-stage (for non-domestic buildings).

According to the numbers presented in last paragraph, the gap in these stages can vary from +35% in best cases to +70% in worst ones.

With good practices described in this chapter the gap can be reduced during all the stages to 0% in best practices to +20% in good practices (see Figure 22).

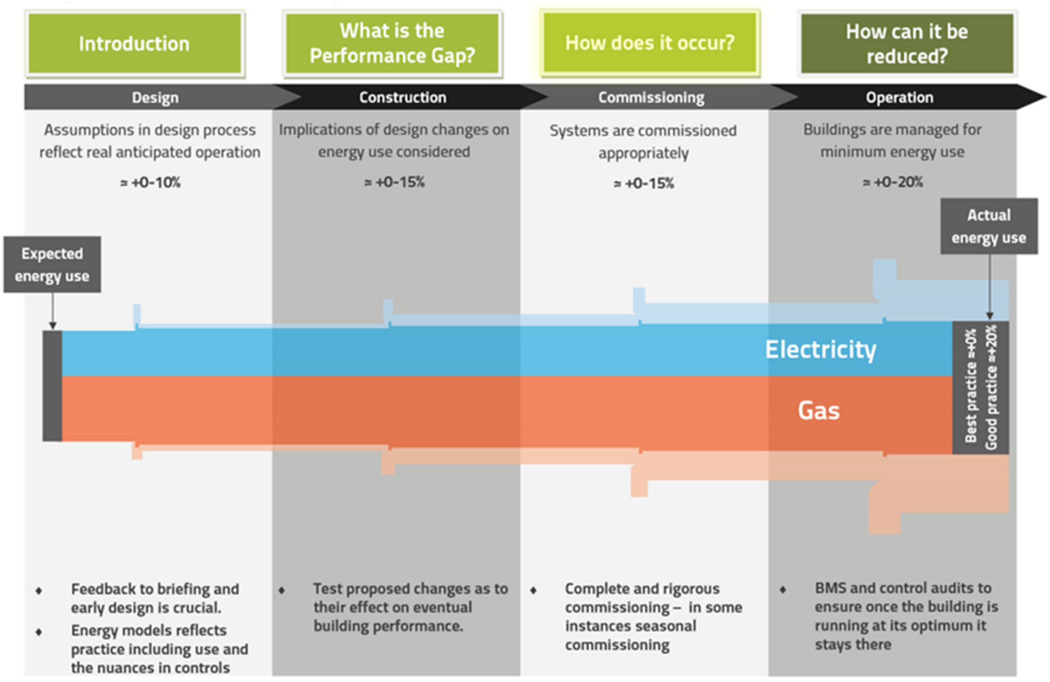


Figure 22: Closing the performance gap (The Green Construction Board)

The good practices and recommendations are presented in Table 1 divided in each construction stage (in x axis) and in stakeholders (in y axis).

Summarizing; it could be said that in the design stage is very important to perform simulations very careful, detailing well thermal bridges and providing all the loads of the building[23] (even not established by regulation). It is also important to design simple and robust, many low carbon technologies do not have to make a low carbon building. Control and metering strategy are key[24]

[23] Similar to PHPP calculations

[24] “Metering strategy should be in place from early in the design process to allow the client to monitor the various systems and sub-systems of the building during occupation”…”In some buildings metering was

During tendering is very important to follow the design specifications and not changing materials or systems in, if some features of materials change, must be checked they don't impact in the energy performance (with simulation if it is necessary).

During the construction stage quality checks are key at the same time that the expertise of workforce.

Making a correct commissioning and handover is very important, ensuring the proper functioning of all systems and making good transfer to maintenance and users. A good follow-up during the first years of the construction is also important and allows a learning loop[25]. In point 7.3 is explained how Soft Landings can improve this learning loop.

.

installed to satisfy BREAM or building regulations without considering the need to understand the operation of the building" (Carbon Trust, 2011)

[25] The Green Construction Board proposes: "Closing the performance gap relies on closing the feedback loop…In practice this works with the introduction of two feedback loops; one to briefing and early design for new building and the other to those who own and operate buildings. The operational performance of a building is coming to the fore in the consciousness of the design team, contractors and building operators and users through the rise in energy costs and legislation such as the CRC and the limited use for DECs. This awareness should be built upon with a more universal requirement to demonstrate operational performance of the building in use." (The Green Construction Board, 2013, p. 16)

7.2 Detailed recommendations to reduce Energy Performance Gap

Table 1. Recommendations to reduce the gap between predicted and actual building energy performance.

Stakeholders	Briefing	Concept design	Developed design	Construction	Commissioning
Owner and investor	Define your design and operational targets for the project prior to the site being chosen and the design team being appointed[2]. Propose your needs to the design team, in terms of the building design, building energy performance, indoor comfort (e.g. thermal, acoustic, visual, etc.), air quality and available resources. Make sure that the design team have experience in designing energy efficient buildings. In the case of a refurbishment, arrange a condition survey (thermographic and air tightness) of the building to be done, in order to identify heat and air leakage points[2].	Engage in the project design to ensure it meets your requirements[2].	Engage in the project design to ensure it meets your requirements whenever any major design changes are proposed[2]. Ensure there is an effective metering and monitoring strategy proposed for the building, which allows you and other building users to understand the breakdown of energy used in the building and take action to improve outcomes[3].	Engage in the building construction process to ensure it meets your views[2]. Make sure that contractors installing innovative systems have a first-hand experience with those systems[1].	Follow the BSRIA Soft Landings process, i.e. appoint designers and constructors to stay involved with the new building beyond practical completion and into the critical initial period of occupation[3]. Ensure the commissioning of systems takes place at some specific point in the year[3]. Recommission weather-sensitive systems in the opposite season of the year and perhaps even during every season of the year[3]. Remember that building energy rating certificates are good indicators of the potential energy performance of a building, but they cannot take into account changes in the design, or any aspects of operation and occupants' behaviour[1]. Appoint the facilities manager responsible for optimal building operation. Ensure there is training provided for building occupants on the use of systems installed.

Design team (architects, engineers)		Propose the building design concept based on the investor's brief. Define the building's energy consumption targets based on national building regulations and investor's needs. Communicate well, with the investor, how the design choices may impact the energy performance of the building and the overall cost of construction and operation. Use dynamic energy simulation to estimate the energy consumption of the designed building (particularly useful in comparing a variety of design options)[2,3]. Provide the whole-life costing, which includes all aspects of project design, construction, commissioning, operation, decommissioning and disposal[2].	Comply with the national building regulations and relevant international standards, as well as quality management systems. Ensure the design team is sufficiently trained in designing energy efficient systems in buildings. Provide all design details and material specifications to avoid any mistakes at the construction stage that may lead to poor building performance. For instance, mark the air barrier on all drawings clearly and provide detailed connections drawings to avoid thermal bridging. Design a building to be partially future proofed, e.g. taking into account the climatic change, with sufficient space for additional services, possibility of extension, etc[2].	Comply with the national building regulations and relevant international standards, as well as quality management systems. Make sure that contractors installing innovative systems have a first-hand experience with those systems[1]. Ensure that the contractors are legally obliged to deliver a building that meets the design intent[2]. Brief site staff on the importance of checking the continuity of insulation and air barrier at all stages of construction[1]. Allow for materials or equipment substitutions only if the impacts on the building performance and operating costs are fully modelled[2]. Appoint an air tightness champion on site with authority to intervene if any work risks undermining air tightness[1]. Consider writing the air tightness target into the main contractor's contract, with penalties if it is not achieved[1]. Appoint an individual responsible for coordinating different sub-contractors working on the building management system[1].	Make sure that multiple systems installed are not 'fighting each other', e.g. cooling against heating[1]. Make sure the controls for various systems, such as heating/cooling, ventilation, renewable energy, lighting, etc. are not overcomplicated for use by occupants[1]. Ensure the building management systems are installed with sufficient thought put into how occupants need to use them[1]. Provide a detailed Operation and Maintenance (O&M) manual explaining the operation of the building and the logic behind the systems installed. Additional to the O&M manual, provide a building logbook, which This is a simple, easily-accessible summary of a building's services, controls strategy, predicted energy performance and the means to monitor it (which allows to compare the actual performance with design predictions)[3].
Certified building energy rating assessor			Comply with the national building regulations and relevant international standards. Perform validated energy analysis of the building and provide a provisional building energy rating certificate.		Comply with the national building regulations and relevant international standards. Perform validated energy analysis of the building and provide a final building energy rating certificate.

Construction companies				Comply with the national building regulations and relevant international standards, as well as quality management systems. Ensure that the building to be delivered meets its design intent (it is a legal obligation)[2,3]. Ensure the site workers are trained, follow the project design and specifications to ensure a high quality construction and building energy performance as designed.	
Material and components supplier				Comply with the national building regulations and relevant international standards, as well as quality management systems. Provide any necessary documentation and technical specifications of the materials and equipment used on site. If required, commission any additional testing in a certified laboratory.	Comply with the national building regulations and relevant international standards, as well as quality management systems. Make sure the controls for various systems, such as heating/cooling, ventilation, renewable energy, lighting, etc. are not overcomplicated for use by occupants[1]. Ensure the building management systems are installed with sufficient thought put into how occupants need to use them[1]. Provide training for facilities manager and building occupants on the use of systems installed.
Other specialist consultants					Utilise thermography, as a useful tool to identify issues in building design, including air infiltration and leakage, thermal bridging and underfloor heating[1]. Utilise air tightness test to demonstrate compliance with the current national building regulations[1].

Facilities manager					Make sure that multiple systems installed are not 'fighting each other', e.g. cooling against heating[1]. Ensure there is training provided for building occupants on the use of systems installed. Building management system calibration and data quality should be checked after handover[1]. Find out the data capacity of the building management system and ensure that data is stored and backed up as needed[1]. Recommission weather-sensitive systems in the opposite season of the year and perhaps even during every season of the year[3].

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- [3]Carbon Trust, 2011, '*Closing the gap. Lessons learned on realising the potential of low carbon building design'*, CTG047 Booklet, Available online: https://www.carbontrust.com/media/81361/ctg047-closing-the-gap-low-carbon-building-design.pdf

7.3 Soft landings

In annex C is reproduced the content published by BSRIA in their guide BG 54/2014 to help articulate the current situation with Soft Landings in the UK construction sector. The content is included largely as originally published, but some minor editing has been done to better suit this application.

Soft Landings can be used for new construction, refurbishment and alteration. It is designed to smooth the transition into use and to address problems that post occupancy evaluations (POE) show to be widespread. It is not just about better commissioning and fine tuning, though for many buildings commissioning can only be completed properly once the building has encountered the full range of weather and operating conditions.

Soft Landings starts by raising awareness of performance in use in the early stages of briefing and feasibility, helps to set realistic targets, and assigns responsibilities. It then assists the management of expectations through design, construction and commissioning, and into initial operation, with particular attention to detail in the weeks immediately before and after handover. Extended aftercare, with monitoring, performance reviews and feedback helps occupants to make better use of their buildings, while clients, designers, builders and managers gain a better understanding of what to do next time. Soft Landings can run alongside any procurement process, potentially in any country. It also provides a natural route for POE and feedback.

8 Conclusions

This document aims to understand in depth what is the Energy Performance Gap and its causes, while providing tools to minimize them. Moreover, the document also gives some guidelines to assess the performance gap from design stage to commissioning.

As mentioned above energy performance gap is the difference between the expected consumption during the design stage and the actual consumption during in-use stage. The causes for this gap can be many and varied, and occur throughout the entire construction process. This document shows an extensive review of existing literature to find out the status of the Energy Performance Gap in several European countries. The results of this search are varied (in some countries the performance gap is widely studied and in others has not been studied yet). These results infer that it is a phenomenon that occurs in greater or lesser degree in most buildings throughout Europe. Although the term energy gap is relatively new, it is likely will pick a relevant topic in the coming years due to its impact in terms of economy and energy (for compliance with the objectives H2020). Therefore, understanding the phenomenon and working to minimize it is very important to ensure the proper energy performance of our buildings.

Only improving quality in all steps of construction process the performance gap can be reduced. The most important causes are explained in point 3 and summarized here. First, during the design stage, poor definition of details and materials used is one of the main causes. Doing an inaccurate energy simulation is another one. Many buildings only make energy simulations to get the EPC. This fact causes that only regulated loads are considered, and some loads with a high impact to energy performance (as lifts, servers) are frequently not take into account. Beside, some elements of the envelope (thermal bridges, etc.) are not well modeled. The difference between the consumption calculated for EPC and the actual consumption in buildings is studied in several countries (see point 2 Understanding the performance gap) and happens in all countries under study. Second, during the construction stage, there are poor training of workforce in energy efficient buildings and this facts makes that construction details are not resolved properly. Another big issue in this stage is material and equipment replacement without considering the implications in building's energy performance. Thirdly, during the commissioning stage the training of building's users is poor or not adequate. Finally during in-use stage using the most important point is the poor communication of the actual building's performance to design and construction teams. This fact makes difficult to learn from the mistakes and improve in future buildings.

Once understood the main causes of the gap, this paper also wanted to quantify how big it is. The gap can vary from almost 0 in best practices to more than double in some buildings. According to the use of the building this gap may be more or less big, CarbonBuzz indicates how (see point 4). Is also important to keep in mind an appreciation: buildings carried out under low energy standards (such as Passivhaus) tend to have virtually no gap or even consume less than expected. Therefore, it is possible to construct buildings without energy performance gap.

In order to avoid performance gaps it is necessary to improve the quality of the entire construction process. In general, during the design stage, proper detailing of all the envelope details, defining the materials and their thermal characteristics and doing a proper simulation including all the building's energy loads (such as elevators, servers, etc., not only the regulated ones) are essential for a good result. Keeping the design robust and simple is needed to facilitate construction. During the construction stage it is necessary to ensure that the contractor builds according to the design specifications taking special care with thermal bridges, airtightness and insulation installation. Quality checks are needed to verify the construction.

Commissioning is important for proper performance of building services and training the building's users and operators seasonal commissioning is also a good idea to ensure that the building performs well throughout the year. A good metering strategy is very useful to know how the building performs during operation. If the building doesn't perform as expected, it is necessary that the design and construction team solves the problems and learns from this experience for future projects.

As previously mentioned, proper and high-quality work is essential in avoiding the performance gap. In order to ensure this high-quality work, Built2Spec provides a series of new technologies which facilitate quality checks (e.g. quantified assessment of thermal properties done with an IR camera, innovative low pressure airtightness tool, 3-D scanning, embedded sensors, a novel lightweight sound source for acoustic testing with smartphones). Moreover, the whole construction process is under investigation in order to develop a BIM- (building information modelling) based tool for construction experts in order to deliver high-quality buildings. High-quality construction depends upon other factors in addition to correct design such as the fact that the materials and components are correctly delivered and installed according to the specifications, detailed and updated information and drawings are at hand on-site (e.g. drawings, specification, installation guidelines etc.) and workers can provide proof of correctness and fulfillment e.g. by taking pictures. Taking pictures and documenting correct installation can also be used for easier communication to avoid mistakes. In order to ensure proper commissioning, Built2Spec will develop several quality checks for this purpose.

Finally, it is described a way to Assess the performance gap between energy design to commissioning. This task is complicated because it is not possible to quantify the gap until in-use stage when is known the actual consumption of the building. Thus assess the gap during commissioning is difficult. What is possible to assess is the potential impact of some thermal characteristics of the envelope on the heating and cooling demand. These features can be measured during the construction stage and commissioning with tools developed within Built2Spec project. Therefore, if these tools measure different values than anticipated ones during design stage could be assessed the related gap in the energy performance of building. We conducted a case study where it is shown how vary the heating demand depending on the level of air tightness. Perform these estimates may enable to assess the part of the energy gap that depends on thermal characteristics of the envelope during the construction phase and commissioning (and take action if it is too much big). The total gap can only be assessed during in-use stage.

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Annex A Summary of Questionnaire Part V

Performance gap: how can we manage it?

Please answer to the two following questions taking into account your experience in construction project

Q1. Which are the typical constraints that affect quality (budget, time, skills…)?

Ecofix: Quality is affected by time, money and specification. The specification is affected by the knowledge of the specification writer and designer and there is still a general lack of knowledge of the impact of

NUIG-ORAN: Problems in communication between designers and construction professionals, due to time, misunderstanding, lack of expertise etc.

PHI:
- Subcontractor with deficient knowledge
- Ignorance
- Poor information transfer (poor technical information sheets)
- Complexity of provisions and regulations

OHL: Skills and competences of the stakeholders. Assigned budget. Timing for developing the works. If construction works are not done by qualified workers, in the stablished period of time for carrying out the works and with the necessary economical resources, quality will be greatly affected.

R2M+DE5: The main constrains we see are:

- Budget is the first constraint.
- Information management: from designers to contractors, during construction itself among all actors involved and post commissioning during handover (“as built” are never really “as built”)
- Quality assurance procedure on site are not technology supported

Budget issue is often connected to point 2 and 3 which we expect to have directly addressed by the B2S platform.

TNO: Time and money which do not match in the end with the intended design and performance requirements. This does not satisfy the designers yet occur due to the client who has the last saying. Also the labour quality is time to time a problem even though the chosen systems or materials are for the intended performance expectations. It is also about changing the perception of designers, engineers from using mainstream products and giving less chance (or having simply less awareness on) the product suppliers.it is also about lack of increased knowledge on landscape of innovative solutions by the main decision makers in design process.

LAKE: Budget –both in terms of the time and expertise to achieve it and the additional cost of materials, products or equipment required

Q2. A cultural change is needed to address the gap issues. We may inspire from the health and safety process. What specific challenges and measures would you address first to close the energy performance gap?

Ecofix: A systems thinking approach to building design and construction is necessary for the industry to begin to understand the impacts that all parts of the building have on performance. In my experience setting a high standard for airtightness drives an awareness of workmanship in all trades and an increase in the general quality of construction. I think this is because there is an objective test and measure of the performance that checks workmanship. I would focus on airtightness, correct installation of insulation and management systems for self-inspection and quality inspections by the designers and specifiers and design team professionals.

NUIG-ORAN: Transparent design process that is clear to the construction professionals. Buildings should be constructed as they are intended in the design; thus, close collaboration between the designers and construction professionals should be maintained.

PHI:
- Cultural understanding of construction / Construction is not low-tech anymore (sound protection, thermal protection, fire protection, statics, building services)! Cars have been recognised as high-tech, although one only has to move it. Construction has not been recognised as such.
- Sense of responsibility of contractors for the benefit of building owners and the entire society respectively.
- Transfer of knowledge related to technical standards and producing respective checklists for quality checks despite the complexity of the provisions and regulations.

OHL: On Site quality checks to check not only the characteristics of building materials but constructive solutions.
Make open, easy and understandable protocols to be followed on site regarding the quality check protocols.

R2M+DE5:
We need strict regulations (and verification means) about construction quality compliance
We need normal people to be informed about building construction quality to make this a market driven need (using high impact messages and channels)
We need to provide technological solutions to ensure quality compliance (like B2S!) and train all actors for using them

TNO: As mentioned, changing the perception and increasing knowledge on product and service landscape.

LAKE:
H & S process is underpinned by law, enforced by a designated body and carries significant penalities. To follow this model would be to accept you need laws, enforcement and penalities for not meeting the requirements, rather than cultural change.

Built2Spec would help those who aspire to best practice to achieve this more efficiently, which in turn may provide some useful cost/benefit case studies for others. But very wide spread change needs to be underpinned by supportive laws and regulations

There also needs to be consideration of the generational issues. The clients and contractors we speak to raise issues with technology acceptance amongst the older generation of site supervisors and managers, but these are the people that have the vital years of experience in on the job. Getting this group to use and accept the technologies will be a significant challenge for Built2Spec.

Q3 Close the performance gap: User personal vision and user needs

#	Issue* (in RED the most common vision)	Category	Important: YES or NOT	Please, give your opinion on this issue	
P1	Limited understanding by planners or funders of the impact of phasing or aesthetic requirements on performance and energy related targets. YES	Land acquisition, concept design and planning	Yes	Agree. Planners and clients make decisions too early without understanding their impact and are often not willing to change their decision. Planners objecting to solar shading for personal aesthetic reasons is one I have encountered more than twice.	Ecofix
			YES	Typically permission to build is granted based on the aesthetics of a proposed building which may not necessarily result in an energy efficient building	NUIG-ORAN
			Yes	The phasing of aesthetic performance and energy related targets are crucial for the successful projects. All stakeholders should be aware how important sufficient consideration of both aspects are.	PHI
			YES	Very important that everyone understands the impact of the aesthetic requirements on performance and energy	OHL
			YES	Really important issue. Having “no” technology knowledge in energy field, or having really low knowledge/experience doesn’t allow to understand all the designer chooses during the design about “why” this detail is better than this, “why” he/she decided to run this path rather than another in some decision, and so forth.	R2M
			Yes	Their concern is not often energy demand/energy use of the building. Thus money, time issues in the decisions of design come earlier.	TNO
			Yes	Managing expectations – planning and building control different and then doesn’t add up to sustainability. Opposed opinions. Tensions on budget and timescales. Sometimes cost implications of meeting planning out strip possible payback e.g. combination facades	LAKE
P2	Limited understanding by concept design team of impact of early design decisions on performance		YES	Preliminary design more often than not considers building aesthetics and internal space only which may impact negatively on energy efficiency	NUIG-ORAN
			Yes	Generally the building and property industries still do not understand the issues of energy use in buildings sufficiently to act on them unless regulated or incentivised to do so.	Ecofix

	and energy related targets.(YES)		Yes	Studies have shown that costs can be reduced if the energetic design is done in parallel with the normal design process. Because modification during the construction process are one of the frequent reason for performance gaps and modifications are frequently done out of economic reasons good and complete design decisions in an early phase help to avoid modifications.	PHI
			YES	Very important that everyone understands the impact of the early design decision on performance and energy targets. Take design decisions calmly, taking into account all variables that can affect the energy performance	OHL
			YES	All the decisions taken during the design stage are fundamental because relying on them all the calculations and related details are based.	R2M
			Yes	Often energy issue comes in definitive design, as there is not enough data to calculate or run accurate simulations in early stage. It is often also the indications are very brief and does not have the priorty comparing the flow, operation, and spatial configuration.	TNO
			Yes	Governed by building regs. Limited understanding trying to achieve Eco bling or sometime planning reqs. Eg solar for solar sake.	LAKE
P3	Inconsistent setting of standards and targets between local authorities (methodology/level) leading to increased complexity of solutions (NOT)		NOT	Building regulations dictate minimum requirements	NUIG-ORAN
			NOT	Not for our project, not a problem we can solve. This is a local issue and of no impact to our project that I can imagine.	Ecofix
			NOT	Does it occur?	
			YES	Solutions will be more complex, so it means that they will be more possibilities to have a higher impact in the energy performance gap	OHL
			YES/NOT	Sometime it could happen. But a professional design team is able to avoid this problem a guarantee a great design by-passing these problems finding a “new” technical solution when/where not included into the standards.	R2M
			-	Not yet, but in the NL< energy performance requirements for new projects are becoming stricter.	TNO
			Yes	Planning regs and legal interpretation different – political changes impact this. Conflicting targets in LA – increase new build and increase green space. However buildings regulations are consistent, but potentially not checked enough.	LAKE
P4	Limited guidance, modelling tools and		NOT	If the desire is there to assess a buildings energy requirements at concept stage the tools and competent designers are available	NUIG-ORAN

	standards available to evaluate and review issues associated with energy performance at early design stages, including overheating.(YES)		NOT	There are plenty of books, guidance, websites, courses and tools for early stage concept design and modeling of energy performance.	Ecofix
			NOT	We hear about that this could be an important issues in the case people do not use the PHPP (the Passive House Planning Package, design PH for easy and early first design). This can be used for all kind of efficient buildings. Passive House Designers do not have this problem.	PHI
			YES	Necessary use and knowledge of modelling tools and standard in the early design stages to avoid problems in the next phases	OHL
			YES	In some real case, sometimes is not easy to find in literature and/or standards/regulations helpful instruction about "how to do" to circumvent the issue.	R2M
			Yes	Energy performance have not become 'rule of thumb' yet for the design decision makers. This needs to be improved, not having an advanced tool which will lack of data due to the nature of early design.	TNO
			Yes	Limitations of RD SAP – far too many assumptions. Also there can be poor asset management systems with little or no relevant information, or not up to date.	LAKE
D1	Inadequate understanding and knowledge within design team (buildability, thermal detailing, tolerances, construction systems and materials, site conditions, SAP and energy issues, performance. (YES VERY IMPORTANT!!!!)	Detailed design	YES	Typically not an issue with 'high end ' builds as extremely competent design teams are in place, on small builds with low budgets this may be an issue	
			Yes	Generally the building and property industries still do not understand the issues of energy use in buildings sufficiently to act on them unless regulated / forced to do so.	
			NOT?	Different premises and targets, and not differing expertise within the project team, result in negative impacts.	
			YES	One of the most important parts is the understanding and knowledge of the design team to make the most accurate design. The construction activities will be based in this design, so, as better definition less energy gap	
			YES	Really important issue. Many times the design team has not all knowledge to provide a great final job.	
			Yes	This is a typical gap between why design team is a design team and not a construction team. Construction team's experiences and propositions for material choices, systems happen in the latter stage where design team continues working on other projects with limited feedback.	
			Maybe	Structural limitations e.g. green roofs, PV. Politcal drivers speak louder than practicalities. Bias towards certain technologies such at PV. SAP doesn't reflect site specific data	

D2	Lack of integrated design between fabric, services, renewables and other requirements (e.g. due to lack of specialist input)(YES, explained in D1)		YES	Previous point above
			YEs	The design team often do not have the skills or knowledge to develop an integrated design or understand the reasons and benefits of doing
			NOT	Actually this difficulties have been overcome.
			YES	It must be taken into account in the design all aspects affecting the energy performance and the integration between them
			NOT	Usually all these actors are (should be) in communication each other.
			Yes	Explained above.
			Yes	its difficult finding a practical solution due to lack of specialist knowledge such as trunking of cables with EWI
D3	Lack of communication of design intent through work stages, e.g. due to discontinuities in design team, specialist involvement or general work contract structure (YES)		YES	Lack of communication of complex design details typically results in poor construction practises
			Yes	
			YES	The intent of the design and the decisions should be known in the case modifications need to be done. Otherwise deviations are most likely.
			YES/NOT	A great project and hence a great design team should take into mind all the management aspects of both design and construction phases.
			Yes	Overall coordination among different stages are difficult due to the time frame of such projects. Continuation of people in the same companies are difficult. Even though the employees still work for the same company, they often change or orient among the different projects. Thus discontinuation is an issue.
			Yes	Effect communications and stakeholder plan – understanding everyone's roles. Who is doing what and why? Must understand tolerances and when to escalate. There is a divide between the pre con data and ability to interpret due to a different generations skill set
D4	Lack of suitable design tool that incorporates compliance check (YES).		YES	Compliance checks are currently laborious and problems encountered may not always be documented resulting in repeated errors
			Yes	For housing the energy rating software provides a check on this aspect of compliance
			NOT	Most of the tools are available. A catalogue with sample thermal bridge calculations might be helpful, thermal bridge calculation tools are available
			YES	Very important to make the compliance check during the design phase using a suitable design tool.
			YES	Useful to have a tool for automatic check.

			No	compliance varies from funder to funder, having a platform that can capture thjis without the need for specialist skill set
D5	Design team not communicating sufficient information regarding critical energy performance criteria of components to procurement team. (YES)		YES	This information is typically not available at the initial stages
			Yes	
			YES	If the requirements are not communicated, this is a severe mistake either by the design team or not to ask by the procurement team. Actually it is difficult to imagine that this happen in reality
			YES	Very important the communication between the design team and the stakeholders involved in the procurement to avoid problems of energy performance
			YES/NOT	It depends on the team. A good team should communicate all the required information.
			YES	same D1
			Yes	Needs to understand each others needs. Needs a proper Monitoring & Verfication plan
D6	Insufficient design information provided for building fabric, potentially leading to critical decisions being left to contractor/sub-contractor at construction phase (YES)		YES	Lack of information will always result in the contractor or possibly site operative making his/her own decision
			Yes	I think architects need to be paid to do more detailed drawings of all the difficult building fabric details and not just the typical details. This applies to thermal bridging details where there is co-ordination with the structural engineer and some subcontractors.
			YES	Similar to above: difficult to imagine that this happen in reality
			YES	Very important to be accurate providing the design information for building fabric to avoid taken wrong choices during the construction phase
			YES	Really important especially when the decision are taken by worksite employees without any background in energy design.
			No	
			Yes	Should be tied in contractually – EPC. Behavior of operatives
D7	Insufficient design information provided for building services, potentially leading to critical decisions being left to contractor/sub-		YES	Lack of information will always result in the contractor or possibly site operative making his/her own decision
			Yes	
			YES	In the case of building services it might happen. It is important that the procurement team is aware of the important details.
			YES	Very important to be accurate providing the design information for building services to avoid taken wrong choices during the construction phase

	contractor at construction phase (YES)		YES	Really important issue especially when the decisions are taken by worksite employees without any background in energy design.
			No	
			Yes	Design creep. Lazy consultants leave out details tba. Detail is often under specified. Understanding the consequences of decisions e.g. PVC vs Alumiminum in relation to cold bridging
D8	Product and system design issues, e.g. concerns about robustness of product design, systems design issues. (YES?)			
			NOT	
			YES	The construction activities will be based in this design, so, as better definition less energy gap
			YES	Having a great background in both product and design issues/aspects is required to achieve a final great job.
			Yes	
			Yes	Maintaining the legacy of the measure from completion to get useful life and durability
PR 1	Manufacturer information lacking critical energy performance detail, relating to either building fabric or services (NOT, DESIGN TEAM HAS THE RESPONSABILITY TO GET THIS INFO).	Procurement		
			NOT	Usually this information is available if requested. This is a responsibility fo the design team.
			YES	The structure and layout of the technical documents needs to be improved significantly.
			YES	Really important. They must be covered all the energy performance details in the technical data sheet provided by the manufacturer
			NOT	Usually in Italy these kind of information are well specified in procurement.
			No	
			Yes	The issue is testing what they say, against the real performance
PR 2	Inadequate consideration of skills and competency requirements at labour procurement (fabric and services).(YES)			
			Yes	
			YES	There is a contradiction between theory and practice. In theory skilled workers are necessary for the contractors to get the contract, in reality……who checks it at the end?
			YES	
			NOT	In Italy for specific work one needs (both designer(-s) and construction company(-ies)) a particular qualification (SOA; ISO9001 etc…)
			Yes	This changes the intended performance and axctual performance.

			Yes	You do need specialist labour. Everyday workers installing specialist products.
PR 3	Product substitution at procurement without due regard for performance criteria (YES)			
			Yes	Specific performance criteria need to be defined in tender and specification documents.
			YES	This is a major problem which occurs frequently. For this a quality check process need to be there!!!!!
			YES	If a product is changed it must have similar technical characteristics and meet the requirements regarding the performance criteria. So, it is very important to check the technical data sheet of the products provided by the manufacturer
			YES	Really Important issue! Any change in material behaviour far from the designed one, could be dangerous for the whole response in terms of energy performances.
			Yes	Very big. E.g. different controls don't work with boiler. Where it becomes critical is where you can't see it – eg cavity wall or solid wall
PR 4	Procurement team lack of understanding of critical energy-performance related criteria.(YES)			
			Yes	Specific performance criteria need to be defined in tender and specification documents.
			YES	Today tendering of construction work is very complex. Not all procurement teams have the required knowledge, this is particular severe if the communication between design team and procurement team is not sufficiently installed.
			YES	One of the most important parts is the skills and understanding of the procurement team about the energy performance criteria
			YES	Really Important issue! If the procurement or tender is prepared by a person without any theoretical background in energy field some relevant aspects can be forgotten and so will be not realized on site. By the way, at least in Italy, the Contractor is responsible to report any design error(-s) and/or missing parts in both tender and/or construction phase.
			Yes	Yes because they are used to going for the cheapest. If very detailed then hard to change. Under a framework can't specify specific products only specify performance e.g. boiler ot xx rather than vallinat
PR 5	Tender documentation not containing up-to-date requirements or trade specifications (YES)		YES	If certain specifications have not been included for in the original quotation due to an exclusion in the tender documentation this typically results in specifications being downgraded
			Yes	Specific performance criteria need to be defined in tender and specification documents.

			YES	In the rush of daily business this is a frequent error. Old tender texts are taken and incorporated with copy and paste. Text need to be updated. But this is also closely related to PR4
			YES	All documentation have to be up-to-date requirements and specifications
			NOT	Tender should not contain commercial information but only technical ones. In Italy is forbidden by the law recall (inside procurement) any commercial information (e.g. company name, product commercial name and so on…) regarding a specific product.
			Yes	Especially consultant produced specs. These are often a cut and paste job
C1	Lack of designer input available to site if issues arise, e.g. due to type of contract (YES)	**Construction and commissioning**	**YES**	If the designer is not available immediately to address matters arising onsite the issue will not be resolved and may result in the contractor deciding on what the appropriate action is which may not be correct
			Yes	Designer input is best if it is continuous throughout the whole process.
			NOT	This is also closely related to PR4, but also to P2. If the communication and handover to the contractor has been done properly this is not a big problem and does not hinder good results.
			YES	All last versions of designs must be available during the construction and commissioning
			YES	Direct interaction between designer(s) and worksite is always recommended. Moreover the interaction with the construction company is recommended too.
			Yes	This is mainly the other way around of the problem, the construction team lacks insights from design and the reasoning behind design choices.
			Yes	Designers refuse to come on site to trouble shoot. Lack of continuity and handover from one stage to another. Lagacy consistency and flow are all affected by this.
C2	Sales or year-end/interim build targets driving programme delivery - putting labour out of sequence and potentially compromising construction quality.(YES)		YES	Unavoidable in any construction market
			Yes	I have no direct experience of this.
			YES	Under this pressure the results become worse, also related to energetic aspects.
			YES	
			YES	Really Important issue! Any change from the planned Gantt Chart could be compromise the final result in term of both safety for the structure and for the worksite workers, and for the quality.
			No	Can't invoice for things not done

C3	Frequently changing site labour limiting ability for lessons to be shared or learnt (YES, but difficult to avoid)		NOT	
			Yes	
			YES/NOT	This is valid for a part of the site workers.
			YES	
			YES	Especially when the worksite workers haven't any experience/background in the field of energy saving/quality.
			Yes	Lacking ownership. Site supervisors and trade supervisors get moved between projects. Good and highly skilled people moved much more often.
C4	Construction responsibilities for energy performance unclear, lack of collaborative working, e.g. services penetrating air barrier. (YES, very important, it has to be solved during design, defining construction responsabilities, it could be interesting creat an specific progile)		YES	Dependent on the design information received
			Yes	These issues need to be considered and resolved during the design, specification and tendering stages.
			YES	Skilled workers are important. They should know what they are doing.
			YES	Very important the coordination and construction responsibilities of teams working in the construction sites. And knowledge about how to perform the works and about the energy performance criteria
			YES	Create a specific profile for energy issue is highly recommended. It should be a person who take care all the energy aspects both during the design process and during the worksite operation in order to check all step-by-step and update the design in a proper manner when a specific issue (not expected during the design stage) comes out.
			Yes	
C5	Product substitution on site without due regard for impact on energy performance.(YES, very important issue!!)		YES	Always an issue
			Yes	
			YES	Especially if the person in charge of energy-relevant verification hasn't been assigned for site visits during the construction period.
			YES	The change of products during the construction works without checking their technical characteristics, will increase the energy gap. It must be put on site the products studied in the design phase or others with similar technical characteristics that meets with the requirements. So, it must be checked their impact on energy performance before their implementation.
			YES	Really Important issue, especially when this modification is taken by a person with any background in energy topics! Any change in material behaviour far from the designed one, could be dangerous for the whole response in terms of energy performances.

			No	
C6	Lack of adequate quality assurance on site and responsibility for QA, e.g. due to site managers being overly reliant on sub contractors' QA processes, variability in processes, lack of supervision, reliance on Building Control. (YES, develope a Quality Assurance Plan, etc.)		YES	Quality supervisors not being sufficiently knowledgeable
			Yes	This issue has led to the 2014 Building Control legislation in Ireland which has created a whole new process of inspections, responsibilities and record keeping.
			YES	This is core, it is the actual reason why we do B2S.
			YES	Develop a Quality Assurance Plan on site and stablish the QA responsibilities
			YES	A part from the cases when a specific energy certification is required (e.g. CASA CLIMA, LEED and so on…) no control are performed.
			Maybe	Depends on the individuals – eg estate renewal for planning vs sutainability
C7	Lack of understanding in sales team of impact of changes, e.g. customer add-ons which affect SAP (YES, but not a key point sales team generally base their decisions on design information)		NOT	Sales team generally base their decisions on design information
			Yes	
			YES-NOT	Maybe the sales should know the background and the overall framework.
			YES	
			YES	Any change from the design could be dangerous for the whole response of the building. Thus any changes should be avoided because even a simple and small change in a local area should compromise the whole structure behaviour.
			Yes	.
C8	Lack of ability to identify some products on site/in situ, e.g. by operatives or for QA or audit purposes. YES/NOT (products generally are correctky identified and approved by the designer)		YES	
			Yes	Evidence of use of correct materials and products according to the design is necessary.
			NOT	Does this occur? If it occurs it could be a problem.
			YES	Products must be correctly identified on site to allow their correct location on the construction
			YES/NOT	Yes, but don't forget that any modification in material behaviour should be evaluated and in case approved by the designer.
			No	
C9	Poor installation or commissioning of services,		YES	Common occurrence
			Yes	

	e.g. due to installation guidance or design drawings not followed, lack of manufacturer installation and/or commissioning guidance (YES, VERY IMPORTANT POINT!!!).		YES	This is a widely disseminated issue. Thermal bridges, unsufficient/wrong or no insulation material. The manufacturer installation guidance is not being followed. No time to read the guidance.
			YES	Design information, installation guidance, commissioning guidance of services must be available on site to check that works are being carried out correctly
			YES	Really Important issue, especially when the worksite workers have any specialization and/or background in energy topics!
			Yes	Major problem. Kit on site not commissioned – e.g. biomass to get planning but not commissioned.Supervision is the issue – has the measure been installed to spec. Procured right kit not plug in right. Commissioning is a big issue.
C10	Short term fixes and improvisations on site without understanding of long-term impact, e.g. mastic for achieving required air pressure test result.(YES, evidence fo use of correct materials and products according to the design is necessary.)		YES	Again, a common occurence
			Yes	Evidence of use of correct materials and products according to the design is necessary.
			YES	The right material is not at hand and the workers improvisate. That’s typical.
			YES	Works must be accomplished considering the impact that they will have at long-term.
			YES	Really Important issue. Any modification should be evaluated and in case approved by the designer in order to have achieved the final goal.
			Yes	
C11	Full design information or installation guidance produced but not available on site.(YES but avoidable for example with Refurbify tool)		NOT	Usually readily available
			Yes	
			No, but…	It not likely that they are not available on site, but a typical source for mistakes: a new version of drawings has been produced, but the workers do not take it. Details elaborated are not looked at. Installation guidelines are lying untouched in the site hut.
			YES	If the design information and installation guidance are not available on site, it is like there are not information. So, it must be there to check that works are being carried out correctly
			YES/NOT	A good designer or a good team of designers should provide all the documentation needed on site.
			Yes	And not available to residents who use it
C12	Site management - inadequate consideration		NOT	Project managers typically proficient when organising tasks
			Yes	

	of sequence of trades and activities on site, later phase work undermining previous works. (very important but NOT important for the perfomance gap, project manager typically profient when organising tasks).		YES	Typical for electricians and installers of building services. A carefully produced insulation layer or airtight layer is damaged.
			YES	An implementation plan must be developed before starting the construction activities
			YES	Really Important issue. The plan is the first aspect to be taken into account to achieve the final goal in an efficient way.
			No	Usually a critical path
C1 3	Lack of site team energy performance related knowledge and skills and/or care. (YES) but need extra training in energy performance			
			Yes	
			YES	Related to C15. Lack of knowledge is still there. Maybe the supervisors are trained but there are a lot of unskilled workers which are hired for low budget.
			YES	Very important the coordination and construction responsibilities of teams working in the construction sites. And knowledge about how to perform the works and about the energy performance criteria
			YES	Sometimes worksite worker have any idea/background in this field.
			Yes	
C1 4	Accredited Construction Details 'tick box' culture, i.e. recorded in SAP but not built on site. YES (Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option)		YES	
			Yes	Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option.
			No?	Not known because the ACD are not known.
			YES	
			YES	Would be a great solution to avoid mistakes when working with profiles of persons without specific skills in building energetic field.
			Yes	RD sap is a major issue
C1 5	Poor installation of fabric, e.g. due to installation guidance or design drawings not followed. (YES, really important issue, is necessary		YES	Typically the cause of the majority of non-conformances
			Yes	Geo-tagged photos one option. Evidence of use of correct materials and products according to the design is necessary.
			YES	There is a lack of acceptance of the ‘theoretical’ rules for high energetic performance against the execution of work as it is done since ages or as it is easy to do.
			YES	All last versions of designs must be available during the construction and commissioning

	evidence of use, good and actualized details, and cheking the construction to avoid this)		YES	Really Important issue. It happens because of worker have not background and skills to follow the drawing, and because there isn't any check during the installation by a specific profile.
			Yes	Cold bridging because no detail. Not filling cavity property – full of rubble or insufficient
V1	Lack of robust verification of planning requirements and standards at completion. YES (really important, this control must be as accurate as possible, geo-tagged photos and B2S platform can helps)	Verification	NOT	Recent amendment to building control
			Yes	Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option.
			NOT	That would be a quite good idea for planning, at completion stage it is quite late.
			YES	At completion, it must be carried out the verification of the standards and requirements. This control must be as accurate as possible.
			YES	Really Important issue. For this reason the possibility to develop into B2S project new portable and user-friendly self-inspection is welcome to improve the final quality of the buildings.
			Yes	Often is not done, or very limited. Performance management, who is watching, governanace, legacy and managing issues post completion
V2	Lack of robust energy-performance related verification, reliance on third-party information (e.g. by Building Control or warranty providers).YES (really important, this control must be as accurate as possible, B2S platform can helps)		Yes	Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option.
			YES	At completion, it must be carried out the verification of the standards and requirements. This control must be as accurate as possible.
			YES	This would help.
			YES	B2S VCMP could be useful for this purpose because all the BLC aspects can be easily checked and documented across the lifetime.
			Yes	Relies on EPC , RD sap which are heavily assumption based.. auditing language not syncronised across the board
V3	Commoditised third-party schemes not independent or checks not adequate (including Competent Persons Schemes). YES		Yes	Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option.
			YES	At completion, it must be carried out the verification of the standards and requirements. This control must be as accurate as possible.
			YES	Really Important issue. Even if commoditised third-party schemes should be an independent "freelance" with a great experience behind.
			Maybe	They vary – CIGA SWIGA are well recognized, other schemes such as Green Deal are not.

V4	Lack of Building Control enforcement ability relating to energy efficiency legal requirements. YES (really important, no easy to check and could be expensive e.g. blower door test)		Yes	Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option.
			YES	Really Important issue. Is not easy to check the energy legal requirements, and also could be quite expensive (e.g. blower door test, thermal inspection and so on)
			YES	Knowledge is required to check the document according to the legal requirements.
			YES	At completion, it must be carried out the verification of the standards and requirements. This control must be as accurate as possible.
			No	n/a
V5	Lack of clarity over documentary evidence required or acceptable for energy efficiency and other regulations applying. (NO)		Yes	Evidence of use of correct materials and products according to the design is necessary. Geo-tagged photos one option.
			NOT	There is a clarity about the necessary documents in Germany, but the knowledge how to produce the documents correctly is not common.
			YES	At completion, it must be carried out the verification of the standards and requirements. This control must be as accurate as possible.
			NOT	In Italy the situation is quite clear about this topic especially when ones apply for a specific energy certification (e.g. CASA CLIMA).
			No	n/a
T1	Limited tests and agreed protocols available for in-situ fabric performance measurement. (maybe depending on the country)	**Testing** (when we have to do this tests to avoid the gap?)	YES	Develop a Protocol of testing performance measurement
			NOT	That is not the problem.
			NOT	The standard test are available even if not mandatory in Italy (a part when ones applies for a specific energy certification), the problem is related to their cost.
			Yes	Testing is often completed via energy consumption (electricity and gas comparing to baseline) for a range of energy efficiency measures – so this doesn't provide specifics on fabric
T2	Limited tests and agreed protocols available for in-situ services performance measurements, including for system performance. (maybe depending on the country)		YES	Develop a Protocol of testing performance measurement
			NOT	There are sufficient tests/measurement possiblilities available.
			NOT	The standard test are available even if not mandatory in Italy (a part when ones applies for a specific energy certification), the problem is related to their cost.
			Yes	Not distinct for each of measures, equipment and services. Blanket overall monitoring E.g overall performance rather than the individual elements.
T3			YES	

	Concern over consistency of some test methodologies and interpretation of data and guidelines (YES)		YES	Clear up methodologies and interpretation urgently required
			YES	Evaluate the possibility to introduce easier test to carry out on field would be useful.
			No	Because limited measures
T4	Limitations of air-pressure testing methodology (QA, robustness of third party certification, protocols). (maybe)		YES	
			NOT	Sufficiently available
			YES	Usually this kind of tests are quite expensive, the possibility to develop into B2S project new portable and user-friendly self-inspection is welcome to improve the final quality of the buildings.
			Maybe	
T5	Lack of suitable end-of-line overall performance test to validate energy calculation models, products and building fabric. YES		YES	
			NOT	Sufficiently available
			YES	B2S VCMP could be useful for this purpose because all the BLC aspects can be easily checked and documented across the lifetime. Thus in the final performance evaluation could be useful.
			Yes	It not necessarily the lack of a suitable performance model and testing, but the enforcement of testing and checking the data. full SAP with editable data would give a true reflection
T6	Tests not replicating or accurately taking into account dynamic effects, e.g. solar gain, microclimate, wind speed, weather effects. YES		YES	
			YES	Only in special cases
			YES	Specific tests should be planned by the Designer for the final check/validation.
			Yes	This is a widespread issue and can relate to product manufacturer claims don't take account of these.
T7	Limited tests and agreed protocols for innovative/less mainstream products and services. YES, with all innovative products exists some unknowledge not		YES	
			YES	This is an issue!!!!
			YES	Standards are usually quite conservative and not so open mind towards new typologies of tests.
			Yes	Products not in situ long enough to understand the durability and long term performance. Also not enough data on a range of applications

	only for testing but also for simulation			
EM1	Commercial pressures leading to optimistic SAP input assumptions. (YES) but a solution could be using products with independent certication or documentatio like European Technical Approval(ETA)	Energy modelling tools and conventions	YES	
				SAP is not used in Germany, therefore not comment possible
			YES	Could happen that some commercial products properties (e.g. thermal, acoustic,…) are pushed too much or presented in a way that can be not so clear to the final user.
			Likely	
EM2	Concerns about accuracy of aspects of the SAP calculation model and assumptions, e.g. thermal mass, hot water, ventilation, overheating, cooling, lighting, thermal bridging, weather, solar shading, community heating, particular technologies. YES		YES	
				SAP is not used in Germany, therefore not comment possible
			YES	It depends from the complexity of case under study.
			Yes	Very much so. Very widespread concern from all parts of the industry. Based on the climate of Sheffield and applies that to all buildings
EM3	SAP conventions not adequate, comprehensive or reflective of site conditions. YES		YES	
				SAP is not used in Germany, therefore not comment possible
			YES	It depends from the case under study. As much complicated is it, much more different could be the standard assumption/hypothesis from the real case. A great design team should be able to avoid these kinds of problems.
			Yes	As above
EM4	As-built SAP not reflective of actual build. (YES, designer has the responsability to ensure a proper model and to			Most energy rating modeling tools developed for the EPBD are compromises and are not accurate for housing. Non residential modeling tools are more sophisticated and accurate but depend more on the user for accuracy. All building modeling tools do not / can not take account of behavior so are usually incorrect. Thus these tools provide at best a relative comparison of energy performance against norms.

	chose the more accurated tool)			SAP is not used in Germany, therefore not comment possible
			YES	
			YES	Numerical model is a simplification of the real case, by the way is designer responsibility to ensure a proper model able to represent in the best way the real/final situation.
			Yes	As above
EM5	Lack of transparency and clear outputs for verifiers to check modelling assumptions (including designers to verify material performance assumptions, building controllers and others). (YES, but depend on the software)		YES/NOT	It depends on the software used during the design phase.
				SAP is not used in Germany, therefore not comment possible
			YES	
			Yes	Very little transparency on products and performance claims.
EM6	Infrequent or insufficient audits of SAP assessors by licensing organisations. (YES)		YES	Create an agenda with the number and dates of audits of SAP assessors
			NOT	Periodic checks, audits and so forth are (should be) performed.
			Maybe	
EM7	Concern over competency of SAP assessors (accuracy of data input, following of conventions, validation of assumptions, provision of design and specification advice). YES (sometimes SAP assessors has short training)		YES	Important aspect. The accuracy in all the aspects present in EM7 are basics and without them a great competency of the SAP assessor cannot be achieved.
				SAP is not used in Germany, therefore not comment possible
			YES	
			Yes	SAP training is only a few days long. This does not provide enough training and assessment to deal with the wide range of buildings.
EM8	Issues surrounding use of calculation procedures related to U-values and Psi-values or associated Standards. YES		YES	
			YES	Perhaps a thermal bridge catalogue would help
			YES	It depends for the complexity of the case under study. I mean if the case under study completely full-fill the calculation hypothesis, there were be no problems with the final

				numeric results, vice versa some problems can appear or I other words the results can be affected by relevant errors.
EM9	Limited as-built test data used in SAP calculations (only air-pressure testing). YES		Yes	
				SAP is not used in Germany, therefore not comment possible
			YES	
			YES	The possibility to develop into B2S project new portable and user-friendly self-inspection could help in this direction introducing more low-cost test during the commissioning stage.
EM10	Limited ability to include new technologies in standard calculation methodologies. YES		Yes	The methodology for new technologies to be included in national energy rating tools is limited, onerous and expensive.
				SAP is not used in Germany, therefore not comment possible
			YES	Calculations will be more accurate as more technologies include. The ideal situation will be making a real model including all technologies
			YES	It depends for the complexity of the case under study. Usually the calculation and design stage needs the introduction/definition of simplified structures. Thus the possibility to include new approaches can depends on the design team ability, background, experience and knowledge.
EM11	Concerns about the robustness or lack of overheating checks. YES		Yes	I agree most modeling for housing does not take account of solar shading or the lack of it which results in problems of overheating in some new dwellings in the Uk and Ireland.
				SAP is not used in Germany, therefore not comment possible
			YES	
			YES	The possibility to develop into B2S project new portable and user-friendly self-inspection could help in this direction.

Annex B Focus on thermal bridges. Italy input.

Thermal bridges are one the most important aspects that can influence the energy efficiency increasing consequently building energy consumption due to increased heat losses (by transmission). Important aspects related to thermal bridges are:

- **hygienic aspects:** possible formation of molds due to condensation on surface (see Figure 3.1.2);
- **structural aspects:** temperature variations inside the structures may determine phenomena of surface or interstitial condensation with consequential reduction in material durability;
- **comfort aspect:** reduction of indoor thermal comfort due to an not homogenous distribution of the indoor temperature in the indoor space.

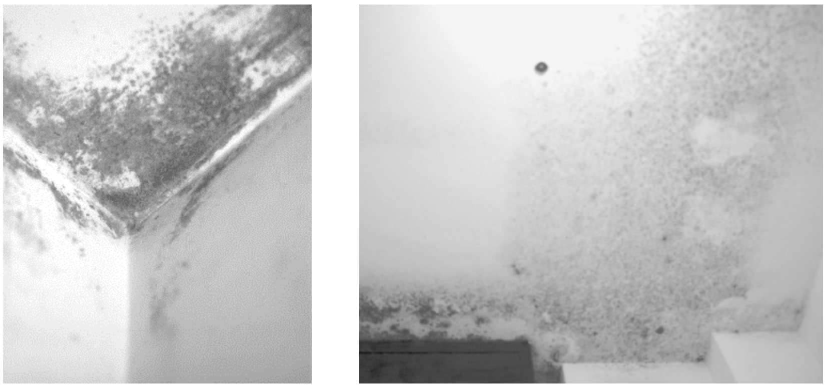


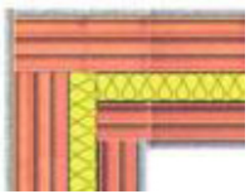
Figure 7.3.1 Molds due to surface condensation.

Thermal bridges "occur" in correspondence of any structural/technological nodes where the heat flow is not perpendicular to the surface of exchange, and it produces a greater heat exchange between inside and outside of the building.

Thermal bridges are usually classified into three different types[26] (see Table 7.3.1):

- **in shape:** it occurs in those points in which the inhomogeneity comes from the geometrical arrangement of equal elements from material and thermal properties (e.g. at the corners of the perimeter walls, in T-joints between partition internal and an external wall, etc.).
- **structure:** occurs coupling different materials (e.g. merging an iron column into a masonry wall).
- **hybrid:** occurs when the above situations are working simultaneously.

Table 7.3.1 Thermal Bridges standard typologies.

Typology	Example
in shape	

[26] http://www.cened.it/06_10_11 – Esempio best practice edilizia.pdf (in Italian).

structure	
hybrid	

A study carried out by "*Politecnico di Milano*, *ANCE Lombardia* and *Cestec S.p.A.* (2011)[27]" classified the most popular typologies of thermal bridge that can be found in buildings according to the most common building technologies. The classification was carried out interviewing Construction Enterprises. The analysis of the gathered data identified **125 types of thermal bridges**; moreover, each of them was associated with its frequency of occurrence. The result (see Table 7.3.2) of the study shown that only 8 types of thermal bridges are considered uncommon, 22 and 13 types are identified as "frequent" by few enterprises respectively, while only 12 types has been identified as "frequent" by all the companies interviewed. Furthermore 37 and 33 types are assumed as "frequently" by one and two enterprise respectively only.

Table 7.3.2 Thermal bridge classification.

	FREQUENCY CLASSIFICATION	Number	%
not common	0	8	6.4%
	1	37	29.6%
	2	33	26.4%
	3	22	17.6%
	4	13	10.4%
frequent	5	12	9.6%
	TOT:	125	100.0%

Another study, carried out by "*De Angelis and Mainini - Politecnico di Milano* (2010)[28]" shows how the influence of the thermal bridges during the design may affect in a non-negligible way the final energetic performance of the building carrying the designer towards wrong designing decisions that may significantly increase the final performance gap.

[27] http://www.cened.it/06_10_11 – Abaco dei ponti termici.pdf (in Italian).

[28] http://tecnologia.assimpredilance.it/Costruire_Classe_A/02a_De_Angelis_07ott10 (in Italian).

In this study the influence of thermal bridges in a standard 2 stories building (about 180 s.m. each story – see Figure 7.3.2) was investigated; standard brick walls (th = 40 cm) are assumed as perimeter walls; flat roof is also adopted.

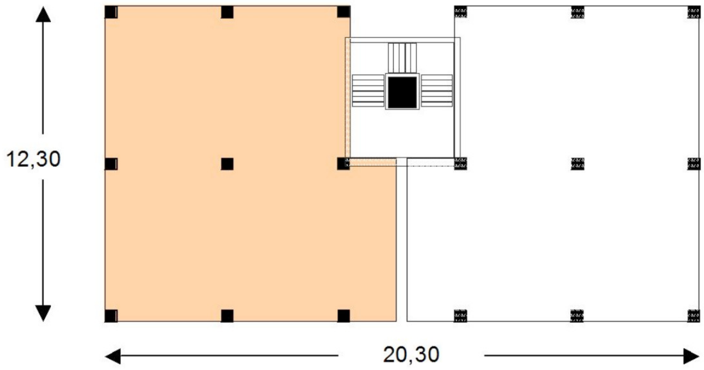


Figure 7.3.2 Molds due to surface condensation.

Neglecting the thermal bridges as first step, the thermal "transmission" losses are summarized in Figure 7.3.3. The main losses occur through the external walls since the external walls are usually the most extended external surfaces in a building.

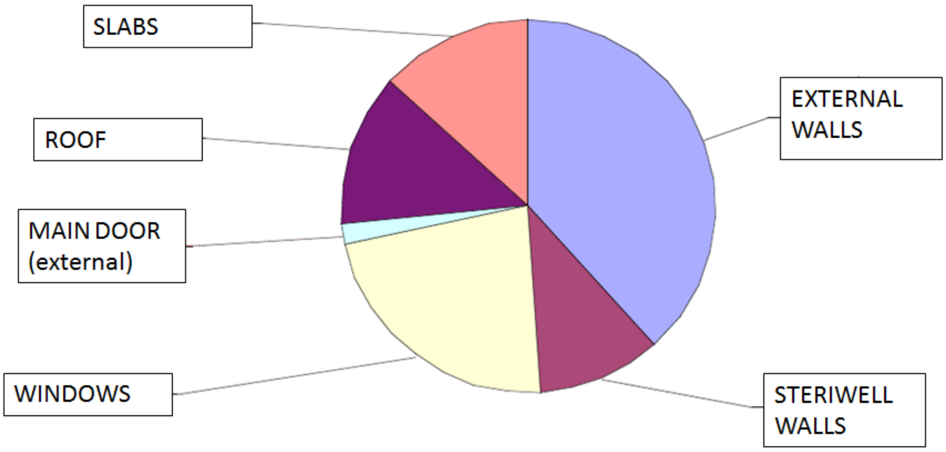


Figure 7.3.3 Thermal "transmission" losses without thermal bridges.

Introducing now the thermal bridges[29], the relative thermal "transmission" losses are represented in Figure 7.3.4. The thermal bridges are evaluated by the "linear thermal transmittance *Ψ*" according their typology – the average value adopted is Ψ_e*=0.80 W/mK*. Adopting increasing strategies to "avoid" thermal bridges is possible to assume decreasing value for "linear thermal transmittance *Ψ*"; assuming as an example Ψ_e*=0.60 W/mK*, and Ψ_e*=0.25 W/mK* the results are summarized in Figure 7.3.5 and Figure 7.3.6 respectively.

[29] The calculation has been carried out by the authors according to UNI/TS11300:2008 (now repealed). Even if the actual code has been updated, the results presented in this work are significant to understand the influence of Thermal Bridges during the design calculations.

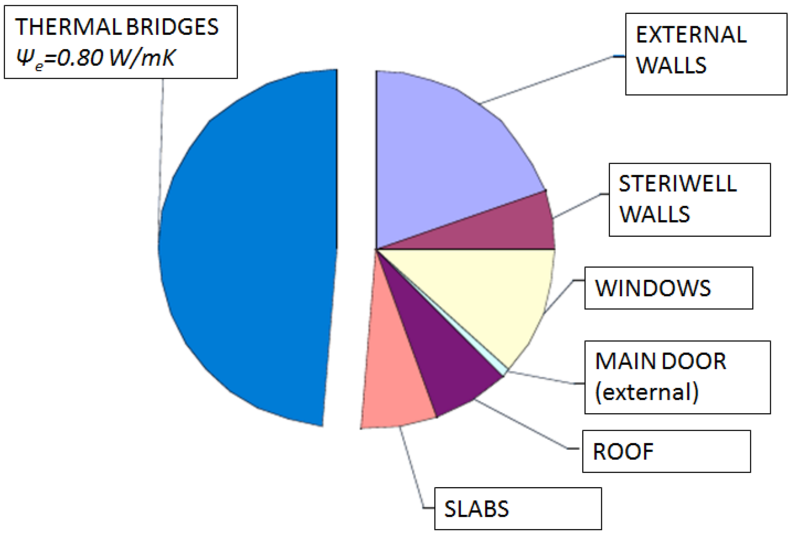


Figure 7.3.4 Thermal “transmission” losses - linear thermal transmittance *Ψ_e=0.80 W/mK.*

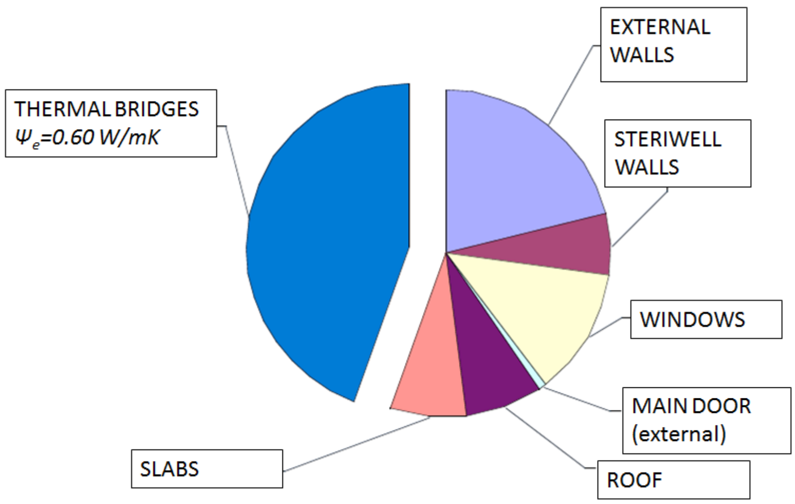


Figure 7.3.5 Thermal “transmission” losses - linear thermal transmittance *Ψ_e=0.60 W/mK.*

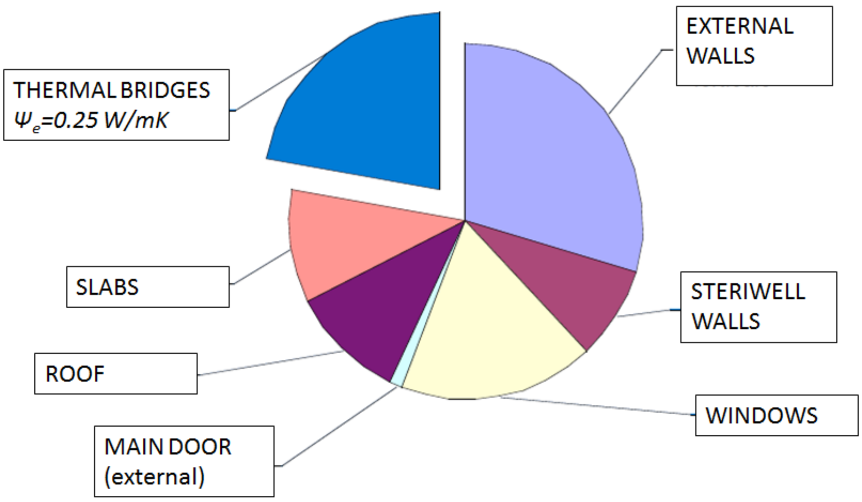


Figure 7.3.6 Thermal "transmission" losses - linear thermal transmittance *Ψ_e=0.25 W/mK.*

Analysing the above results is clear as un-controlled thermal bridges may significantly effects the whole thermal response of the building; thus these aspect cannot be under estimated during the design.

Since, as observed above, thermal bridges are quite sensitive with respect to the whole building energy performance , Italian regulations and standards are quite "severe" imposing to the designers how to estimate them and how to evaluate them to avoid under estimation of their effect to the whole energy response of the construction.

The current code in force in Italy to evaluate the energy performance of buildings is the UNI/TS 11300-1,2:2014[30]. With reference to the thermal bridges this code states that thermal bridges must be evaluated by:

1. numerical simulation - according to UNI EN ISO 10211 code;

or:

2. using "Thermal Bridges Abacus" drafted according to UNI EN ISO 10211 code[31].

both for new constructions and/or refurbishments.

The first method is based on the classic Finite Element Method (FEM). An example of this analysis is provided in Figure.8.

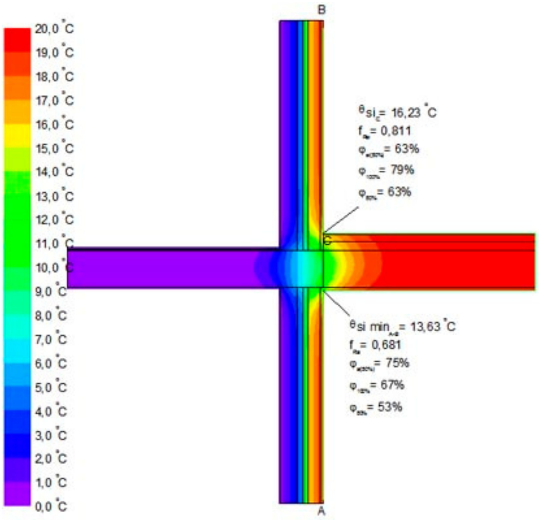


Figure 7 Example of thermal bridge Finite Element Analysis (FEA).

The idea behind the Abacus is to allow the designer to evaluated the "transmittance per unit length of the Thermal Bridge" simply knowing a few inputs: e.g. transmittance of the walls, wall thickness, thermal conductivity. These data can be easily gathered from survey on site and/or from technical datasheets. Thus, the solution provided by the Abacus is for sure the easiest way to evaluate the thermal bridges and nowadays almost all commercial software have proper Abacus database (Figure.8).

30 In force code to draft the Energy Performance Certificate (*APE = Attestato di Prestazione* in Italian) is the "DECRETO MINISTERIALE *D.M. 26/06/2015* (Gazzetta Ufficiale 15/07/2015 n. 162).

31 In D.M. 26/06/2015 Abacus have been updated.

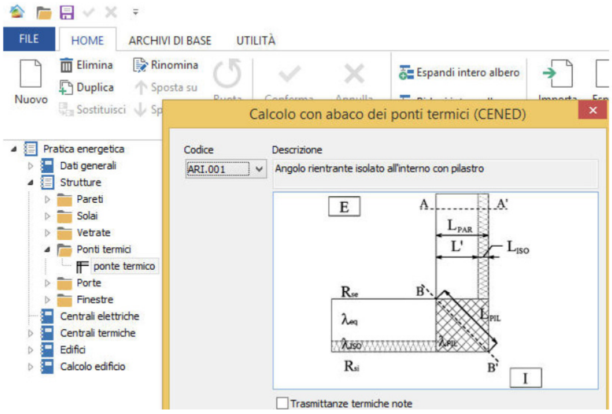


Figure.8 View of the Abacus window of "Termo 3 software" by Namirial.

The most popular Italian Abacus, and the ones designers must adopt in their calculations are:

- **CENED - Abaco dei Ponti Termici:** freeware abacus of 90 different typologies of thermal bridges drafted by the *Politecnico di Milano*, *ANCE Lombardia* and *Cestec S.p.A.*[32];
- **Atlante Nazionale dei Ponti Termici:** published by *Edilclima Edizioni* (2011) – authors: *Vincenzo Corrado* and *Alfonso Capozzoli;*
- **Abaco dei Ponti Termici svizzero**: freeware Swiss Abacus (in French).

UNI/TS 11300:2014 code introduces significant improvements regarding the evaluation of thermal bridges. Old code (UNI/TS 11300:2008) allowed a simplified methodology to evaluate the thermal bridges based on *"a percentage of the whole thermal transmittance"*. A comparison of the approaches in the two codes is presented in the next table (Table 7.3.3).

Table 7.3.3 Calculation Method comparison.

Thermal Bridge Calculation Method	**OLD CODE (UNI/TS 11300:2008)**		**NEW CODE (UNI/TS 11300:2014)**	
	new construction	**existing buildings**	**new construction**	**existing buildings**
as a percentage of the thermal transmittance	✗	✓	✗	✗
Abacus OLD VERSION (UNI/TS 11300:2008)	✓	✓	✗	✗
Abacus NEW VERSION (UNI/TS 11300:2014)	NA	NA	✓	✓
Numerical Simulation (FEA)	✓	✓	✓	✓

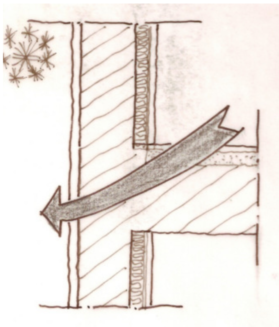
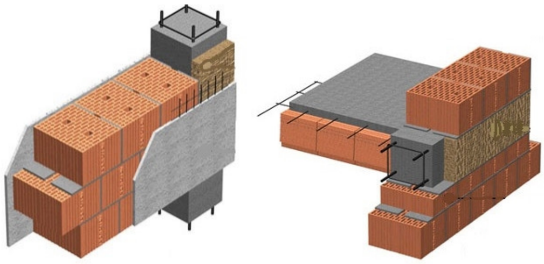
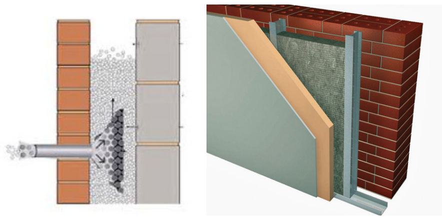
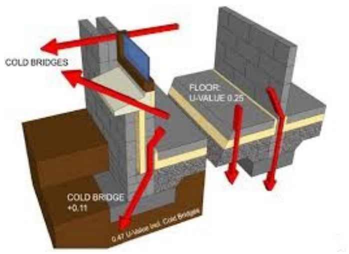
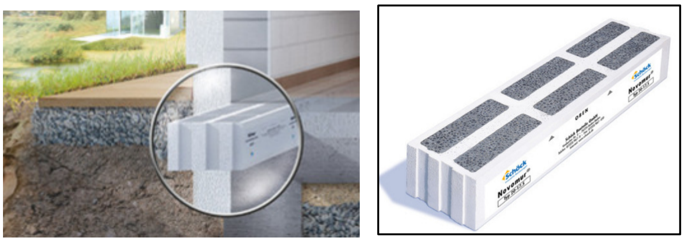
Thermal bridges cannot be avoided but can be reduced adopting proper strategies. There are some best practices to be applied during design process; some examples are:

- External/Perimeter walls, foundations, etc. (example in Table 7.3.4):

[32] http://www.cened.it/06_10_11 (in Italian).

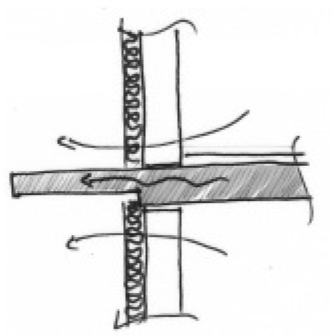
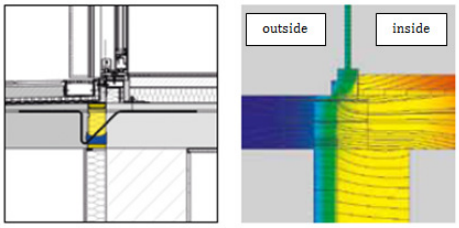
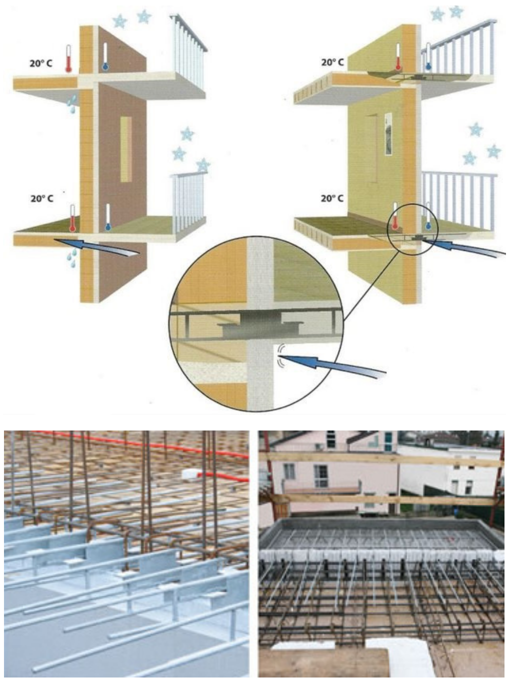
- avoid weaknesses as thermal niches for radiators;
- provide a sufficient thermal insulation from the outside to solve the thermal bridges due to the pillars (thermal coat);
- prolong the thermal insulation of external walls below the level of the first slab;
- additional insulation in correspondence with diaphragm, wall and pillars.

Table 7.3.4 Thermal Bridge in external walls and related best practices.

Schematic representation	Best practices
 *External Walls*	 *insulation of beams and columns*
	 *thermal coats*
	 *filling "wall cavity" with proper thermal insulation material*
	 *wall bottom side insulation*
 *Foundation*	 *foundation thermal decoupling SCHOECK solution (Schöck Novomur®) - (http://www.schoeck.it)*

- Overhangs, balconies, external stairs, etc. (example in Table 7.3.5):
  - provide a "thermal break" between the balcony and the ceiling using special structural elements;
  - provide proper structural elements detached from the building and / or anchored in a few points;
  - provide proper thermal insulation on both sides of the element.

Table 7.3.5 Thermal Bridge in balconies and related best practices.

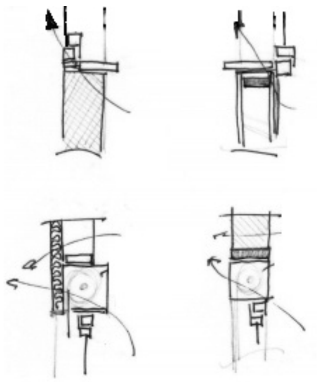
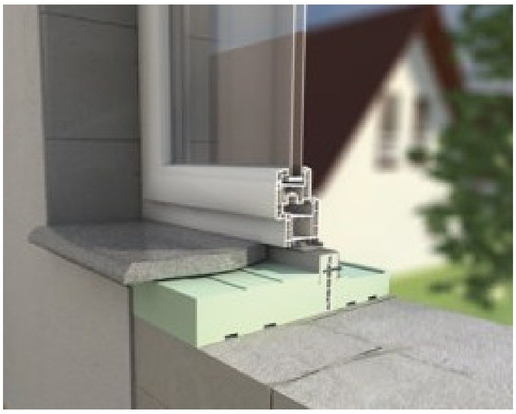
Schematic representation	Best practices
 *Thermal Bridge in a balcony*	 *thermal decoupling - SCHOECK solution (http://www.schoeck.it)*
	 *thermal decoupling - MENSOLINO solution for standard RC, bricks,… buildings (http://www.pontarolo.com/)*

	 **thermal decoupling - achieved posing a layer of EPS insulant material along the steel structure in contact with the vertical X-LAM external panels** **(http://espertocasaclima.com/2015/03/balcone-pontetermico-in-struttura-in-x-lam-zona-climatica-e-gg-2784-lavis-tn/)**

- Window (example in Table 7.3.6):
  - isolate any concrete lintels;
  - insulate the bottom side of any the sills and for each of them realize the “thermal break” between inner and outer side;
  - create a continuous layer of insulation material all around the windowing hole, and overlap the thermal insulation to the frame.

Table 7.3.6 Thermal Bridge in windowing and related best practices.

Schematic representation	Best practices

 *Thermal Bridge in a balcony*	 *insulation below the sill*  **perimeter insulation around the windowing**

- Roofs/Slabs (example in Table 7.3.7):
  - provide a "thermal break" between the structures;
  - provide proper insulation layer.

Table 7.3.7 Thermal Bridge in roofs/slab and related best practices.

Schematic representation	Best practices

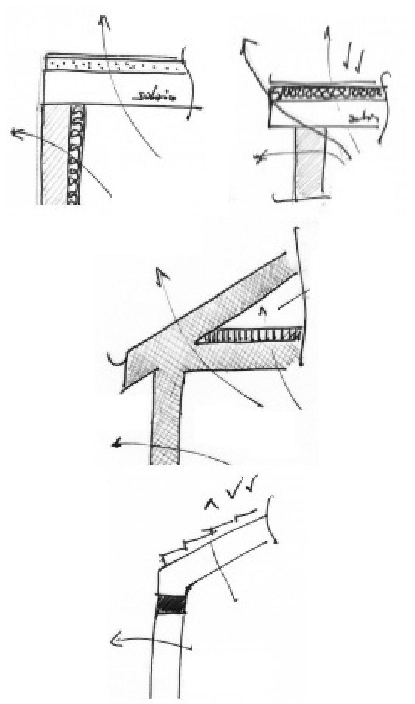
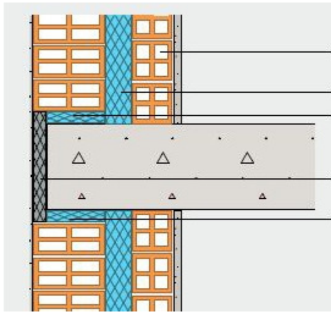
 *Thermal Bridge in roof/slab*	 *slab thermal break*

Figure 7.3.9 shown a comparison of the effects of thermal break in different applications. The benefits in term of indoor temperature in underlined by the color bar. The thermal break significantly reduce the heat losses.

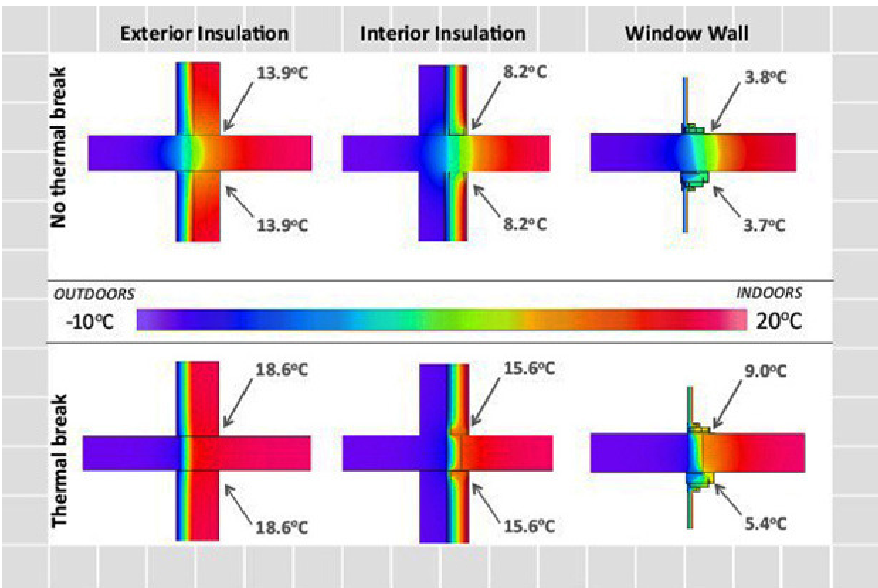
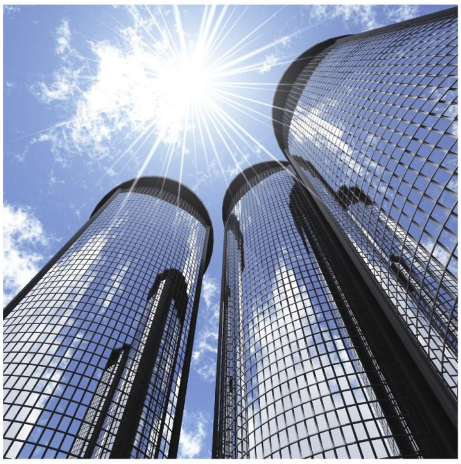


Figure 7.3.9 FEA of the Thermal Break effects (http://www.architetturaecosostenibile.it/normative/leggi-decreti/calcolo-ponti-temici-uni-338/).

Annex C UK input for T1.4

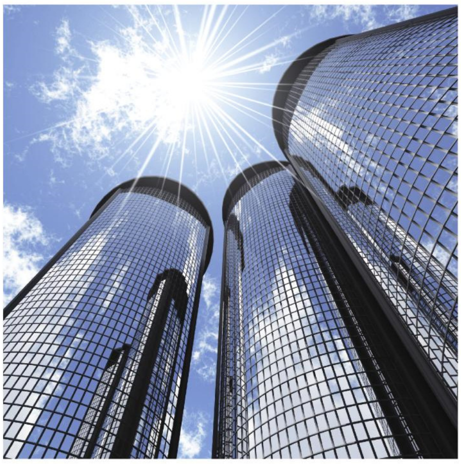


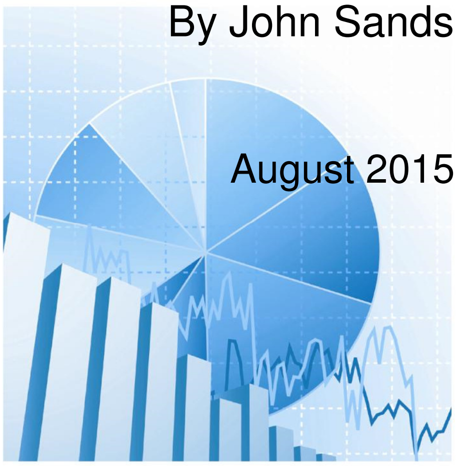
Built2Spec - WP 1.4 Methodology to assess change to the design/commissioning performance gap

UK input to WP 1.4

Carried out for

Built2Spec





By John Sands

August 2015

Built2Spec - WP 1.4

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CONTENTS

1 Introduction

This report has been produced in support of Task 1.4 of the '*Built to specifications – self inspection, 3D modelling, management and quality check tools for the 21st century constructions work site*' project, and relates to practices and behaviours in the UK construction and asset operations markets. This document also presents BSRIA's input to D1.2, Performance Gap Assessment Methodology.

1.1 Background to Task 1.4

In section 1.3.3 *WT3 Work package descriptions* of the *Description of Actions* document, the scope of Task 1.4 is described as follows:

> 'Task 1.4: Methodology to assess change to the design/commission performance gap
>
> One impact specified in the call text is a "Reduction by at least 50% of the mismatch of energy performance between design stage and commissioning stage due to construction processes." This requirement generated some interesting discussions from the partners and a methodology will be required for that so that it can be communicated to the pilots, implemented and reported.
>
> In this task a methodology will be developed to assess which out of the large amount of normal activities within the design, detailing, implementation, commissioning and maintenance phases of a construction project can contribute significantly to reduce the energy performance gap.
>
> Apart from the call text requirement, such a task is worthwhile because it will increase the credibility and rigor of project results and the associated foreground for exploitation and impact.'

This report looks at these objectives in the context of the UK construction and asset operations markets, and describes related activities, processes and behaviours to support or reinforce them. The specific topics covered in this report are:

- Performance gap
- Construction processes including UK legislation, regulation, plans of work, construction procurement routes
- Recent changes to the construction process in the UK including construction initiatives, Building Information Modelling (BIM) and Soft Landings.

2 The Performance Gap

2.1 What is the performance gap and what are the main factors causing it?

The performance gap is the difference between the predicted energy performance of a house and its performance as-built. This gap is caused by many different factors as stated in recent reports[33] including:

1. A lack of training provided to the workforce that builds houses in energy performance and what affects it. This means that the expertise in energy performance that were available for the design stage of the process are no longer available for the construction stage, so unintended changes occur causing the performance gap to occur.

2. New entrants into this work force are not being trained in energy performance so do not know the reason why certain things are designed into a house.

3. The Government isn't leading the way to try to improve as-built energy performance.

The issue of the difference between energy consumption of an asset assessed during the design stage and what is actually consumed during operation has been evident within the UK construction industry for many years. This is often referred to as the "performance gap".

The reasons for this gap range and accumulate throughout the design and operation process to result in buildings that often use more than double their expected energy. Some examples of why and where the performance gap issues are occurring are:

Briefing stage

Performance gap issues can occur as a result of poor briefing – e.g. this can occur if the client fails to inform the design team of what they want and how they want to operate their new building.

Design stage – concept, developed and technical

Decisions at the design stage have a significant impact on performance in use. For example, changes in the design or value engineering in an attempt to save costs can interfere with rigorous design principles, compromising the performance of the final result. There may also be design errors or inaccurate assumptions which will create unrealistic baselines for expected performance.

Predicting how occupants will behave is a factor that comes into play at the design stage. Behaviour, particularly in domestic buildings, can vary significantly depending on the type and number of occupants, employment status and personal interests. If incorrect assumptions are made or the design team fail to understand the occupant's needs then differences between predicted and actual performance will occur.

Construction stage including installation

[33] Zero Carbon Hub publications

There are issues occurring at the construction stage of a project that impact on the performance once a building is in-use and therefore contribute to the performance gap:

- If the building fabric characteristics are different to those used in the design, variation in performance will occur.
- Installation errors or poor quality of installation.

Commissioning, handover and close-out

Commissioning is sometimes poor and can be the stage compromised the most in the construction process. If the timetable slips the commissioning period is often squeezed.

The focus at the handover stage should be on guides, manuals, walkthrough, support, all designed for usefulness, completeness, usability and sensitivity. However, similar to commissioning, handover is often rushed and incomplete.

In-use, post-occupancy stage

There is currently no widespread culture of reviewing what has been constructed and then using that knowledge to inform future projects. Initiatives within the UK are looking to change this – see Soft Landings, section 4.3.

2.2 Industry research into the Performance Gap

A number of studies have been carried out in the UK over the last 10 years or so, to try to identify the causes in order to be able to find solutions. This section includes research outputs and articles from a number of recent studies looking at this issue.

2.2.1 Closing the Performance Gap: First Signs of Good Research and Development – Director of the Leeds Sustainability Institute, School of the Built Environment and Engineering, Christopher Gorse, Leeds Metropolitan University

Closing the Performance Gap: First Signs of Good Research and Development

The 20 years of work undertaken at Leeds Metropolitan University has uncovered significant deviation between the designed and intended building performance and that achieved when buildings are actually constructed. The recognition of the deviation between that expected and that delivered has caused debate and confusion, with many professionals and trades not fully understanding the consequences of this finding and pressing ahead with construction practices that don't work. If buildings fail to meet the specified contractual requirements, they are not fit for their intended performance. The construction industry is now seeing its clients and tenants seeking redress for buildings that are costing more to operate than they should do. At the other end of the scale there are some notable exceptions that are engaging in intensive research and development and making significant improvements to building performance.

The Leeds building performance work, initiated by Professors Low and Professor Bell, now falls under the leadership of Professor Chris Gorse. The knowledge gained through this period of continuous research at Leeds Metropolitan University is substantial and progressing at a pace. While the research is sizable, there is still much work to be done to understand the built environment and measures needed to ensure negative impact on the environment is reduced.

With the legal commitment to reduce carbon emission, under the Climate Change Act, and the direct pressures of the Energy Performance and Building Directive, industry leaders are setting the agenda for change. However, in some cases, change has started prematurely without proper insight into the processes and innovations. Before new products are distributed they need to be tested and the knowledge gained through research should be used to inform future developments. Some knowledgeable professionals, have a good understanding or what is required whilst others demonstrate a level of inadequate understanding by the underperformance actually achieved. Interestingly, whilst the research has shown that many buildings underperform, the construction industry has not seen the product recalls which are typical in other industries. In other industries when reputable companies uncover problems with systems and components produced, their products are recalled and improvements made without cost.

Up-grading the building stock

The scale of the ecobuilding and upgrading of the building stock is substantial, requiring considerable research and development and a steep learning curve to maintain paces with the advances made. Currently, so few of the existing 22 million homes in the UK operate close to the standards expected and legislated for that the whole building stock is in need of an Eco upgrade.

The retrofit market for domestic buildings is estimated at £200 billion over the next 20 years (King, McCombie & Arnold 2012). According to King et al, with an average 10,000 for each building upgrade, a spend rate of £7 billion per year is required up to 2020 and £15 billion from 2020 to 2030. If this money is not to be wasted, the industry must design and build reliably and with confidence, to ensure the investment achieves the expected benefits. Unfortunately, the industry has a reputation for being weak on building quality, especially thermal building performance. However, we are now seeing notable good exceptions, supported by research, that demonstrate how we can reliably achieve low energy buildings with high thermal comfort standards.

Retrofit, Eco funded Refurbishment and Green Deal

Refitting the whole building stock has some significant challenges which industry has to overcome. Meeting design aspirations is more difficult with existing buildings as there are often aspects of the existing structure that we do not fully understand. Without costly detailed forensic investigation, the qualities of the existing structure remain largely unknown. The performance of an existing building and improvements achieved through a thermal upgrade is dependent on the condition of the existing structure, its size, building type, materials, components and the properties that manifest when new retrofit measures are introduced. For each building type the performance is likely to vary, however when interventions are carefully considered measured improvement is achievable. Through research and development, we are learning how to gain more consistent low energy behaviour and more consistent building behaviour over a wider range of buildings. Where interventions are successful and tangible benefits achieved the products go to market with confidence and valid building performance claims.

The Leeds Metropolitan University and Joseph Rountree Foundation study of the retrofit project at Temple Avenue shows significant and stepped improvement in the thermal performance of the building. The retrofit measures were undertaken in two distinct phases of thermal upgrade and benefits were achieved. As well as the thermal performance upgrades, the property also benefitted from improved aesthetics, new windows, finishes and an insulated cladding layer that prolongs the expected life and usefulness of the structure.

Through our other retrofit research we are also seeing other, carefully considered and controlled, interventions that change the building enclosure from being unsealed, perforated and uncontrollable fabrics to building elements that are more able to restrict thermal and air movement, enabling the property to be controlled.

Nearly Zero Standards Achieved

The 2013 results published by Leeds Metropolitan University on the thermal performance of domestic buildings, show the Passivhaus dwellings outperforming all other buildings studied. Surprisingly the buildings studied also had one of the closest relationships between the expected designed performance and that achieved in reality. While many believe that as the design and regulatory standards become more stringent they become more difficult to achieve. However, the results suggest that it is possible to design and build nearly zero properties. Against the research that was responsible for identifying the performance gap and raising concern about the size of the discrepancy it is reassuring that thermally efficient designs can be drafted and built with confidence. The research undertaken over a 20 year period show that some properties studied experienced twice the expected heat loss, while recently the low energy properties studied were within acceptable tolerance. Obviously this does not need to be the case. The research shows that a failure to design and build properly results in significant underperformance, while clearly with the right attention low energy and carbon standards can be achieved.

References

King, D, McCombie and Arnold S (2012) The case for centres of excellence in sustainable building design. London, The Royal Academy of Engineering

LSi (2013) Centre for the Built Environment Resources and Publications, http://www.leedsmet.ac.uk/as/cebe/

2.2.2 The Performance Gap – want can we learn from Darwin? – Tom Kordel, Senior Energy Consultant at XC02 Energy, published on the UKGBC website

There is broad acknowledgement in the construction industry of late, that buildings tend not to perform in reality to the standards their design calculations predict. This is commonly known as the “performance gap”.

You might hope that the gap has been getting smaller as the building industry catches up with the pace of legislation, but in fact early indications are that it is growing at a worrying rate. This hasn’t gone unnoticed, and there are organisations in the industry (e.g. UKGBC, Carbon Buzz, Usable Buildings Trust etc.) who are attempting to reverse the tide.

There are a range of reasons for this gap that compound throughout the design and operation process to result in buildings that often use more than double their expected energy. Decisions at the design stage, that seem unimportant at the time, can have a significant impact on performance in use. Value engineering can water down sound design principles until the final built product quality is compromised. Occupant behaviour often confounds our expectations and leads to a building that, if operated as expected, might perform well, to disappoint us simply because we either failed to properly understand the occupant’s needs or because we did not successfully communicate to the client how best to operate their new building.

Commissioning is currently a notably weak link in the construction process. When timetables slip, the commissioning period is the first to get squeezed. Similarly in budgetary terms commissioning is perhaps seen as less crucial than other areas. The commissioning engineer (CE) is typically hired by the main contractor, which inevitably leads to a pressure to sign off systems as the deadline of practical completion approaches. In smaller projects particularly, the CE is often the installer, which can be a mixed blessing. The installer knows their part of the install inside out, but they may not fully appreciate how their system integrates into the rest of the building design quite so well. Standard manufacturer settings might not be ideally suited to every installation.

How do we fix this situation? We don't yet have a clear answer, but some frameworks such as Soft Landings are producing promising results and there are perhaps other changes that can improve matters. If the client typically hired the lead CE rather than the contractor, they might end up with a commissioning process that is impacted less by completion deadlines. If the budget and time allocated for commissioning could be protected this might also help the situation. But these things are unlikely to become standard practice. Not without some incentive, some accountability, some feedback. On a broader scale, we know that the issues at each construction and design stage are affecting our buildings, but in a culture where buildings are handed over and forgotten about, there is little motivation, other than a time limited and often ill-used defects period, to fix things. Part L and EPCs focus on building design, not results; so as long as it looks good on paper as a designer, we're happy.

This status quo can't last. If we're to meet the ambitious CO_2 targets that have been set, we have to improve our buildings in reality as well as in theory. This can't happen if we don't learn as an industry from our own creations. There has to be feedback for things to improve, both quantitative and qualitative. How much energy does the building use, where does it go and why? Are the occupants comfortable in this building? If not, why not? What could have been done better? How can the building be optimised? – These are all questions we should be asking about every building we complete.

In short, as shown in the case of natural selection, feedback is essential. Without it we end up perpetuating the bad ideas, while the good ideas don't get their chance to multiply.

Building Performance Evaluation (BPE) is an attempt at providing this feedback, and in an ideal world we would carry it out on every new building. However, it can be an expensive and time consuming activity, and most clients or project teams will not be willing to invest the money required to carry it out unless it is compulsory or cost effective. I believe it can be cost effective if we examine it over a long enough period or a broad enough scope. The savings to the industry as a whole generated by working out what systems and designs are most effective are considerable. We just need to find a way to line up the interests of the individual parties involved with the interests of the industry.

There are growing calls in the construction industry for the government to implement mandatory DECs for all, and some even suggest removing the design targets in Part L altogether, and in their place introduce performance targets based on actual in use results. This would be a significant shake-up and could be just the medicine the industry needs to boost the feedback loop. With increasingly stringent performance targets, the industry would quickly learn to ensure buildings perform in operation. As an inevitable side effect building design and construction would begin to evolve in the way it ought to.

2.2.3 Closing the gap. Lessons learnt on realising the potential of low carbon building design – Carbon Trust, part of their 'Sharing our experience' series

This booklet (see link below) was produced based on real data gained during 28 case studies from the Department of Energy and Climate Change's Low Carbon Buildings Programme and their work on refurbishments. The projects cover many sectors including retail, education, offices and mixed use residential buildings.

https://www.carbontrust.com/media/81361/ctg047-closing-the-gap-low-carbon-building-design.pdf

2.3 Summary of findings

The following section summarizes the findings gathered on the performance gap during a short research period looking at Zero Carbon Hub studies.

2.3.1 The Performance Gap

The performance gap is the difference between the predicted energy performance of a house and its performance as-built. This gap is caused by many different factors as stated in the Zero Carbon Hub's end of term report for July 2014. The report included many different reasons for the gap as well as what can be done by services in the housing industry and by the government to increase the shift towards houses that produce no performance gap. This report summarises the points made in the Zero Carbon Hub's end of term report about the causes of the performance gap and what can be done to close the gap and potentially eliminate it.

What is the performance gap and what causes it to occur?

The performance gap is the difference between the designed energy performance of a house and the as-built energy performance. This gap is caused by the lack of training provided to the workforce that builds houses on energy performance and what affects it. This means that the expertise in energy performance that were available for the design stage of the process are no longer available for the construction stage, so unintended changes occur causing the performance gap to occur. Another reason given for the performance gap is that the new entrants into this work force are not being trained in energy performance. A third reason given for the energy gap was that the Government isn't leading the way for improvements to the as-built energy performance.

2.3.2 Priority changes for industry

Change in continuity

The lack of continuity with regards to energy performance is one of the main causes of the performance gap as the expertise needed to keep the energy performance up to the level of the design of the house is not kept as unintended changes are made that reduce it. Zero Carbon Hub has therefore suggested that, what they described as, an 'energy champion' is appointed, and will be involved in the entire process for the construction and design of the houses. This ‘energy champion’ would have the required expertise to make sure that all of the houses are built to the spec they were designed to be, this in turn would eliminate some of the energy gap and increase the continuity, therefore causing a reduction in the performance gap.

Change in processes

Currently in industry the moment the house design is ready to move onto the next stage of the process, it goes without a seconds thought about whether its energy performance is the same as it was before the start of that part of the process. Due to this lack of adequate checking Zero Carbon Hub have proposed that the design of the house should be checked as to whether it would have the same energy performance as the original design before it is allowed to continue to the next stage. This will mean that the performance gap is closed even more as the steady loss of energy performance from the original design will be mostly eliminated as it will be checked at each stage for any changes in its energy performance.

Change in training for new entrants and the current workforce

The new entrants into the workforce should be trained in energy performance so that they can contribute to the continuity of the energy performance expertise in the construction part of the process. More extensive training for them would mean that unintended changes would not occur as they would know what the consequences of that change would include and how it would affect energy performance. Furthermore the training provided to the current workforce would enable these changes in knowledge to occur in the construction stage before the new entrants arrive from their training. This would mean that the new entrants would just add to the knowledge of the current workforce, so the performance gap will be closed even more.

Change in attitudes towards competitors

Zero Carbon Hubs idea of the online ‘Knowledge Hub’ is a way of keeping a level playing field in the housing industry. The ‘Knowledge Hub’ is a proposed online service on which companies post their discoveries about causes and solutions to the performance gap. The hub would enable all companies to have access to the same data, so all should be able to build houses that have the energy performance levels that they were designed to have and not end up with unintended changes.

2.3.3 Priority actions for Government

Show clear direction

The government should show that they want the construction industry to implement measures to counteract the performance gap and to give the industry a reason to do it. Zero Carbon Hub suggest that they should not put any regulations in place to counteract it but let the industry have control over that until 2020, by which time industry should be addressing the situation with the performance gap and be able to prove it.

Show that they are serious about closing the Performance Gap

The government should show that they are serious about helping closing the gap. To do this they should help fund R&D into testing the energy performance of planned houses more accurately, in order to support the industry in providing the required information to quantify the performance gap, but also help create learning loops so that everyone in the industry gains from the government funding.

Strengthen the requirement for compliance

Zero Carbon Hub are encouraging the government to take action by 2016 to ensure that the Zero Carbon Hub revisions to energy modelling practises, SAP processes and verification procedures, along with a requirement for appropriately qualified personnel to carry out energy modelling, can be implemented. This will mean that there would be more persons with higher levels of qualifications working in the industry, so a greater proportion of the workforce would know what will and what won't affect the energy performance of a building.

Support of skills and knowledge improvement

The government should be encouraged to accelerate the demand for personnel with higher levels of education and more specialised qualifications. This would drive the industry to develop its skills and knowledge so that the performance gap can be driven to close up as more specialised skills will be required.

2.3.4 Improving skills of the existing workforce

Site operatives

Site operatives need to be educated in energy performance so that they know what they can and can't do to the design of a building. They also need to be taught not to drastically change the design of a building so that the finished building is as close to the original design as physically possible. They also need to be taught that when the drawings and designs they are given to construct the building from are inadequate they should take them back to site management. The best order to build the buildings in so that the energy performance isn't affected during the construction also needs to be taught.

Other construction managers and building professionals

Stakeholders in the housing industry must be made suitably aware of low energy designs and the performance gap. This would mean that more money would be put into funding houses that are more energy efficient and have less of a performance gap. It is apparent that there are often issues between design and construction teams due to a lack of specific collaborative planning sessions involving both teams. If these planning sessions were to happen then the construction team would be able to understand clearly what the design team want the house to be like and which sections of the house are vital to its energy performance and which sections aren't.

3 The Construction Process

3.1 The UK construction market

The UK construction market is very mature, and is regulated by a combination of primary legislation and local rules and practices.

3.2 Legislation and Regulations

3.2.1 Primary legislation

The main piece of primary legislation controlling construction in the UK is *The Building Act 1984*. This primary requirement is interpreted further through secondary requirements such as the Building Regulations. Specific requirements exist for three areas within the UK - England and Wales, Scotland and Northern Ireland, but generally follow the overall requirements.

Other legislation includes:

Sustainable and Secure Buildings Act 2004

This introduced new powers and requirements with respect to a range of building related issues

The Party Wall etc. Act 1996

This covers issues around work on a wall or building element which may be part of more than one structure

Building Regulations

The legislative framework of the Building Regulations is principally made up of the Building Regulations 2010 and The Building (Approved Inspectors etc.) Regulations 2010

Local Acts

There are many Local Acts in operation in various areas in England and Wales. The local authority will be the arbiter of relevant Acts under their jurisdiction

Charges for Building Control

The Building (Local Authority Charges) Regulations 2010 enable local authorities in England and Wales to charge for carrying out their main statutory building control functions relating to the Building Regulations

3.2.2 Planning permission

The construction of new buildings and facilities in the UK must be in accordance with policies determined by central Government, aimed at allowing development which is sustainable and in the interests of the communities in which they may be located.

In 2012 the previous planning requirements were replaced by the National Planning Policy Framework. This change was aimed at simplifying the planning process and giving local communities a greater say in what development is permitted locally.

The National Planning Policy Framework sets the minimum requirements from a central Government perspective, and the local authorities and communities have the freedom to produce further requirements to suit the particular needs of the local environment.

The National Planning Policy Framework constitutes guidance for local planning authorities and decision-takers both in drawing up plans and as a material consideration in determining applications. It states 12 'core planning principles' that should:

- be genuinely plan-led, empowering local people to shape their surroundings, with succinct local and neighbourhood plans setting out a positive vision for the future of the area. Plans should be kept up-to-date, and be based on joint working and co-operation to address larger than local issues. They should provide a practical framework within which decisions on planning applications can be made with a high degree of predictability and efficiency;
- not simply be about scrutiny, but instead be a creative exercise in finding ways to enhance and improve the places in which people live their lives;
- proactively drive and support sustainable economic development to deliver the homes, business and industrial units, infrastructure and thriving local places that the country needs. Every effort should be made objectively to identify and then meet the housing, business and other development needs of an area, and respond positively to wider opportunities for growth. Plans should take account of market signals, such as land prices and housing affordability, and set out a clear strategy for allocating sufficient land which is suitable for development in their area, taking account of the needs of the residential and business communities;
- always seek to secure high quality design and a good standard of amenity for all existing and future occupants of land and buildings;
- take account of the different roles and character of different areas, promoting the vitality of our main urban areas, protecting the Green Belts around them, recognising the intrinsic character and beauty of the countryside and supporting thriving rural communities within it;
- support the transition to a low carbon future in a changing climate, taking full account of flood risk and coastal change, and encourage the reuse of existing resources, including conversion of existing buildings, and encourage the use of renewable resources (for example, by the development of renewable energy);

- contribute to conserving and enhancing the natural environment and reducing pollution. Allocations of land for development should prefer land of lesser environmental value, where consistent with other policies in this Framework;

- encourage the effective use of land by reusing land that has been previously developed (brownfield land), provided that it is not of high environmental value;

- promote mixed use developments, and encourage multiple benefits from the use of land in urban and rural areas, recognising that some open land can perform many functions (such as for wildlife, recreation, flood risk mitigation, carbon storage, or food production);

- conserve heritage assets in a manner appropriate to their significance, so that they can be enjoyed for their contribution to the quality of life of this and future generations;

- actively manage patterns of growth to make the fullest possible use of public transport, walking and cycling, and focus significant development in locations which are or can be made sustainable; and

- take account of and support local strategies to improve health, social and cultural wellbeing for all, and deliver sufficient community and cultural facilities and services to meet local needs.

Local planning authorities set out the strategic priorities for the area in a Local Plan. This should include strategic policies to deliver:

- the homes and jobs needed in the area
- the provision of retail, leisure and other commercial development
- the provision of infrastructure for transport, telecommunications, waste management, water supply, wastewater, flood risk and coastal change management, and the provision of minerals and energy (including heat)
- the provision of health, security, community and cultural infrastructure and other local facilities, and
- climate change mitigation and adaptation, conservation and enhancement of the natural and historic environment, including landscape.

Planning applications are to be submitted for each qualifying project via the appropriate local authority planning department. Typically in England and Wales, a decision on a particular application will be given within eight weeks of submission of all required planning documents. This period may be extended if further information is needed due to the nature of the application.

3.2.3 Building Regulations

Whereas the planning process is concerned with the form and location of development, the technical quality of what is constructed is dealt with under Building Control requirements.

Once planning permission has been granted, a submission must be made to the appropriate building control body for approval prior to starting work. The Building Regulations is the primary legislation for controlling the quality of construction in the UK. The Regulations themselves consists of 14 technical 'parts' which set overall objectives, but do not prescribe how to achieve them.

The Building Regulations are made under powers provided in the Building Act 1984, and apply in England and Wales. The current edition of the regulations are 'The Building Regulations 2010' and the Building (Approved Inspectors etc.) Regulations 2010 and the majority of building projects are required to comply with them.

Further amendments made to the Building Regulations 2010 and the Building (Approved Inspectors etc.) Regulations 2010 are:

- The Building Regulations etc (Amendment) (No.2) Regulations 2013 (SI2013/1959) comes into force as set out in the regulations
- The Building (Amendment) Regulations 2013 (SI 2013/1105), comes into force on 3 July 2013
- The Building Regulations etc (Amendment) 2013 (SI 2013/181), and correction slip, came into force on 5 February 2013
- The Building Regulations etc (Amendment) 2012 (SI 2012/3119), and correction slip to come into force at various times in 2013
- The Building (Amendment) Regulations 2012(SI 2012/718),
- The Building (Amendment) Regulations 2011(SI 2011/1515),

The Building Regulations contain definitions, procedures, and what is expected in terms of the technical performance of building work.

For example, they:

- Define what types of building, plumbing, and heating projects amount to 'building work' and make these subject to control under the Building Regulations
- Specify what types of buildings are exempt from control under the Building Regulations
- Set out the notification procedures to follow when starting, carrying out, and completing building work
- Set out the 'requirements' with which the individual aspects of building design and construction must comply in the interests of the health and safety of building users, of energy conservation, and of access to and use of buildings

Checking that the Building Regulations have been complied with is done by Building Control Bodies - either the Building Control department of the local authority or a private sector Approved Inspector. Certain types of building work close to or directly affecting the boundary or party wall of premises may also be covered by the "Party Wall Act" which places obligations on people carrying out work.

Some non-domestic premises may also be subject to requirements in Local Acts.

3.2.4 Approved Documents

Guidance on how to achieve compliance with the Building Regulations is provided in the form of Approved Documents. These describe approved methodologies for achieving the broad requirements of the

Regulations, and are used by the building control authorities to assess compliance of any relevant proposed building project. The full list of Approved Documents is:

Approved Document A (Structural safety)

This section covers the technical guidance that supports Part A of schedule 1 of the Building Regulations concerned with the requirements with respect to structural safety.

Approved Document B (Fire safety)

This section covers the technical guidance that supports Part B of schedule 1 of the Building Regulations, concerned with the requirements with respect to fire safety.

Approved Document C (Resistance to contaminants and moisture)

This section covers the technical guidance that supports Part C of schedule 1 of the Building Regulations, concerned with the requirements with respect to site preparation and resistance to contaminants and moisture.

Approved Document D (Toxic Substances)

This section covers the technical guidance that supports Part D of schedule 1 of the Building Regulations, concerned with the requirements with respect to toxic substances.

Approved Document E (Resistance to sound)

This section covers the technical guidance that supports Part E of schedule 1 of the Building Regulations, with the requirements with respect to resistance to sound.

Approved Document F (Ventilation)

This section covers the technical guidance that supports Part F of schedule 1 of the Building Regulations, concerned with the requirements with respect to ventilation.

Approved Document G (Sanitation, Hot Water Safety and Water Efficiency)

This section covers the technical guidance that supports Part G of schedule 1 of the Building Regulations, with the requirements with respect to Sanitation, Hot Water Safety and Water Efficiency.

Approved Document H (Drainage and waste disposal)

This section covers the technical guidance that supports Part H of schedule 1 of the Building Regulations, with the requirements with respect to Drainage and waste disposal.

Approved Document J (Heat producing appliances)

This section covers the technical guidance that supports Part J of schedule 1 of the Building Regulations, with the requirements with respect to heat producing appliances.

Approved Document K (Protection from falling)

This section covers the technical guidance that supports Part K of schedule 1 of the Building Regulations, with the requirements with respect to protection from falling.

Approved Document L (Conservation of fuel and power)

This section covers the technical guidance that supports Part L of schedule 1 of the Building Regulations, with the requirements with respect to Conservation of fuel and power.

Approved Document M (Access to and Use of Buildings)

This section covers the technical guidance that support Part M of schedule 1 of the Building Regulations, with the requirements with respect to Access to and use of buildings.

Approved Document N (Glazing safety) From 6 April 2013 - Only relevant to Wales

This section covers the technical guidance that supports Part N of schedule 1 of the Building Regulations, with the requirements with respect to glazing safety.

Approved Document P (Electrical Safety)

This section covers the technical guidance that supports Part P of schedule 1 of the Building Regulations, with the requirements with respect to electrical safety.

Part Q (Security: Dwellings)

This section covers the technical guidance that supports Part Q of schedule 1 of the Building Regulations, with the requirements with respect to the security of dwellings.

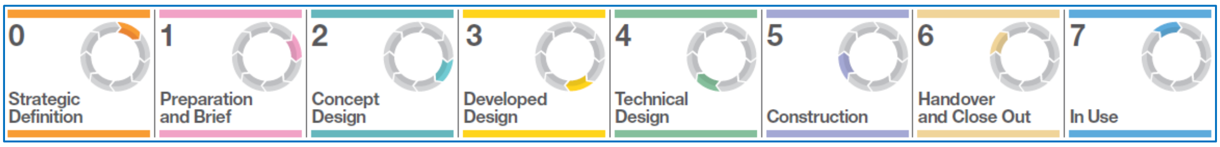
3.3 Plans of Work

The general construction process in the UK is reflected in the various plans of work which exist. Organisations such as the RIBA (Royal Institute of British Architects) and the CIC (Construction Industry Council) have produced broadly similar plans of work, with the RIBA document being the most widely used.

The plan of work is used to describe what the various parties are required to do throughout the project, either in terms of activities or outputs. However, it should not be confused with the form of contract which is the legal contract used to employ the parties.

3.3.1 RIBA Plan of Work 2013

The RIBA Plan of Work 2013 organises the process of the briefing, designing, constructing, maintaining, operating and using building projects into a number of key stages. It details the tasks and outputs required at each stage which may vary or overlap to suit specific project requirements. This version of the Plan of Work replaces the previous version, which had been in use since 2007.



The RIBA plan of Work, previously the 2007 version but now the 2013 version, has been the predominant plan of work used throughout UK construction for building projects. However, it is not as widely used for infrastructure projects where more specialist forms have been used, often produced by particular clients to reflect their own practices and requirements.

3.3.2 CIC Scope of Services

The CIC Scope of Services, first published in 2007, was a detailed scope of services (what people do rather than what they produce) from inception through to post practical completion, and could be used by various members of the project team including consultants and constructors.

In line with other developments around BIM in 2013 and 2014, the CIC modified its stages with those detailed in PAS 1192-2. The revised version is shown below.

3.4 Construction procurement routes

3.4.1 What is procurement?

Procurement is a term which describes the activities undertaken by a client or employer who is seeking to bring about the construction or refurbishment of a building.

This section describes the various forms of procurement currently used in the UK construction market, and is based on an article produced by JCT (Joint Contracts Tribunal), publishers of contract forms for use throughout the construction industry.

On most projects, clients (usually through their advisers or in-house teams) will start the procurement process by devising a project strategy. The strategy entails weighing up the benefits, risks and budget constraints of a project to determine what the most appropriate procurement method is, and what contractual arrangements will be required.

With every project, the client's concerns focus on time, cost and quality (or performance) in relation to both the design and construction of the building.

The client's policies, resources, organisational structure, and preferred contractual arrangements will all need to be taken into account in choosing the right procurement method for their project.

Understanding risk is essential, as although each procurement method follows a well-established set of rules and procedures, there are risks associated with choosing any particular route.

Successful procurement relies on all parties involved in the project complying with their respective obligations, and identifying and dealing with risk appropriately from the outset.

Procurement Method

There are four main procurement methods:

- Traditional/Conventional
- Design and Build
- Management
- Integrated

Traditional/conventional:

The traditional or conventional procurement method has been a standard practice in the construction industry for 150 years, following the emergence of general contracting firms and independent client consultants. There are two main features of the traditional method:

1. The design process is separate from the construction (although JCT contracts provide for design of specific parts of the works to be carried out by the contractor)

2. Full documentation (i.e. drawings, work schedules, bills of quantities) must be supplied by the client before the contractor can be invited to tender for carrying out the work.

Other features of the traditional/conventional procurement method are:

- A contractor is usually selected and appointed by competitive tender, but sometimes by negotiation.
- The terms of many traditional contracts require the client to appoint a professional consultant (i.e. architect, quantity surveyor, contract administrator) to act as an independent contract administrator.
- Full documents are needed for the tendering process – including that from specialist sub-contractors. Time is needed to adequately prepare this.
- The client has control over the design through their appointed consultants (i.e. architect). Generally there is no design responsibility on the contractor.
- Design and construction are separate sequential processes – this can increase the overall time of the project.
- There is reasonable certainty on the cost of the project because the contract figure is usually known at the outset. The contract does have provision for cost to be adjusted later, if required.
- Speculative risks are balanced between the parties. A lump sum contract is more in favour of the client whereas a measurement contract is less so. A traditional lump sum approach in terms of design, quality and cost is relatively low risk procurement option for a client, however the time required for the project overall is likely to be longer than other procurement methods.

Types of traditional/conventional contracts include:

- **Lump sum contracts** - With lump sum contracts, the contract sum is determined before construction work is started. Contracts ‘with quantities’ are priced on the basis of drawings and firm bills of quantities. ‘Without quantities’ means a contract priced on the basis of drawings and usually another document, such as a specification or work schedules.
- **Measurement contracts** - The contract sum for measurement contracts is not finalised until completion of the project, where it is assessed on measurement to a previously agreed basis. This type of contract can arise where the works to be carried out by the contractor cannot for good reason be accurately measured before tender. Normally the design will be reasonably complete and an accurate indication of quality will be available to the tenderer. The contract of this type with least risk to the client is probably that based on drawings and approximate quantities. Measurement contracts can also be based on drawings and a schedule of rates or prices. A variant of this is the measured term contract under which individual works can be initiated by instructions as part of a programme of work, and priced according to rates related to the categories of work likely to form part of the programme.
- **Cost reimbursement contracts** - Sometimes referred to as ‘cost-plus’ or ‘prime cost’ contracts, these work on the basis that the sum is calculated from the actual costs of labour, plant and materials to which an amount is added to cover overheads and profit. The overhead and profit amount can be a fixed-sum, percentage, or some other reimbursement payment. This type of contract is only generally used where the circumstances of the project preclude other alternatives or where a partnering ethos is in place, as it can be quite high risk for the client.

Design and build:

Design and Build procurement works on the basis that the main contractor is responsible for undertaking both the design and construction work on a project, for an agreed lump-sum price.

Design and build projects can vary depending on the extent of the contractor's design responsibility and how much initial design is included in the employer's requirements. Nevertheless, the level of design responsibility and input from the contractor is much greater on design and build projects than a traditional contract with a contractor's designed portion.

Adequate time must be allowed to prepare the employer's requirements (the employer usually appoints consultants to facilitate this), as well as time for the contractor to prepare their proposal and tender price. It is vital that the proposal matches all of the employer's requirements before any contract is entered into.

The employer has control over any design elements of the project that are included in their requirements, but once the contract is let responsibility over design passes to the contractor, so the employer has no direct control over the contractor's detailed design.

The contractor can carry out the design in a number of ways. Often they will appoint their own consultants or use their own in-house team. It is also common practice for the contractor to take on the employer's consultants and continue to use them to complete the detailed design under what is known as a novation agreement.

Other features of the design and build procurement method are:

- As design and construction can be carried out in parallel, the overall programme time of design and build projects can be shorter. However this depends on how much design the contractor is responsible for.
- There is reasonable certainty over costs because the contract price is known at the outset. Provided the employer does not order changes during the construction of the work, the contractor will be obliged (subject to the conditions) to complete the project for the contract sum. If the employer does require design or specification changes during the construction period, the contractor advises as to the effect this may have on costs or additional time needed.
- Design and Build is a relatively low risk procurement option for the employer, in terms of cost and time. There can be a risk related to design and quality, particularly if the employer's requirements were not properly gathered and if insufficient time went into examining the contractor's proposal.

Types of traditional/conventional contracts include:

- **Package deal or turnkey contracts -** This is where the employer accepts a proposal based on a standard design from the contractor, effectively providing a single point of responsibility as the contractor is responsible for the design and construction of the entire project.

- **Design and build contracts** - This is where project documents are compiled with the contractor's design obligations relating to the whole of the works in mind.

Management:

Management procurement is a method where construction work is completed using a series of separate works or trade contracts which the main contractor is responsible for managing. The contractor does not actually do the physical work, but is paid a sum for managing the project through the various works packages.

The employer starts by appointing consultants and a contract administrator to prepare drawings, a project specification and cost plan. The employer has control over design throughout the project through their professional team. The contractor is appointed by negotiation or tender, and interview. The works packages are usually let by competitive tender.

It is beneficial for the proposed contractor to be involved as early as possible as they will provide expertise in terms of buildability and programming of the works packages.

Other features of the design and build procurement method are:

- Design can proceed in parallel with construction, and much of the design might be of a specialist nature related to a specific package of work. Early starts on site are often possible and overall project time can be reduced as a result.
- There is no certainty over cost at the outset and work proceeds on the basis of the cost plan. The final cost of the project will not be known until the final works package is let, however costs can be monitored and controlled by the employer's professional team.
- Design changes are possible during the construction phase, provided that the changes do not affect work on packages already let, which can result in aborted work.
- Completion within the contract period is an obligation of the contractor, and extensions of time cannot be granted without permission from the contract administrator.
- Risk is largely with the employer, in respect of costs and time. A degree of trust and in-house expertise is required for management procurement projects. However this is a low risk option for the employer in terms of design and quality because of the control they have over the professional team.

Management procurement generally works on the basis of two different methods:

Management contracts - With management contracts, the employer appoints a professional team and a management contractor who is responsible for managing the works. The management contractor does not directly undertake any of the construction, this is spilt into packages and carried out by works contractors. The management contractor appoints the works contractors, and they are directly and contractually accountable to the management contractor. A pre-construction phase will allow a programme of works packages to be developed from the drawings, specification and cost plan, which are then let out by competitive tender.

Although contractually responsible for the works contractors, the management contractor is not liable for any default by a works contractor, provided they have complied fully with the terms of the management contract.

A variation on this method is 'design and manage' where the management contractor is responsible for the design team as well as the works contractors.

Construction management - With construction management contracts, the employer will appoint a professional team with either an in-house manager, or enters an agreement with a construction manager to oversee the work. The construction manager does not directly undertake any of the construction work, this is split into packages and carried out by trade contractors. The employer appoints the trade contractors and is directly responsible for them. The construction manager manages the works, but the employer has a major role in directing the project.

Integrated:

Integrated procurement, sometimes known as collaborative procurement or partnering, is intended to focus the participants of a project on the mutual objectives of delivering a project on time, to budget and to quality. It is about working as a team, regardless of organisation or location, to meet a client's needs.

JCT's range of partnering documents set the standard for collaborative contract working. Partnering is a principle that can be applied to most JCT contracts and provision is made for this in our Non-Binding Partnering Charter (PC/N).

4 Changes to the construction process in the UK

4.1 UK Construction initiatives

In May 2011, the UK Government Cabinet Office published its Government Construction Strategy. It stated that there was widespread acknowledgement across Government and within industry – backed by studies – that the UK did not get full value from public sector construction; and that it had failed to exploit the potential for public procurement of construction and infrastructure to drive growth.

The strategy detailed a programme of measures which the Government would take to reduce costs for construction projects by up to 20% within the lifetime of that parliament. A number of these measures had the ability to impact directly on construction performance, and therefore the gap between what was designed and what realised in operation.

A key aspect of the strategy was to replace adversarial cultures with collaborative ones, and one specific initiative identified was BIM (building information modelling). This should promote collaborative processes, resulting in better performing built assets, together with savings in costs and carbon emissions.

4.2 Building Information Modelling (BIM)

4.2.1 Government BIM requirements

In preparing the Government Construction Strategy, a number of source documents and reports were considered. The BIM Industry Working Group published a paper in March 2011 to brief the Government's Client Construction Group (replaced by the Government Construction Board) on its progress and findings. This document described BIM in terms of maturity levels and set their suggested target at Level 2, defined as:

> 'Managed 3D environment held in separate discipline "BIM" tools with attached data…'

The UK Government's BIM strategy set the target of achieving Level 2 BIM on central departmental construction projects by 2016, and embarked on a 5-year programme to develop the necessary tools and processes to enable the industry to achieve their target.

This work is now nearing completion, and the BIM Level 2 requirement is defined by a number of standards and documents published over the last two years or so. These are:

1. **PAS 1192-2:2013** Specification for information management for the capital/delivery phase of construction projects using building information modelling

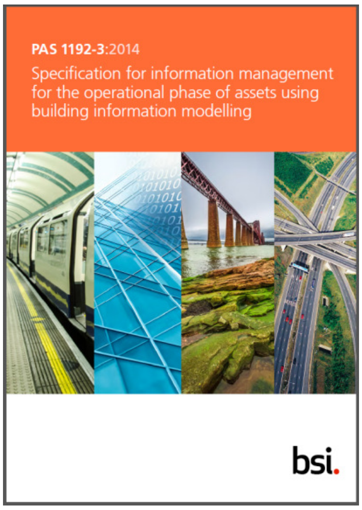
2. **PAS 1192-3:2014** Specification for information management for the operational phase of assets using building information modelling
3. **BS1192-4:2014** Collaborative production of information. Part 4: Fulfilling employer's information exchange requirements using COBie – Code of practice
4. **PAS 1192-5:2015** Specification for security-minded building information modelling, digital built environments and smart asset management
5. **Building Information Model (BIM) Protocol**
6. **GSL (Government Soft Landings)**
7. **Digital Plan of Work**
8. **Classification**

PAS 1192-2:2013 builds on the processes described in BS 1192:2007, and introduces new concepts such as employer's information requirements (EIR) – the employer's expression of what information they require from the project and the format it should be in, and BIM execution plans (BEP) – the supply chain's response to the EIR showing how it will meet its requirements.

It also describes the project information model (PIM), defined as the information model developed during the design and construction phase of a project. It is developed initially as a design intent model and then becomes a virtual construction model.

PAS 1192-3:2014 takes the processes descried in earlier 1192 publications and develops them for use in the operational life of assets. In turn, this leads to the use of new concepts such as organizational information requirements (OIR) – the information which the organisation needs to know in order to run the business, the asset information requirements (AIR) – the information the organisation needs about the asset it is responsible for, and the asset information model (AIM) – the information or data set which describes the asset.

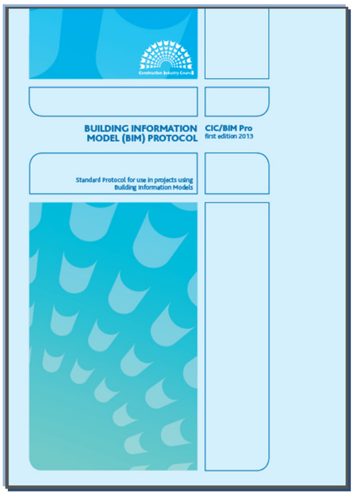
This is an important document for the FM industry as it sets out the need for comprehensive and accurate information, the AIM, which can be used as the basis for all asset-related decision making. However, it also requires that the AIM is kept up-to-date to accurately reflect the status of the asset.



BS 1192-4 defines requirements for the exchange of information throughout the lifecycle of an asset, and includes requirements for reviewing and checking for compliance, continuity and completeness. COBie is the UK Government's chosen information exchange scheme for federated BIM Level 2, alongside graphical BIM models and PDF documents.

PAS 1192-2015 has been written to help all those involved in providing and operating assets to understand the security implications – both physical and cyber – that sharing increasing amounts of data may have. This PAS was in preparation at the time of writing and is due for publication in summer 2015.

The BIM Protocol was published by the CIC in February 2013 and identifies building information models that are required to be produced by the project team and puts in place specific obligations, liabilities and associated limitations on the use of those models. The protocol can also be used by clients to require the adoption of particular ways of working – such as the adoption of a common naming standard.



Soft Landings is a form of graduated handover for new and refurbished buildings, where the project team is contracted to watch over the building, support the occupant and to fine-tune the building's systems, for up to three years post-completion.

The link with a Soft landings process – or **GSL** (Government Soft Landings) in the case of the Government – may initially seem a tenuous one, but the data gathered during the operational phase of an asset can be very important in helping to shape project needs through effective EIRs. It is vital that the way the asset is used and maintained is considered during the briefing and design process to help provide assets which work as required by the occupants.

The UK Government has taken the principles of Soft Landings and developed it for use within its own procurement strategy. This particular version has been termed Government Soft Landings, or GSL, and its key objective, as stated in *The Government Soft Landings Policy – September 2012*, is:

> "Aligning the interests of those who design and construct an
>
> asset with those who subsequently use it"

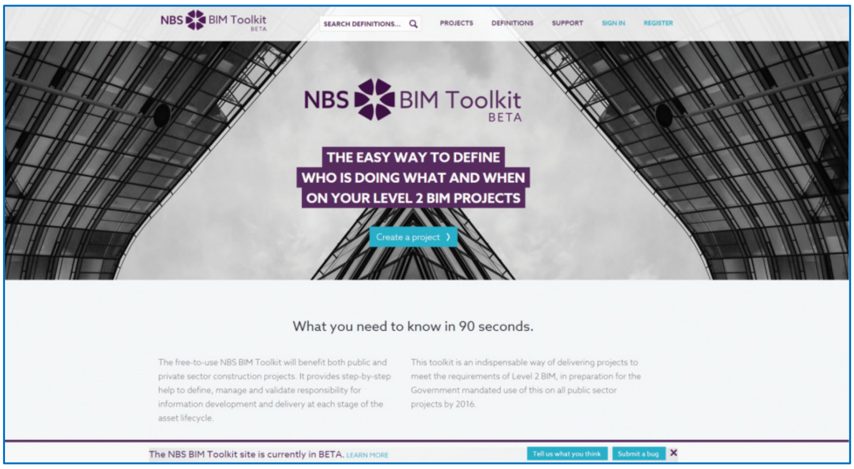
Although the GSL process generally follows the Soft Landings methodology described by the Usable Buildings Trust (UBT) and BSRIA, it differs in one very significant way – it includes the use of metrics to demonstrate compliance with the stated project outcomes. More information on Soft Landings and GSL is contained in 4.3.

Digital Plan of Work (dPoW) and Classification have been seen as the two missing pieces of the BIM Level 2 jigsaw, and are the subject of a research project funded by Innovate UK (formerly the Technology Strategy Board). This delivered the first beta version in April 2015.

The output is an on-line tool which enables clients to prepare a plan of work for a project, which can then be exported for use in other documents such as EIRs. This plan of work allows the user to identify the different outputs required at each stage of the project process, and also to assign the delivery of those to a member or members of the project team.

The tool also has the ability to provide classification codes for various aspects of the construction process, and a number of classification tables were available as part of the beta release, including those for complexes down to products.

It is expected that a more complete version of the tool will be available later in 2015, taking into account feedback from the beta version.



4.3 Soft Landings

4.3.1 Introduction to Soft Landings

The following content has been published by BSRIA in their guide BG 54/2014, and is reproduced here to help articulate the current situation with Soft Landings in the UK construction sector. The content is included largely as originally published, but some minor editing has been done to better suit this application.

Background to Soft Landings

There is a growing realisation that sustainability, energy efficiency and the overall performance of new and existing buildings needs to improve radically. Clients, governments, and society are looking to the construction industry to meet increasingly challenging targets: for owners as robust sustainable investments, to satisfy occupiers, and to tread lightly on the environment.

Unfortunately, the construction industry and its clients do not yet have the right structures in place to deliver these improvements reliably. **Surveys of recently completed buildings regularly reveal massive gaps between client and design expectations and delivered performance (the performance gap), especially energy performance.**

There are many reasons for this, including:

- Many designers do not take sufficient account of how occupiers use and manage buildings and the equipment they introduce.
- Achieved performance is becoming increasingly dependent on technology, which often needs careful attention if it is to work as intended. Pre-handover commissioning is seldom enough.
- Solutions that look good in design calculations can often prove to be too complicated to be manageable, both through the design and delivery process and particularly in use. Designers can

easily forget that management is a scarce resource, as can those procuring clients who do not have a direct involvement in building operation.

An underlying problem is that designers and builders are normally employed to produce or to alter buildings, and are expected to go away as soon as the work is physically complete and handed over. They are seldom asked or paid to follow-through afterwards, to pass on their knowledge to occupiers and management, or to learn from the interaction. Consequently, the industry does not unlock all the value in the buildings it creates. Nor does it fully understand what it is creating, what works well, and what needs to be improved.

In the process, the industry is also missing opportunities for improving the knowledge base for its people, its organisations, and indeed for everybody. One might be tempted to blame the industry for this, but the causes are more deeply rooted, making it difficult for anybody to step far out of line.

The rigid separation between construction and operation means that many buildings are handed over in a state of poor operational readiness and suffer a hard landing, particularly – as often happens – when delays have led to the telescoping of the commissioning period. Problems can be worst where complicated or unfamiliar techniques and technologies are used and nobody can understand why, or what they need to do. If the problems are not dealt with rapidly, occupants' initial enthusiasm can easily turn into disappointment.

Doing things differently

To meet these changing expectations, and to reduce the gaps between predicted and achieved performance, the design and construction professions must not only focus on technical inputs, but put much more emphasis on in-use performance strategies. The desired operational outcomes need to be considered at the very earliest stages of procurement, managed right through the project and reviewed in use.

This culture shift in the way buildings are delivered will require:

- Better and more direct understanding of how buildings are actually used and managed
- Integration of follow-through and feedback into clients’ appointments and industry procurement processes
- Better review and reality-checking and fine-tuning during the procurement process
- Closer links between design, construction, operation, research and development, so that experience gained on all projects is rapidly internalised, digested and fed-forward to inform existing projects and future work.

The industry and its clients must move fast: especially to reduce greenhouse gas emissions, which otherwise threaten to trigger rapid climate change. The challenge is immense and time is short: buildings last a long time, but the industry changes slowly. The required alterations are radical, but we need ways of making an orderly transition from existing procedures to improved procedures.

The purpose of Soft Landings

Soft Landings can be used for new construction, refurbishment and alteration. It is designed to smooth the transition into use and to address problems that post occupancy evaluations (POE) show to be widespread. It is not just about better commissioning and fine tuning, though for many buildings commissioning can only be completed properly once the building has encountered the full range of

weather and operating conditions.

Soft Landings starts by raising awareness of performance in use in the early stages of briefing and feasibility, helps to set realistic targets, and assigns responsibilities. It then assists the management of expectations through design, construction and commissioning, and into initial operation, with particular attention to detail in the weeks immediately before and after handover. Extended aftercare, with monitoring, performance reviews and feedback helps occupants to make better use of their buildings, while clients, designers, builders and managers gain a better understanding of what to do next time. Soft Landings can run alongside any procurement process, potentially in any country. It also provides a natural route for POE and feedback.

Soft Landings provides additional support throughout the process, especially:

- During inception and briefing, to establish client and design targets which are better-informed by performance outcomes in use on previous projects. It also commits those joining the design and building team to follow-through after handover and for project management to begin to allocate responsibilities for ongoing reviews of design intent and anticipated performance, and to prepare for the other activities required.

- Alongside the design and construction process, to review performance expectations as the client's requirements, design solutions, and management and user needs become more concrete and the inevitable changes are made. In addition the team must plan for commissioning, handover and aftercare, and involve the occupier much more closely in decisions which affect operation and management.

- In the weeks before and after handover. Although practical completion is important legally and contractually, with Soft Landings handover is no longer the end of the job, but just an event in the middle of a more extended completion stage. Before handover, the team prepares to deliver the building and its systems in a better state of operational readiness. When the occupants begin to move in, the aftercare team (or team member) will have a designated workplace in the building and be available at known times to explain design intent, answer questions, and to undertake or organise any necessary troubleshooting and fine-tuning. Both before and after handover, the design and building team will work closely with client, occupiers, and facilities managers to share experiences and smooth the transition into use.

- During the first three years of occupancy: to monitor performance, to help to deal with any problems and queries, to incorporate independent post occupancy surveys (such as occupant satisfaction, technical and energy performance), and to discuss, act upon and learn from the outcomes. Achievements and lessons should then be carried back to inform the industry and its clients.

4.3.2 Introduction to the Soft Landings process

Why use Soft Landings?

Soft Landings helps clients and occupiers to get the best out of their new or altered buildings. It is designed to reduce the tensions and frustrations that so often occur during initial occupancy, and which can easily leave residual problems that persist indefinitely. At its core is a greater involvement of designers and constructors with building users and operators before, during and after handover of building work, with an emphasis on improving operational readiness and performance in use.

Soft Landings is not just a handover protocol. It also provides the golden thread which links between:

- The procurement process: setting and maintaining client and design aspirations that are both ambitious and realistic, and managing them through the whole procurement process and into use

- Initial occupation, providing support, detecting problems, and undertaking fine-tuning; and

- Longer-term monitoring, review, post-occupancy evaluation (POE) and feedback – drawing important activities into the design and construction process which are both rare in themselves and often disconnected.

Other important but less directly tangible benefits include client retention owing to the improved levels of service, greater mutual understanding between designers, builders, clients, occupiers and managers, education of design and project team members in what works well and what may be causing difficulties. It also helps to develop industry skills in problem diagnosis and treatment.

What is special about it?

Soft Landings is embedded in the entire procurement process from initial scope to well beyond project completion. Conventionally, buildings are simply handed over to the client and the design and building team walk away, never to come back, except to deal with snags or reported failures. By contrast, Soft Landings helps to:

- Minimise the chances of unsatisfactory performance by strengthening the vulnerable areas of traditional scopes of service, which too often result in occupier complaints downstream.

- Address and even pre-empt problems during the early occupation phase, by providing an on-site designer/contractor representative or team that can assist occupiers and management.

- Ensure that lessons from closer interaction with the occupiers – and from evaluating actual building performance in use – are learnt and shared to the benefit of all stakeholders.

Soft Landings helps to bring things together

Many techniques of project feedback and post-occupancy evaluation (POE) are aimed at one particular stage of a project or to suit a single discipline or element such as building services engineering. Many are used solely in the post-occupation phase when it is too late to tackle the strategic problems that originated in briefing, design and project management. Soft Landings provides a process carrier for these techniques, so helping to unite all disciplines and all stakeholders and to extend the procurement process beyond handover.

As POE becomes more routine, findings and benchmarks from previous POE surveys can be used to help calibrate client and design expectations. Where practicable, results from these surveys can also provide metrics that allow these expectations to be tracked from briefing, through design development, construction and commissioning, and into operation.

How do contractual duties change?

Soft Landings extends the duties of the team before handover, in the weeks immediately after handover, for the first year of occupation, and for the second and third years. In order to improve the chances of success, it reinforces activities during the earlier stages of briefing, design and construction. The overall objective is better buildings, with better performance which matches more closely the expectations of the client and the predictions of the design team.

Soft Landings creates opportunities for greater interaction and understanding between the supply side of the industry and clients, building users and facilities managers. It helps everybody concerned to improve their processes and products, and to focus innovations on things that really make a difference.

Is there a standard scope of service?

Soft Landings procedures are designed to augment standard professional scopes of service, not to replace them. They can be tailored to run alongside most industry standard procurement routes to create the most appropriate service to suit the project concerned.

Major revisions to industry-standard documentation are not necessary. The main additions to normal scopes of service occur during five main stages:

1. **Inception and briefing** to clarify the duties of members of the client, design and building teams during critical stages, and help set and manage expectations for performance in use.

2. **Design development and review** (including specification and construction). This proceeds much as usual, but with greater attention to applying the procedures established in the briefing stage,

reviewing the likely performance against the original expectations and achieving specific outcomes.

3. **Pre-handover**, with greater involvement of designers, builders, operators and commissioning and controls specialists, in order to strengthen the operational readiness of the building.

4. **Initial aftercare** during the users' settling-in period, with a resident representative or team on site to help pass on knowledge, respond to queries, and react to problems.

5. **Aftercare in years 1 to 3 after handover**, with periodic monitoring and review of building performance.

The following section explains how Soft Landings aligns with RIBA Plan of Work and BSRIA BG 6/2014 Design Framework for Building Services, and outlines the content of the five stages in Soft Landings.

Table 1: How Soft Landings aligns with the 2008 and 2013 editions of the RIBA Plan of Work and the workstages of BSRIA BG 6/2014 Design Framework for Building Services.

RIBA 2008 Stages	RIBA 2013 Stages	CIC stages 2012	Soft Landings	Soft Landings supporting activities	BSRIA BG 6/2014 *Design Framework* pro-formas
	0 - Strategic definition	0 - Strategic definition			0 - Strategic activities
A Appraisal	1 - Preparation and brief	1 - Preparation and brief	Stage 1. Briefing: identify all actions needed to support the procurement	Define roles and responsibilities	1 - Preparation
B Design brief				Explain Soft Landings to all participants, identify processes and sign off gateways	
C Concept	2 - Concept design	2 - Concept design	Stage 2. Design development: to support the design as it evolves	Review past experience. Agree performance metrics. Agree design targets	2 - Concept
D Design development	3 - Developed design	3 - Developed design	Scheme design reality-check	Review design targets. Review usability and manageability	3a & 3b - Developed design
E Technical design					
F1 F2 Production information	4 - Technical design	4 - Technical design	Technical design reality-check(s)	Review against design targets. Involve the future building managers	4a, 4b & 4c - Technical design
G Tender documentation	Information exchanges will vary depending on the procurement route and building contract. Designers can create a bespoke Plan of Work for the client's chosen procurement route in order to set out specific tendering and procurement activities for each stage.		Optional tender stage reality-check	Include additional requirements related to Soft Landings procedures	
H Tender action			Tender award stage reality-check	Include evaluation of tender responses to Soft Landings requirements	
J Mobilisation K Construction to practical completion	5 - Construction	5 - Fabrication design		Confirm roles and responsibilities of all parties in relation to Soft Landings requirements	5 - Construction
	6 - Handover and close-out	6 - As constructed	Pre-handover reality-check	Include FM staff and/or contractors in reviews. Demonstrate control interfaces. Liase with move-in plans	6 - Handover
			Stage 3. Pre-handover: Prepare for building readiness. Provide technical guidance		
			Post-handover sign-off review. Ensure all outstanding reality-checked items are complete and system is signed off and operational		
L1 Post-practical completion	7 - In Use	7 - In use	Stage 4. Aftercare in the initial period: support in the first few weeks of ocupation	Incorporate Soft Landings requirements	7 - In use
L2				Set up home for resident on-site attendance	
L3			Stage5. Years 1 to 3 Aftercare: Monitoring review, fine-tuning and feedback	Operate review processes. Organise independent post-occupancy evaluations	

The workflow table above has been revised to make it compatible with other Soft Landings publications. It also includes reality-checking worksteps (shown in green) as outlined in BSRIA BG 27/2011 Pitstopping – BSRIA's Reality-checking Process for Soft Landings. Additional guidance is freely available from www.softlandings.org.uk and www.usablebuildings.co.uk.

Stage 1: Inception and briefing

Briefing is the most crucial stage of procurement. If it is not done well, it is all too easy to sow the seeds of future misunderstanding and discontent. A common problem is to put too much emphasis on the intended product, at the expense of the general background, performance requirements (both qualitative and quantitative), and the processes by which solutions should be developed and tested. The more time that can made available for constructive dialogue, the greater the likelihood of success.

To obtain the greatest value from Soft Landings, the expectations and performance targets that emerge from the briefing process should be arrived at within a well-structured, logical and recorded context. However, for various reasons it may not always be possible to give the briefing stage all the time it deserves at the outset. Consequently, Stage 1 of Soft Landings also establishes tasks, responsibilities and review procedures that allow the brief to be re-examined in response to new findings, and to help ensure that critical issues are not lost along the way.

Stage 1 checklist:

- B1. Define roles and responsibilities
- B2. Review past experience
- B3. Plan for intermediate evaluations and reality checks
- B4. Set environmental and other performance targets
- B5. Sign-off gateways
- B6. Incentives related to performance outcomes

Stage 2: Design development and review

Once a project team has adopted Soft Landings at Stage 1: Inception and briefing, then design development, technical design, production information and tendering will proceed much as usual. However, people will need to bring a somewhat different approach to the process. In particular:

- Everyone joining the client, design and construction teams will need to be made aware that Soft Landings is in operation and commit to adopting its principles.

- All team members will be encouraged to obtain and contribute insights from the performance-in-use of comparable projects.

- Client and design targets will be informed by actual performance in use, reviewed at intervals as the project progresses, and have any adjustments agreed and signed-off.

- Requirements for independent post-occupancy evaluation (POE) services will need to be verified. To assist comparability and transparency, where appropriate and practical, the same metrics should be used for the design targets and what the POE will measure.

- The design process should include reality-checking workshops, including reviews by experts in building performance.

- To accompany the design data, an illustrated narrative will be developed on how the building will work from the point of view of the manager and the individual user. This can evolve into the technical and user guides that will be issued to managers and occupiers at handover.

- Close attention needs to be given to the usability and manageability of the proposed design solutions, and in particular moving parts, electrical components and their control interfaces. Where the occupiers are known, their facilities managers and user representatives should be involved in reviewing the proposals and commenting not just on the design intent but also on the details of the management and user interfaces, including the equipment selected and its location.

- Suitable preparations must be made during design and construction to plan, programme and resource the critical periods in the weeks immediately before and after handover.

To make sure that all angles are covered, tender documentation may require unfamiliar interventions by other design team members.

Stage 2 checklist:

D1. Review past experience

D2. Design reviews

D3. Tender documentation and evaluation

Stage 3: Pre-handover

The main purpose of the pre-handover stage is to help to ensure that by the time the building is handed over it is not just physically complete, but ready for operation. A building readiness sub-programme therefore needs to be developed in good time, and well ahead of the start of commissioning work. Activities by the design and building team must also include static commissioning (such as inspections of airtightness details, checks of window opening devices and linkages, and envelope pressure tests). Commissioning of building services needs extending to include, for example, natural ventilation, renewable energy systems, metering installations and effective user interfaces. Great care needs to be given to demonstration, training and documentation. Proposed activities by the client and occupier also need to be reviewed, such as staffing, operation and maintenance contracts, and move-in plans including fit-outs where relevant.

It is essential that the client's management team takes over the operation of the building in a timely fashion. Problems that occur after handover can often be traced back to insufficient understanding by the occupier's staff of technical systems (particularly building services) and their user interfaces, or where solutions have been developed without enough understanding of user and operator requirements. Too often, buildings start their operational lives with too few operating staff, who are not sufficiently trained, know little about the design intent, have had no opportunity to attend a demonstration, and are unfamiliar with the systems provided and how to use them.

To avoid problems, the project team should take more care in design and specification and to pay more attention to the contractor's proposals for commissioning and handover. They will also need better understanding of operator skills and requirements and better arrangements for demonstrating interfaces and systems properly to operating staff before handover. The time spent will lay the foundations for future co-operation.

Clients play a vital part in ensuring building readiness. If they leave staffing too late (as they often do), problems with initial performance is very likely. However much the designer and constructor do to help, resolution is nearly impossible if there are no good operators available on site.

A design and construction team is often told very little about how the occupier intends to move themselves into the building. As a result, occupiers can easily make incorrect assumptions about how ready the building will be to receive them, and what access and services will be available. This in turn can cause clashes and disappointments while the move is under way, and sour initial user experiences of their new or altered building. With Soft Landings, designers and builders need to be involved with the occupier's logistics planning, if only to a small extent.

Even in the best-managed projects, the commissioning period can get squeezed, owing to delays outside the control of the design and building team, and an occupier's business requirement for a non-negotiable handover date. Soft Landings will help to reduce the effects of any such slippages as the continuity it provides between the pre-handover and aftercare stages makes it much easier for any outstanding commissioning activities to be continued after handover.

Stage 3 checklist:

P1. Environmental and energy logging review

P2. Building readiness programme

P3. Commissioning records check

P4. Maintenance contract

P5. Training

P6. Building management system interface completion and demonstration

P7. Migration planning

P8. Aftercare team home

P9. Compile a guide for occupants

P10. Compile a technical guide

P11. O&M manual review

Stage 4: Initial aftercare

The service during the initial aftercare period is intended to help the occupiers to understand their building, and the facilities managers to operate its systems. The aftercare team is there to provide information and support, to respond to any questions that arise and to investigate any problems that emerge. It is important that the building's facilities or management team is properly resourced, so they have the skills and time to take advantage of this service. Soft Landings will not work properly if the occupiers think they can sit back and leave things to the aftercare team.

During the initial aftercare period, one or more members of the design and building team will be present on site for typically four to six weeks immediately after move-in. After this initial period, the residential presence of design and construction team members will taper off, but periodic reviews will continue, as outlined in Stage 5.

The size and complexity of the project and the occupants' move-in timetable will determine how much time will be required, over what period, and for how many people. It could be as little as one day per week, but much will depend on what actually happens once the occupier moves in.

One of the team should act as the main point of contact for overall liaison. This will usually be the architect, but that depends on the project. Building services and commissioning engineers always need to be closely involved and readily available, because many initial queries are often related to the use and performance of unfamiliar mechanical, electrical and control systems and environmental control strategies.

The aftercare team must be visible, with a workplace in a readily-accessible location and not hidden away. Team members must work not just with the facilities management team, but be accessible to everyone. Occupants must therefore be told that the aftercare team is operating, what it will be doing, where it will be, and when. The times of residence need to be regular (such as every morning, or every Tuesday) so everybody knows what to expect.

Team members must make themselves available to deal pre-emptively with queries and misunderstandings. The observations they make, the questions they answer, the responses they get and the insights they derive will help prevent minor problems developing into longer term chronic irritants for the occupants and the client alike. Their period of residence also provides an opportunity to observe and learn from initial feedback and problem-solving.

Visibility also includes sessions at which the aftercare team describes the building and its systems to groups of occupants as soon as possible after they move in, and introduces them to the guide for occupants (see box). The aftercare team will also provide news on issues, problems and progress, normally via the occupier's intranet.

Aftercare is not an administrative exercise nor should it be a superficial attempt at marketing. Instead it should be a proper professional service. Where it is done effectively it will generate a lot of goodwill. Being seen to be on the side of the users helps a lot – and ensures a meaningful invitation to the official opening.

Stage 4 checklist: The aftercare checklist covers the initial period of occupation, typically four to six weeks after handover.

A1. Resident on-site attendance

A2. Provide workplace and datacomms links

A3. Introductory guidance for building users

A4. Technical guidance

A5. Communications

A6. Walkabouts

Stage 5: Years 1-3 Extended aftercare period

Once the initial aftercare period is over, the Soft Landings service moves from regular visits to periodic reviews. The aftercare team is there to provide insights, review performance, and help the users and operators to get the best out their building, not to run it on their behalf. Responsibility for operation and provision and initial review of routine information (such as BMS logs and meter readings) must lie firmly with the building’s facilities management team.

In Year 1, the primary focus should be on settling everything down, making sure that the design intent is well understood, identifying any problems, and logging usage and change. There may well also be a need to fine-tune systems, particularly lighting controls and HVAC systems, in order to optimise effective and energy-efficient operation and to take account of occupant feedback and changes in weather and occupancy.

In Years 2 and 3 the reviews become less frequent, concentrating on recording the operation of the building and reviewing performance. By then the facilities management team should be fully in command of the building’s systems, be dealing with all problems (usually without reference to the design and building team). They should also be collecting and reviewing their own data, and refining their operational strategies. The Soft Landings process will have helped them to overcome any initial difficulties.

The aftercare period will also include a number of (preferably independently conducted) post-occupancy surveys. The type, coverage, method and timing of these surveys will depend on what has been agreed for each project. Where the design and building team has committed to undertaking an occupant survey or surveys, and following-up on any problem areas, the brief should include suggested survey timings. In general terms:

- The timing of the first occupant survey depends on the project. It is best to wait until occupants have experienced one full heating and cooling season. Phased handover, phased occupation, or additional fit-out works may also justify a delay beyond 12 months. The Soft Landings team need to judge carefully the point at which survey results are likely to reflect the building’s steady pattern of operation. Performing the first survey too soon may mean the results have too many caveats to be of much value.

- Occupant focus groups held in the initial aftercare period can provide valuable initial reactions and help to target early action. However, these can also be held prematurely, particularly if initial teething problems are still fresh in the memory. Focus groups can also be dominated by a vocal minority who set the agenda on behalf of the others who may be more meek. Focus groups therefore need to be properly facilitated and the results used with caution. Combining focus groups with occupant questionnaires can lead to survey fatigue.

- Year 3 is the best time for a second survey to summarise the occupants' views on the long term performance of the building. It allows enough time for the building and its systems to have settled down, for fine-tuning in year 2 to have had an effect, and for any initial problems to be long past.

Everybody involved in the extended aftercare service will gain valuable information and insights. This feedback will help the building to work better and the client and occupiers to get the best out of the design. The feedback also provides valuable intelligence that all those involved will take back to their work, their organisations and the industry. This in turn will help to improve the goods and services they and the industry provide and make sure that their future efforts are targeted more accurately on the things which will really make a difference.

Stage 5 checklist: These activities are repeated each year, though at a reducing frequency.

Y1. Aftercare review meetings

Y2. Logging environmental and/or energy performance

Y3. Systems and energy review

Y4. Fine tune systems

Y5. Record fine-tuning and usage change

Y6. Communications

Y7. Walkabouts

Y8. Measure environmental, energy and human factors performance

Y9. End of year review

4.3.3 GSL (Government Soft Landings)

A briefing note has been prepared by the Soft Landings User Group which compares Soft Landings and GSL, and an extract is included here.

Background to GSL (Government Soft Landings)

The Government Soft Landings policy was driven by the Government Construction Board and evolved during the period 2011/12. It was seen as an opportunity to incorporate principles of the soft landings concept into the procurement of centrally funded projects. Interestingly, GSL policy doesn't explicitly recommend the adoption of the BSRIA Soft Landings Framework, but makes reference to it, thus allowing the Government to manage its own policy independent of any third party and to stress its own interpretation for soft landings.

In September 2012 the Cabinet Office formally announced the policy that by 2016 all centrally funded projects should be delivered in accordance with Government Soft Landings.

It should be noted that GSL is designed to cater for the procurement needs of central government departments. It will not be mandatory for local authority procurement, schools or hospitals.

GSL is promoted by the Government's BIM Task Group and its adoption is intended to be integrated with Government's implementation of BIM.

The Government Construction Strategy has set a target for projects procured by Government Departments to deliver 20% lower costs. The adoption of GSL is part of the Government's effort to help reduce total project costs through the lifetime of the asset.

Five key features of GSL, as stated at the BIM Task Group website, are:

1) GSL will be used to reduce cost and improve performance of asset delivery and operation.
2) All departments will appoint a GSL Lead to manage the GSL Golden Thread on all projects.
3) All departments will actively manage aftercare during early operations, supported by the design and construction team.
4) Post Occupancy Evaluation will be used as a collaborative tool to measure and optimise asset performance and embed lessons learnt.
5) BIM will be progressively used as a data management tool to assist the briefing process.

Source: http://www.bimtaskgroup.org/gsl/

GSL policy requires a GSL Champion, or Champions, to be appointed. This may be an individual or the responsibilities can be distributed across members of the project team.

According to the Government's Departmental Brief, GSL Champions should have the following responsibilities:

- Represent the needs of the End Users; Occupiers, Visitors and Facilities Managers
- Actively engage with the End Users to ensure their needs are input into all stages of the project
- Actively engage with the Project Team to ensure these needs are considered at all stages of the brief, design, construction, handover and in use support
- Support the Project Manager in developing and implementing the Aftercare Plan and Post Occupancy Evaluation studies
- Support the ongoing development of GSL through membership of the GSL Champion Stewardship Group

The GSL policy requires specific objectives and measures of success to be determined at the strategic briefing stage. Project targets, according to GSL policy, should cover:

a) Social outcomes (e.g. functionality and meeting user requirements)
b) Economic outcomes (e.g. capital and operational costs)
c) Environmental outcomes (e.g. energy, water and waste targets)

Comparison of GSL and Soft Landings Framework

There are many similarities between the Government's interpretation of soft landings and the BSRIA Soft Landings Framework. These similarities include:

- An emphasis on the need for better collaboration between the procurement team (designers and constructors) and end-user/ operational representatives.

- The need to review and agree project outcomes at the beginning of a project. (On this matter the GSL policy is very specific about identifying a range of economic, social and economic objectives/metrics).

- The adoption of Soft Landings should be used by industry to learn lessons from the evaluation process and the lessons should inform better design practice.

- Particular attention should be given to the pre-handover stage, with regards to testing, commissioning, training and hand-over documentation, and the initial aftercare period, so that building management representatives are better prepared for moving in to the building.

- There should be a period of extended post-occupancy evaluation. This will typically be up to three years, although this should be determined on a project by project basis. (The motives for the evaluation are slightly different in the BSRIA Framework and GSL policy. The BSRIA Framework sees this evaluation as a component of extended aftercare by the professional team; the GSL policy views the evaluation as a crucial means to check that performance metrics have been met).

Some of the differences are:

- GSL policy recommends the Soft Landings Champion is an appointed member of relevant Government Department, unless another arrangement is more practical. The BSRIA Soft Landings Framework guidance recommends the client has a Soft Landings representative, or Champion, and the project delivery team has a Soft Landings Champion (it could be a consultant, project manager or someone else in the delivery team with an interest in the end-user activities).

- The implementation of GSL is aligned with the Government's public sector policy for the implementation of BIM in 2016, although GSL could still be implemented on a project without BIM. The BSRIA Soft Landings Framework does not inherently require BIM to be adopted for a soft landings project or make reference to it.

- GSL contract guidance requires objectives to be set for capital cost and operational costs, and for these costs to be reviewed and updated as the project progresses. GSL also therefore helps to provide a mechanism for clients monitor project costs. While the BSRIA Soft Landings Framework does not require costs to be regularly evaluated, project teams have the freedom to include cost control as a specific objective.

- GSL requires targets to be set at the strategic briefing stage (RIBA stages 0 and 1) which can be reviewed again by the Government Department at Stage 2, whereas the Soft Landings Framework recommends targets are set at the concept design stage (RIBA stage 2), after the strategic principles have been established and options have been reviewed.

- GSL requires, as a minimum, the following key aspects to be addressed: functionality, environmental performance, FM operations, training, commissioning and hand-over. The BSRIA Soft Landings Framework is less prescriptive, and gives more freedom to the project team to determine the key project objectives.