Design for Performance Pilot Programme: Technical Report

Pilot Programme findings and proposed next steps

Document type:	Report
Client:	Design for Performance Executive Board
Client representative:	Sarah Ratcliffe, CEO, Better Buildings Partnership
Other details:	
Title:	Design for Performance Pilot Programme: Technical Report
Date published:	05/06/2018
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FOREWORD

The primary function of an office building is to create a comfortable and healthy environment in which occupants can work productively. Operational efficiency is critical to the achievement of these objectives and also enables the building owners and occupiers to address the challenges associated with climate change, energy security and costs. This is increasingly dictating that new office buildings must be energy efficient.

It is a startling fact that we in the UK have no idea if our buildings are energy efficient: we do not accurately predict it and we do not measure it. This is surprising given the interest in buildings being energy efficient and their significant share of UK energy demand.

The thesis of Design for Performance (DfP) is that measuring operational energy efficiency is critical to improving the performance of office buildings. Furthermore, increasing disclosure requirements and concerns about the risk exposure of poorly performing assets means that developers want confidence that their new buildings will perform well. DfP is a process to underwrite the operational performance of new office buildings.

There are regulations in the UK that seek to assure that new buildings are energy efficient and an impending remit that these regulations mandate “nearly zero” energy buildings. However, there is an awkward fact that unless performance outcomes are measured, it is impossible to obtain evidence as to whether these design-based regulations are effective in achieving their intended result[1]. And indeed, in reality, the evidence has been growing for many years that they are not.

So how is it that another country, with a commercial office market not dissimilar to that of the UK, has on average halved the energy intensity of its new office buildings over the last 15 years? Australia has placed measured performance outcomes at the heart of its approach, simultaneously demanding a relentless focus on performance throughout the design, construction and early operation phases, starting with an operational performance target being set in stone from the outset.

Energy efficiency is a weak driver of institutional and behavioural change, especially when evidence is invisible. Critically, the case for DfP rests on more fundamental motives. For the investor and developer, the paramount purpose of a new office building is to generate a financial return - office buildings in the Australian market with better energy efficiency ratings produce higher yields, through higher income returns and stronger capital growth. Better rated buildings are seen as better quality buildings, and command rent premiums occupiers are willing to pay. Occupiers are increasingly focused on ensuring that the space they occupy is smart and promotes occupant well-being. What could be smarter than a building designed for performance? What delivers better well-being than building services operating in their sweet spot, efficiently and as intended?

The DfP initiative has been set up to learn from Australia’s success and seeks to understand whether and how it could be replicated in the UK market. Written originally for the DfP Executive Board, this report summarises the background to DfP (as detailed in the Feasibility Study) and provides significant technical detail on the lessons learnt from the DfP Pilot Programme; it also describes the benefits of DfP for different stakeholders and the next steps for DfP in the UK.

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[1] We are “flying blind”, as Bill Bordass noted so poignantly back in 2001. BORDASS W. Flying Blind: Things you wanted to know about about energy in commercial buildings but were afraid to ask The Association for the Conservation of Energy and the Oxfordshire Energy Advice Centre, October 2001

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1. Executive summary

1.1 Background to Design for Performance

Design for Performance (DfP) aims to address the operational energy efficiency of new commercial office buildings. It focuses on the "base building" services (collectively known as the landlord services) and therefore represents the operational energy efficiency of the property. It is a metric of interest to investors targeting lower carbon portfolios and, notably, potential tenants seeking to occupy an efficient building.

Empirical evidence has demonstrated that in the UK the mechanisms intended to drive building energy efficiency show only a weak correlation with actual operational energy use and that a 'design-for-compliance' culture prevails leading to a well-documented 'performance gap'. By stark contrast, evidence from the Australian commercial office market shows that a focus on performance outcomes supported by a scheme to rate the operational energy efficiency of the base building has been transformational in improving the energy efficiency of commercial buildings.

The DfP initiative has focused on the Australian NABERS *Commitment Agreement* framework for new offices and explored whether it is possible to replicate this in the UK. It has conducted a 3 year programme of work including a Feasibility Study[2] and a pilot programme to provide a sound evidence base from which to consider whether it is feasible and desirable to introduce such a scheme in the UK. This report provides a summary of the work undertaken to date, together with detailed findings of the pilot studies and an indication of the next steps that would be required to implement a Design for Performance approach to new buildings in the UK.

1.2 Key findings

The pilot projects have enabled the DfP Executive Board and project stakeholders to understand whether the theoretical process and benefits of DfP identified in the earlier Feasibility Study can be borne out in practice. They have demonstrated both the potential for, and urgent need of, application of DfP in the UK market. The key findings are as follows:

- **DfP in-use performance targets are critical:** The commitment to a base building performance target is critical to driving a Design for Performance approach:
  - The lack of performance outcomes in clients' briefs reverberates across the supply chain. The DfP approach can help in acknowledging the value of accurately predicting performance outcomes, setting expectations appropriately and securing these outcomes in operation.
  - Achieving a target is a collaborative endeavour like a relay race - activities in earlier stages determine success at later stages and the converse: challenges at later stages often have their root causes in choices made earlier. The pilots demonstrated that the existence of a performance target would have been a key 'enabling' commitment and should be set in the early stages (Stage 1 or 2) to ensure that the performance outcomes are embedded within the supply chain contracts and that these are reflected in the whole life cycle of the building from design through to operation.

- **DfP projects are responsive to occupier demands:** The current technical specification and delivery of offices in the UK does not accurately reflect the energy demand and services required by occupiers.

[2] Bordass, WT, Cohen, RR and Bannister, P "Design for performance: UK Commitment Agreements: Making measured energy in-use the objective for new office buildings, Feasibility Study Final Report, published by the Better Buildings Partnership (BBP), May 2016.

- The preponderance of shell-and-core design in the premium office market leads to major issues in efficiency compounded by the incumbent view that ‘continuous service’ for occupiers is a pre-requisite for acceptable design.
    - The DfP pilots demonstrated that the focus on performance outcomes enables developers to much more accurately predict and secure performance in use by enabling the design and services of the building to respond to changes in demand, different operating hours or the presence of voids. Advanced modelling that includes HVAC simulation is core and enables developers to understand plant capacity requirements more robustly, with efficiency benefits including costs and emissions, but also producing buildings that can be more responsive to occupier feedback and serve occupiers on an ‘as-needed’ basis.
    - The DfP Pilots demonstrated that metering configuration plays a critical role in being able to delineate and measure energy in a way that makes accountability for energy consumption transparent, an important enabling factor in improving energy efficiency. Central visibility of all HVAC system controls is a pre-requisite for efficient building operation and thus essential if a good base building rating is desired.

- **DfP skills are nascent and need to be developed:** DfP provides an antidote to the industry design-for-compliance regime where the lack of attention to post-construction performance has led to a de-skilling across the sector. By shifting the focus to performance outcomes, the supply chain can focus skills development on delivering better buildings:
    - There are opportunities for skills development across the sector (architects, designers, engineers, contractors, managing agents & property managers) these are multi-faceted and include HVAC design, advanced modelling, construction quality, commissioning, fine-tuning and post occupancy feedback.
    - Skills to support a DfP scheme would also need to be developed, most especially individuals who have the appropriate competencies to become members of the Independent Design Review Panels and DfP rating assessors.
    - There are a small number of individuals with these skills in the UK, but the UK industry is significantly behind its counterparts in Australia and the US.

- **DfP performance verification enables outcomes to be valued by the market:** A credible rating system that verifies energy performance would enable investors and occupiers to value a building that performs well. The DfP pilots demonstrate that the lack of visibility of performance in use is a key barrier to market transformation.

In summary, the challenges identified in the pilot studies can be tackled effectively by the development of a design-for-performance culture:

- By setting clear targets and embedding these throughout the supply chain, the expectations of building investors, owners and occupiers concerning the performance of buildings in use can be met and verified.
- By focussing on measured post-construction performance outcomes, the technical barriers are addressed by creating demand for new performance-based solutions rather than unquestioned continuation of standard industry practice.
- By creating a demand for better buildings, the industry is incentivised to upskill and encouraged to compete based on performance-driven differentiation.

The DfP Executive Board commissioned the DfP Feasibility Study and then the pilot study programme with the purposes set out in Section 2.4. This report was originally intended as an internal report for the DfP Executive Board. On completion of the pilot study programme, the DfP Executive Board:

- Approved this Pilot Programme final report as an accurate representation of the project outcomes and agreed to its external publication.
- Agreed to set in motion the proposed transition phase for DfP in the UK.

1.3 What needs to be done to kick-start DfP in the UK?

The DfP and pilot studies have demonstrated that there are strong drivers and a coherent rationale for establishing a scheme to support Design for Performance. This report also details the building blocks that need to put in place for this to happen including:

- Leadership from key players in the market - a cohort of pioneers that commit to following the DfP process and set target operational ratings at the start of new projects.
- A scheme infrastructure for an authoritative base building rating scheme needs to be funded and developed to reflect the specific nature of the UK market, including careful consideration of the rating scale and the rules/guidance to ensure they are fit for purpose.
- Market development is required to provide visibility within the market place and enable those adopting DfP to have their approach acknowledged and valued in the market.
- Governance structures need to be established to protect the integrity of the scheme, enable its continuing development and to advocate for wider adoption.
- Capacity building and training needs to take place to enable the industry to develop the skills to deliver Design for Performance.
- Engagement with a wide range of stakeholders is critical to ensure that the DfP approach is embedded within existing standards and professional frameworks.

Although many of those participating in the DfP pilots cited barriers to change, very few considered these to be insurmountable. Furthermore, frustrated by the deeply entrenched design-for-compliance culture, a plethora of initiatives that are based on design intent and poorly performing buildings, developers see Design for Performance as an exciting new vehicle to create better buildings. The DfP pilot studies have helped to build a strong consensus among leading practitioners in support of Design for Performance and have helped to identify the key steps that need to be taken to introduce a Design for Performance approach to the UK.

2. Introduction

2.1 Background

Design for Performance (DfP) is an industry funded and backed initiative which aims to change the way we design new office developments in the UK. DfP looks abroad to the hugely successful NABERS Commitment Agreement that has transformed prime office development in Australia and tests the applicability and opportunity of developing such a framework in the UK.

DfP aims to end the culture of satisfying theoretical efficiency metrics and instead target outcomes using a Commitment Agreement style process. A Commitment Agreement in Australia commits the signatory from the outset to achieving a specific base building energy performance verified by measurement. This lends certainty to occupiers signing a pre-let that the building will fulfil its promises.

DfP has conducted a 3 year programme of work including a feasibility study and a pilot programme which provide a sound evidence base from which to develop such a scheme in the UK. This report sets out the findings from the pilot programme and the justification for embarking on a transition phase which aims to establish a fully-fledged DfP scheme in the UK in 2019.

The Design for Performance initiative has been funded by BBP members British Land, Legal & General Property, Nuveen Real Estate and Transport for London and by other leading organisations in the UK construction industry: the energy simulation company EDSL, Laing O'Rourke, NG Bailey, Stanhope, Willmott Dixon and CIBSE. Overall industry funding was matched 85% by the Usable Buildings Trust (UBT) charity, which enabled extensive input from leading experts in Australia. The initiative is also supported by the New South Wales Office of Environment and Heritage (OEH), which is responsible for running the NABERS scheme on behalf of the Australian government. The core team is led by Verco and includes BSRIA, Arup, UBT and Energy Action, the original developer of NABERS Energy, and a key technical consultant to OEH. Other organisations directly involved in DfP pilots include AECOM, Built Physics, Hoare Lea & Partners, The Crown Estate, Waterman Building Services and Watkins Payne. The initiative also has the backing of BEIS, BRE, BCO, BPF and UKGBC.

2.2 Inspiration and aims

New buildings in the UK are supposed to be energy efficient. However, the regulations intended to achieve this outcome are failing: they secure efficiency in theory but not in practice. With performance rarely measured, this failure has been invisible. The problem is particularly acute for air-conditioned offices because the compliance regime does not require scrutiny of the details of HVAC systems and their controls. Research has confirmed that many new UK prime offices are using up to five times more energy than necessary[3].

A new development with a base building performance 'guarantee' could be marketed as a property whose measured energy performance will match what it says on the tin. As well as positioning a new office as a sustainability exemplar, this could also make it more attractive to tenants seeking space in a building that is in principle demonstrably better designed, better constructed, better commissioned and better operated and maintained. Furthermore, the experience from Australia indicates that a DfP approach does not need to mean a more expensive building. With its focus on identifying reliably how a building will perform during each hour of a typical year, DfP can lead to capital cost savings because plant and systems are correctly sized for plausible demand scenarios, and less complicated. Significantly, DfP tends to encourage simple and robust design with less focus on "features" that can add cost for little performance outcome benefit.

[3] Cohen, RR, Austin, BS, Bannister, P, Bordass, WT and Bunn, R, "How the commitment to disclose in-use performance can transform energy outcomes for new buildings", BSER&T Special Issue, 2017. http://journals.sagepub.com/doi/full/10.1177/0143624417711343

A core tenet of DfP is that it is an approach that has been proven to work with great success in the Australian market over the last 15 years, since the Commitment Agreement was introduced there in 2002. What has been achieved in Australia and how the UK compares are detailed in Appendix A.

2.3 Timeline context of report

The origins of DfP can be dated back to the period following the coming into force in 2008 of the 2003 Energy Performance of Buildings Directive (EPBD). This culminated in multiple stakeholders supporting a mandatory roll out of Display Energy Certificates to commercial buildings through the Energy Act 2011. A UKGBC task force specifically recommended "annual DECs for landlords' services" should become mandatory, starting with multi-let nondomestic buildings over 1,000m^2.

Although DECs were not in the event extended to commercial buildings, with this groundswell of support for measuring their operational energy efficiency, in 2012 BBP commissioned Verco and the UBT to develop a Landlord Energy Rating (LER), a NABERS-style investment-grade energy rating scheme for UK offices, that could be applied by its members on a voluntary basis.

A specification for an LER and a prototype Excel based tool were duly developed, and during 2013 the tool was tested on about 85 buildings belonging to BBP members. This process exposed challenges with the configuration of HVAC systems and their sub-metering in *existing* buildings[4].

These constraints caused the BBP to explore a different path towards securing the outcomes that were being observed in Australia: to focus on *new* buildings, where it was considered it should be possible to design out the obstacles of engineering services and sub-metering configurations encountered in the existing stock. The hypothesis was to examine the apparent ability of developers in Australia to achieve the performance outcome they sought for a new office building, understand what was involved and consider if a comparable approach could be adopted in the UK market. The initiative was christened Design for Performance (DfP) because it seemed this was the approach in Australia, and it contrasted with UK practice which can be characterised as 'design for compliance'.

The DfP initiative heralded a new strategy for BBP's research which sought to:

- demonstrate that energy efficient operation can be achieved in new buildings, ensuring that new stock does not 'add to the existing problem' (the large energy demand of buildings).
- ensure that the base building energy performance of new buildings is directly measured, can be benchmarked and rated and that the rating scheme establishes a trajectory towards net zero energy in operation.
- identify exemplar pathways for improving the existing stock.

The timeline of the LER development and key phases of the DfP initiative are shown in Table 2.1.

[4] BBP members were seeking an investment-grade base building rating scheme for existing UK offices akin to the NABERS system in Australia. This required a harmonised scope for the energy uses that would be included in the benchmarking process, so that all buildings would be rated on the same basis. A key attribute was that the necessary data should be readily available and quality assured, enabling a rating to have reasonable 'transaction cost' and be investment grade. However, typically the metering arrangements in existing offices were not set up to measure all the energy used for whole building HVAC. This militated against a simple process by which an assessor could collect the necessary operational energy data needed for an LER. The final version of the LER tool attempted to overcome these challenges by incorporating a methodology that allowed estimation of those elements of the defined energy scope that were not directly metered. It also created a quality caveat for the rating driven by the level of estimates included: for a valid rating, default estimates had to be <10% of the total energy AND default plus professional estimates had to be <25% of the total. This attempted work-round could leave the LER dependent on assessor judgements and create a significant quality assurance burden.

2012 – 2013	Landlord Energy Rating (LER): Developed for BBP - a NABERS style system aimed at existing multi-let commercial offices
2015 – 2016	Design for Performance Feasibility Study: Deep dive review and comparison of the situations in the UK and in Australia.
May 2016 - April 2018	Design for Performance Pilot Programme: Apply and test DfP on real developments at various points in procurement and operational journey.

Table 2.1 Timeline summary of key phases of the DfP initiative, 2012 – 2018

The first DfP step involved a Feasibility Study into introducing NABERS-style Commitment Agreements to the UK. Commitment Agreements were introduced in Australia in 2002 to allow in-use energy performance to be targeted at inception and briefing stage, reviewed during design, construction and initial operation, and verified by an investment-grade rating using 12 months of metered data.

The six month study, from October 2015 to March 2016, set out the justification, structure and forward actions for creating a UK Commitment Agreement whereby a developer of a new building or major refurbishment commits to achieving a specific, measured in-use base building energy target. Its findings, captured in fourteen main conclusions, resulted from extensive input by Australian and UK experts and widespread consultation with the many stakeholders from both the property and construction industries who are involved in creating and then managing large new office buildings.

The study found that Australian teams can now routinely achieve in-use energy performance of landlord's services ("Base Buildings") in line with the predictions of models. Experience in Australia has also shown that tenant activities have marginal influence on Base Building ratings, once occupancy hours are taken into account. The study concluded that it would be technically feasible to close the Base Building energy performance gaps in the UK by using Commitment Agreements.

Following the Feasibility Study, the DfP funders agreed to support an 18-month programme of pilot studies. The programme set out to identify up to ten new office building developments at different stages of the construction cycle, and have each apply the Australian best practice approaches relevant to the activities each development had underway during this window. This report documents the findings from the pilot studies that were undertaken.

2.4 Purpose of pilots

The key objective of the Pilot Programme was to provide a strong evidence base for proceeding to a fully-fledged DfP Scheme. The core tasks were to:

1. Apply five key elements of a Commitment Agreement approach, summarised in Table 2.2, to live office development projects to determine their impact, practicality and likely additional time and resource requirements (if any)
2. Collate the evidence arising from all the pilots to create a coherent picture of the technical and organisational scope for Commitment Agreements to be applied in the UK
3. Disseminate the findings to stakeholders and invite feedback, and consider the key governance and other issues for moving beyond the pilot stage, summarised in Table 2.3.
4. Present a clear case for making a decision on whether to proceed to a transition phase which could establish a fully-fledged DfP scheme in the UK in 2019.

Key element	Commitment Agreement Activity
A	Committing to a Project Agreement – the mechanics for developers and contractors
B	Advanced dynamic simulation of HVAC plant and controls
C	Independent design review
D	Early operation fine-tuning of controls and comparing meter data with simulation model outputs
E	Tracking and sustaining annual base building operational energy use at target level

Table 2.2 Elements of the Commitment Agreement process considered by pilot studies

	Governance, infrastructure and other issues
1	Governance issues – what oversight is needed for a UK Scheme: • Executive Board, Industry Advisory Group and Administration Body • Market development
2	Technical infrastructure: • Standard for base building rating • Scheme rules including metering protocol
3	Developing the necessary skill base: • Establishing UK panel of independent experts to undertake design reviews • Ensuring capacity for advanced simulation • Creating a cohort of assessors accredited to produce quality assured ratings
4	Institutional challenges created by conventional UK market practices: • Having responsibilities for whole building HVAC divided between landlord and tenant • Providing central point visibility of HVAC control • Ensuring oversight of tenant fit-outs
5	How policy making could support DfP: • Incentivising disclosure of base building ratings on sale or let to drive the market

Table 2.3 Governance and other issues considered during the pilot study programme

2.5 DfP Feasibility Study

The DfP Feasibility Study represented a deep dive into practices in Australia. The headlines of the detailed conclusions are repeated here:

1. Base building energy intensity of recently completed London offices appears to be typically at least twice that of their counterparts in Melbourne, on a like-for-like basis, and three to six times as much as the best.
2. The size of the prize for the UK prime office sector is huge but there's a lot that is routine in Australia to catch up with, not least multiple skills gaps in the UK's supply chain.
3. Differentiating base building energy use from the energy used for occupiers' activities is absolutely key.
4. The base building performance-in-use rating is a pivotal KPI for all supply side stakeholders in the Australian market (contractors, MEP engineers, building managers, managing agents).
5. The UK will need to develop a base building definition and an easy to understand (consumerised) 'brand', comparable to the NABERS Energy star rating.
6. Advanced simulation modelling has been central to good design and performance achievement in Australia.
7. Independent design reviews remain a key technical driver of good performance outcomes and the process of industry education and advancement.
8. Australian teams can now routinely achieve in-use ratings in line with the predictions of models.
9. Even with a good design and high quality construction, it remains essential to apply intensive commissioning and fine tuning.

10. Mandating transparency for base building energy efficiency ratings has empowered the market in Australia to drive improvement and innovation.
11. Tenants in Australia associate higher NABERS base building energy ratings with better buildings and are willing to pay more to rent them.
12. Buildings with higher NABERS energy ratings produce higher yields and therefore secure higher asset values.
13. The impact of energy performance on asset value and yield makes the base building energy rating a core business KPI for developers, landlords and investors.
14. Generically, the 'Design for Performance' process is applicable to all managed non-domestic buildings but large offices have specific attributes making them the best place to start.

2.6 DfP Pilot Programme

The Pilot Programme set out to apply the key ingredients of Australia's success in up to ten new office development projects in the UK, or major refurbishments. In the event, six pilot studies have been undertaken (see Table 2.4), two of which are continuing beyond the end of the programme, to enable full monitoring for at least a year.

The findings of all the pilot studies are described in detail in Section 4 of this report.

Multiple other projects were explored in some detail as pilot study prospects. Although these did not progress to full pilots, the contexts and reasons for this are summarised in this report to increase understanding of the challenges DfP has to overcome and to learn the lessons.

Pilot Sponsor	Riba Stage	Operational Targets	Base Building Metering	Advanced Simulation	Independent Design Review	Commissioning & Fine-tuning	Monitoring & Verification	Operational Rating
British Land	1-2 (Refurbishment)	✓	✓	✓			✓	✓
LGIM Real Assets	3-4	✓	✓	✓	✓	✓		
Nuveen Real Estate	3-4 (Refurbishment)	✓	✓	✓	✓	✓		
Stanhope	3-4	✓	✓	✓				
Transport for London	7	✓	✓	✓	✓	✓	✓	✓
The Crown Estate	7	✓	✓			✓	✓	✓

Table 2.4 Completed pilot studies

2.7 Collaboration with existing voluntary standards and guidelines

The strategy of the DfP Executive Board has been to avoid DfP becoming an additional new initiative which participants would need to be persuaded to add to their extensive list of other sustainability activities. DfP has worked with the following organisations and initiatives to achieve alignment and integration wherever possible:

- BCO Guide to Specification (the next update is expected in 2019)
- BREEAM New Construction 2018, which includes a new Verification stage informed by DfP
- GLA, specifically the new London Plan proposals to close the gap between design and actual energy performance for major new developments in London
- London Energy Transformation Initiative (LETI)
- BSRIA Soft Landings Framework 2018 update
- CIBSE Guides e.g. 2018 update of TM39 Energy Metering
- Investor indices operators such as GRESB
- Climate Bonds Initiative's investment standard for new construction.

2.8 Governance and infrastructure

Pilot programme activities have included exploring the process by which Design for Performance can be advanced from its current pilot status to a fully-fledged scheme. This has involved considering governance issues and what infrastructure would need to be put in place to enable a scheme to start operating. These issues are covered in Section 7 of this report.

2.9 Next steps

The next step for DfP would be a transition phase which made the preparations necessary for a fully-fledged Scheme to get underway. A preliminary business plan explores how the necessary governance and scheme infrastructure might be put in place (see Section 7).

3. What is Design for Performance?

This section describes each step of the DfP process, as it would work in a formalised scheme.

Set performance target for building

The essential starting point is for the building developer to set a target rating for base building energy performance. This must entail a formal commitment to work throughout the design, construction and commissioning towards the operation of the premises being at or better than the target rating. This commitment to a target rating must be written into the tender documentation for the main contractor, who would be expected to pass it through, in an appropriate manner, to all parties involved in the construction, commissioning and operation and management of the building and whose contributions might impact the performance outcome. A Project Agreement template, akin to the NABERS Commitment Agreement, will be needed to document formally the developer's commitment. It might be lodged with the Scheme Administration Body and/or a local planning authority as a declaration of intent.

A Project Agreement for the UK should include a requirement for an early design workshop to brief the architect and MEP engineer design consultants on the target and the DfP process in general, and to provide early design feedback.

An example of how the developer commitment needs to permeate instructions for all relevant parties would be the terms of appointment for the MEP consultant engineer undertaking the initial design of the building's HVAC systems and controls. The Brief for the MEP engineers should include requirements to take responsibility for some key technical steps relating to DfP, so that all MEP tenders respond to these tasks explicitly, describing how they will be fulfilled. This should create a level playing field for MEP organisations bidding for the job. Three core MEP responsibilities, likely to be essential for a Project Agreement to achieve its objectives, are:

1. **advanced simulation of the design** and its HVAC system and controls, with the aim of predicting base building energy use in operation (see section 3.2).
2. **responding to an independent design review** (see section 3.3)
3. **extended commissioning, intensive post occupancy fine tuning and monitoring** against expected performance (see sections 3.6 and 3.7).

In addition to instructing the building's supply chain providers about the target, the building developer should reinforce their commitment by including the target rating in all agreements to lease and including in all leases a clause that discloses the Project Agreement.

It is noted here that a key challenge for DfP is dealing with a status quo where responsibilities for whole building HVAC are divided between landlord and tenant and potentially there is no central point visibility of HVAC controls[5]. Central visibility of all HVAC system controls is a pre-requisite for efficient building operation and thus essential if a good base building rating is desired.

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[5] It is common in the UK, especially in prime London offices, for landlords to provide a central HVAC service to all the tenants in a building, but to outsource provision and fit-out of HVAC systems on tenant floors to the tenants themselves, with tenants often installing their own BMS and having their own FM team. The landlord's managing agent for the building and their (often third-party) FM team may have little or no visibility of each tenant's system, creating the need for the central service to be provided 24/7 in case any tenant system calls for heat or coolth. This makes efficient base building operation virtually impossible. In Australia, the landlord retains control of on-floor HVAC which avoids duplication of effort and control ambiguities and so produces lower overall costs of occupancy (capex and opex). The Australian approach caters for the same demanding multi-national tenants and financial institutions present in the UK, yet the market accepts that landlords have single point responsibility for the full servicing of the building.

Dynamic simulation of building design and HVAC system

Dynamic thermal simulation of the building, with a time step of one hour or less, should be undertaken to predict heating and cooling demands under a range of expected conditions of use. DfP requires the building and its HVAC system and controls to be modelled simultaneously, in explicit detail, in order to simulate how the HVAC system would operate and be controlled to meet the predicted building heating and cooling zonal loads. The aim is to create confidence that the developer's target rating will be met under various plausible scenarios for tenant use and weather.

An explanation of how the simulation techniques necessary for DfP differ from current UK practices is given in Appendix B. The approach to simulation is not ground-breaking, in the sense that it has become routine practice in Australia, with the process defined in the NABERS Commitment Agreements Handbook for estimating NABERS ratings Version 1.1, February 2019, and it is used to a significant extent in the US under the guidance of ASHRAE 90.1 and ASHRAE 209-2018. ASHRAE offers an accreditation scheme for "Building Energy Modelling Professionals", known as the BEMP Certification. BEMP was developed with the participation of the U.S. affiliate of the International Building Performance Simulation Association (IBPSA-USA) and the Illuminating Engineering Society (IES). BEMP certification validates competency to do the following:

1. Model new and existing buildings and HVAC systems with the full range of building physics
2. Evaluate, select, use, calibrate and interpret the results of energy modelling software where applied to building and HVAC systems energy performance and economics.

Worldwide there are currently some 450 people with the BEMP qualification, of which some 350 are in North America, not surprisingly given its ASHRAE roots and that the exam uses imperial units. The UK probably needs to develop something comparable to BEMP, to give confidence to clients procuring advanced simulation services and to underpin DfP's need for advanced simulation.

It is noted here that in some respects the UK holds a world-leading position in advanced simulation, by virtue of two of the most commonly used advanced simulation software platforms originating here: EDSL-TAS and IES <VE>. Both these software packages are developed and operated by companies based in the UK, have full advanced simulation capability and are widely used by practitioners in the Australian market. Both are also used in the UK for HVAC simulation, but to a very limited extent, due to a lack of market demand. Another UK-based platform for advanced simulation is Design Builder which provides a user-friendly interface for the US based software EnergyPlus.

If anything might be considered a silver bullet in producing Australia's success with Commitment Agreements, it would be their application of advanced simulation, which to a significant extent lies at the heart of DfP. There are several key objectives for the simulation activities:

- To understand how the HVAC system would operate for each hour of the year and thereby confirm plant capacity requirements more robustly. Load duration curves could be produced for each item of major equipment, enabling the designers to identify how much time would be spent in more or less efficient operating modes.
- To confirm that the proposed design is capable of meeting the base building energy performance target rating; typically, the building should simulate to at least a quarter star better than target to engender confidence the actual operation will achieve the target.
- To undertake 'off-axis scenarios' to check the resilience of the base building rating to all plausible future scenarios for tenant hours and intensity of use and weather[6]. It is to be expected that different tenants may have longer or shorter hours of use than a base case standard condition, including late working, two-shift working and weekend working; some spaces may end up being

[6] The DfP feasibility study noted some MEP consultant engineers in Australia insist on minimum tenant ratings also being achieved (e.g. 1 star) before signing up to stretching base building targets, to give themselves perceived protection against excessive tenant energy intensity affecting the base building services efficiency. Modelling studies demonstrate this to be unnecessary, but the ease of mind it affords is understandable. We feel this option can be left to the market to decide.

unoccupied (void) for significant periods, etc. A better rating will be achieved if the HVAC is designed so that different zones can be serviced independently, and only occupied zones are serviced; otherwise the target might not be met[7]. A developer should expect the target rating to be achieved under all reasonably likely future scenarios.

- To inform the development of a verification plan which identifies necessary sub-metering[8].
- To produce monthly targets for each sub-meter and each sub-system (heating, hot water, cooling, fans, pumps, etc.)[9].
- To inform the optimisation of HVAC control, including testing the sensitivity of performance to common control and operational failure modes.

In summary, advanced building simulation is a process which involves creating at the design stage a virtual building to reflect accurately the energy usage of an actual or proposed building, under expected and plausible conditions of use over a year. The model should inform all stages of the building's development from design, through construction and commissioning, and most innovatively (for the UK) in the early operation tune up and monitoring and targeting phases.

Independent design review

The independent design review (IDR) would be undertaken by a member of a UK panel of approved independent experts. The IDR Panel would comprise a small group of experienced energy efficiency professionals who have been assessed for high levels of expertise in relation to:

- New building projects and the design of HVAC services and their controls
- Commissioning/tuning of buildings
- Energy auditing and energy efficiency improvement of buildings
- Simulation of building performance.

The IDR is designed to assist the design and construction team in understanding the choices they have and risks they face in delivering the target. It scrutinises the design, metering plan and the simulation outputs with the overarching objectives of checking whether it is probable the building will achieve its target base building rating, identifying potential improvements in either the current design or the design team's next design or both, and generally disseminating good practice to the industry.

The typical output from an IDR would be a report in spreadsheet format that includes the following components:

- a review of the architectural design, considering layout, orientation, materials selection, glazing and shading
- a review of each building services package, including mechanical services, electrical services (including lighting), hydraulic services and vertical transport; this will include commentary on:
    - risks in design, construction and operation with consideration to the target energy performance level, environmental impact and maintenance
    - options, alternatives and avenues of enquiry that may assist the improvement of the design and effectiveness of controls
    - items within the design that may lead to shortcomings with regards to energy efficiency outcomes, environmental performance and/or maintenance requirements.

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[7] The NABERS base building rating defines energy efficiency using the principle that a building should receive no benchmark 'allowance' from lettable space for any period it is unlet.

[8] CIBSE TM39 (2019) describes the metering needed to measure a base building rating. It is recommended that all energy use by base building HVAC plant is measured by landlord sub-meters.

[9] IES, for example, enables 'meters' to be located in the model which mirror proposed actual meter positions, whilst TAS predicts the energy use for each item of plant which can be aggregated to produce targets for each planned meter.

- a review of the proposed energy metering in order to provide commentary regarding the suitability and/or adaptation of the metering to measure post-construction outcomes
- a detailed review of proposed controls and/or the recommendation of optimised control approaches suitable for the project
- issues and recommendations relating to the proposed commissioning process and ongoing management practices, to help ensure that the building performs to its potential
- a peer review of any already completed simulation work.

The detailed design review report will provide clear identification of issues along with specific recommendations for consideration and learning. It will also note issues that might be more appropriately considered for the next comparable design.

At least one workshop would be expected to present the findings of the review to the design team and developer representatives.

The exact timing of an IDR can vary according to project circumstances, with earlier reviews giving more opportunity for changes before things become fixed, whilst reviews at a later stage can have the advantage of looking at a more developed design and, as a result, more meaningful modelling.

Producing recommendations in a spreadsheet format facilitates commentary by the design team and then, the reviewer's responses to the design team's feedback and comments. This process for documenting the design review has proved successful in multiple DfP pilot studies.

Final design

Changes arising from the IDR should be consolidated into the final design package. Key aspects relating to the performance target are a first draft of the Description of Operations and a performance validation plan: it should be explicit at this stage how the sub-system monthly energy use predictions of the simulation model will be tracked and verified by measurements with sub-meters.

Construction and completion

During the construction stages, it is important to keep the simulation model and a tentative Description of Operations (DesOps) up to date with any significant design changes. If any changes threaten the achievement of the target rating, after a value engineering process, for example, further modelling may be needed to demonstrate the target would not be compromised.

The draft DesOps should be made available to tenderers for the controls engineering and used as an input into the design of the control system. The objective should be for the implemented control strategy to mirror the control system assumed by the simulation model. If the actual controls replicate how the building operates in the model, the actual HVAC system performance should be close to the simulated performance, giving confidence the target rating will be achieved. Any refinements introduced to the DesOps should be reflected in a revised version of the DesOps document that emerges on completion and handover.

It is noted here that base building performance can be undermined by unsympathetic tenant fit-outs. It is therefore strongly recommended that the landlord's MEP engineers have effective oversight of tenant fit-outs, including veto of proposals which would prevent a target rating being achieved[10].

[10] Tenants can still manage their own on-floor fit-out, but landlords require oversight and approval of the design from their own consultants to ensure the tenant system does not compromise the landlord's ability to provide an efficient and effective service (and the promised base building rating). Tenant fit-out may include HVAC servicing for hot-spots like on-floor server rooms, but this would use energy off the tenant's meter, not the landlord's HVAC.

Early operation tuning, monitoring and verification

Intensive fine tuning

A key objective of commissioning should be to ensure the controls in the completed building are consistent with the simulation model of the final design and the revised Description of Operations.

For successful delivery of target ratings, intensive fine tuning during the Defects Liability Period has been found to be essential. This typically includes:

- at least 4 tuning exercises during the course of the defects liability period, each including a detailed review of BMS operation
- continued commissioning activity to identify and rectify defects.

A smoother accomplishment of the DfP process and target rating will be secured by the need for these early operation activities being recognised from the beginning of a project and built into the remit of all those involved, including the MEP engineers, control engineers, managing agents and facilities managers. Fine tuning specifically will be facilitated by the design of the BMS and clear, consistent and accurate documentation (e.g. across drawings, asset registers, the Description of Operations and the BMS itself).

It is noted that where responsibility for whole building HVAC control and maintenance is divided between landlord and tenants, early operation fine tuning activities may become more complex.

Measurement and verification

A key part of the DfP process is to establish building and subsystem targets based on the detailed simulation, potentially down to sub-meter level. Once the building is in occupation, measured energy use data should be collected, following the validation plan, and monthly monitoring reports prepared comparing sub-metered performance to simulated predictions. The reports should highlight any risks that the base building rating will fail to meet the target, and identify potential remedial actions.

Performance based maintenance contracts for managing agents and facilities managers are likely to produce the best chance of achieving the target base building rating. Meters should be treated as maintainable assets and the task of meter data collection and processing should be included in the requirements of the maintenance contract.

It is recommended the verification process follows the principles shown in Figure 3.1, enabling predictions and measurements to be compared on a like-for-like basis.

The steps in summary are:

- use model to predict energy use at design stage with expected conditions (left hand stack)
- measure base building energy end uses under actual conditions (right hand stack)
- reconcile these by re-running the design model under the actual conditions, to get a like-for-like comparison (middle stack vs right hand stack).

This last step could be time intensive for collecting reliable data on actual conditions, but the effort expended can be moderated according to the enthusiasm of stakeholders to check the match between design and actual, and learn from the deviations. There should be an expectation that metered values will be close to the simulated targets.

Actual performance should be reported with at least the granularity illustrated in Figure 3.1. Where significant discrepancies occur, suggestions should be made for their potential causes and the remedial actions which might mitigate them, and their feasibility either on the current project or for future projects. Monitoring all the base building and regulated energy uses and reporting monthly against the targets predicted by the simulation models should help to verify controls and meters are operating as expected and enable the contractor and/or O&M team to investigate potential causes of ‘energy defects’, where the energy used by a sub-system or measured by an individual sub-meter is deviating significantly from its expected value.

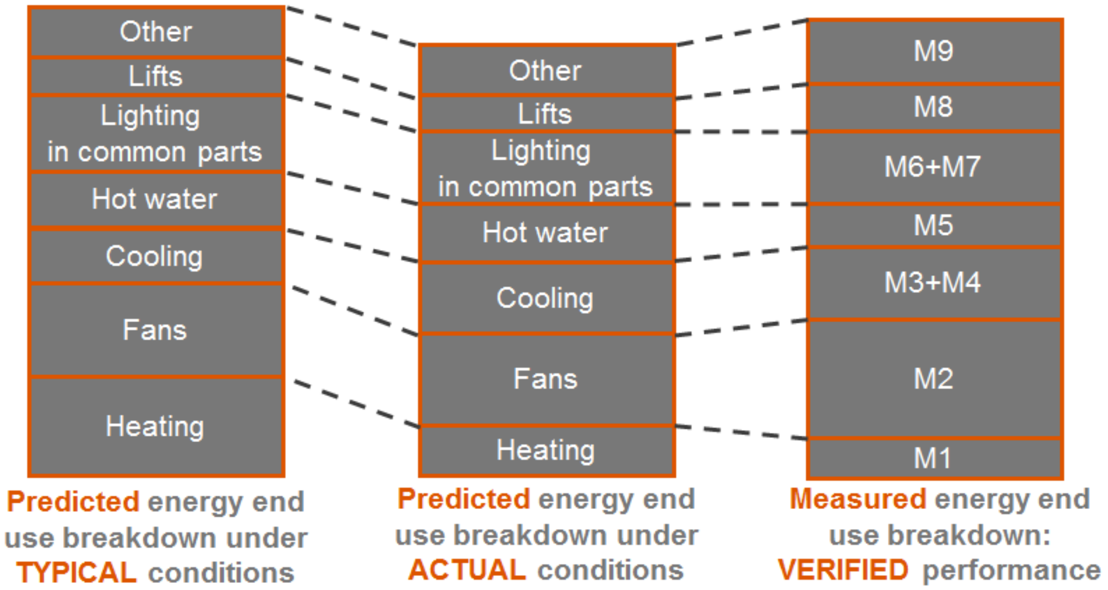


Figure 3.1 Illustrating how measurements can be compared with a calibrated model

Tracking the NABERS rating

The start of the formal measurement of base building performance should start once occupancy has reached 75% of lettable floor area and continue for a further 12 months. The base building rating, using a mix of actual and forecast energy use to cover a full year, should be tracked from the end of the first month, with each month of forecast being replaced by measured data as time proceeds. The monthly monitoring reports should highlight any risks the base building rating will fail to meet the target, and potential remedial actions.

It is noted that in Australia, the Contractor retains enough control during the first year of occupation to ensure the FM team can deliver the target performance. This means that once the target rating has been demonstrated to be achievable in year 1, the FM team can be expected to continue to achieve it in subsequent years.

Independent assessment of base building energy rating

The final step needs an independent accredited assessor to produce a formal rating for the building and lodge it with the scheme administrator so it can be subjected to the standard QA processes.

In Australia, contractual retentions are typically placed on the builder and mechanical contractor based on energy rating performance i.e. base building rating performance failure is treated as a defect. The end-of-period independent formal assessment of the base building rating therefore has to be completed prior to contractual release. This approach developed as a natural industry response to the need to manage performance risk and was not mandated under the NABERS Commitment Agreement. The UK industry will need to determine its own path on this issue.

A typical Project Agreement would require the landlord to provide tenants with annual updates of the base building rating, for the duration of their leases.

Conclusions on DfP process

The detailed description of each component of the DfP process illustrates how advanced simulation is a key technical factor that should permeate a building's development from concept design to achievement of a target measured rating (and informing the next design), as illustrated in Figure 3.2. Advanced simulation modelling of a building should both be a central driver of the design and guide expectations once the building is in operation. It should be used to define a draft DesOps at the detailed design stage which can underpin the initial setting up of the BMS and enable the actual controls to be 'tuned to the simulation' during early operation. The model should also underpin the validation plan for the building's energy rating, ensuring meters are installed in the necessary locations and providing targets for each meter against which actual performance can be tracked.

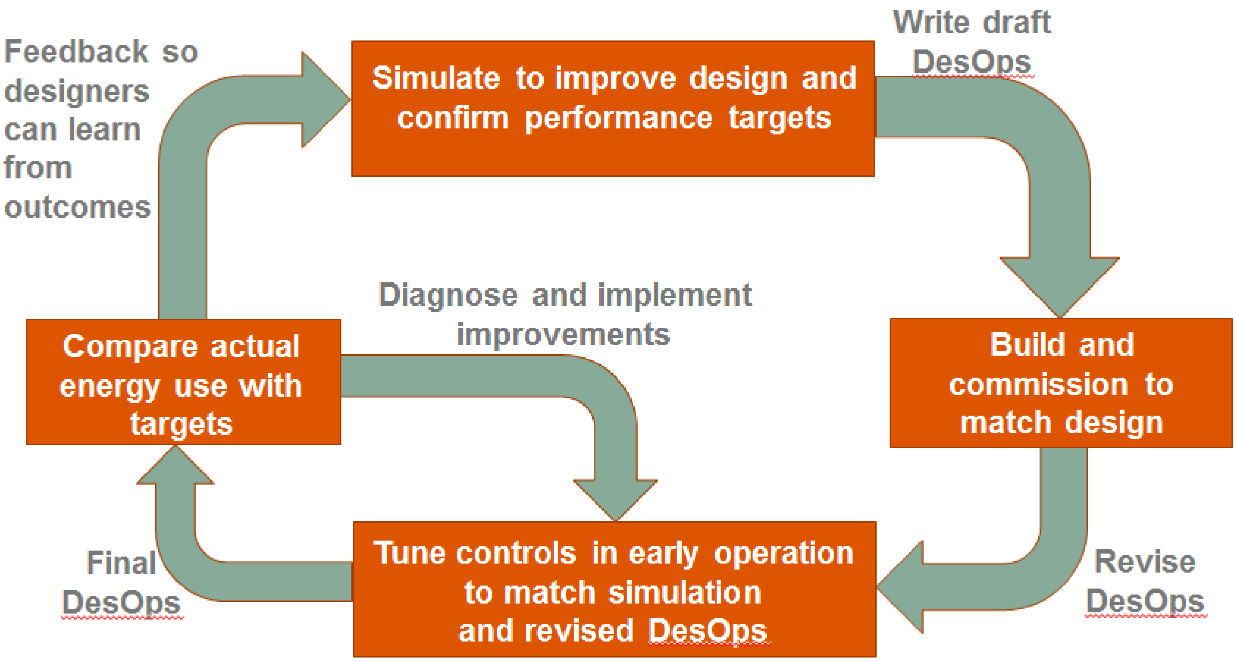


Figure 3.2 Ensuring lessons learnt are incorporated into the design of the next building project (DesOps = Description of Operations)

The influential, perhaps even dominating role that needs to be played by the virtual representation (digital twin) of the building (especially its HVAC system) in advance of it being a measurable entity in full operation makes it apparent that the modelling itself will need to be undertaken by a team including people with a strong mechanical engineering background. This will be necessary to model each item of equipment and its associated control correctly. Closer ties and ideally full integration of the M&E design team and the modelling team is likely to be required which may meet some resistance, particularly as it is often taken for granted today that a compliance check model can sit entirely separately from any design process.

When the UK reaches the position where investors and developers assign paramount importance to a building's performance-based energy efficiency rating, it becomes inevitable that the original design team will receive feedback on what worked well and not so well in their design, enabling them to improve their next design (top left of Figure 3.2). In Australia, this has driven a systemic change in how energy efficiency is considered in the design, construction and operation of office buildings, with innovation flourishing across the supply chain.

To conclude this section on the DfP process, it is noted that the whole is significantly greater than the sum of its parts. Better performing buildings will emerge from doing all the steps in an integrated way: those steps to be done later in the process being designed in and facilitated during earlier steps.

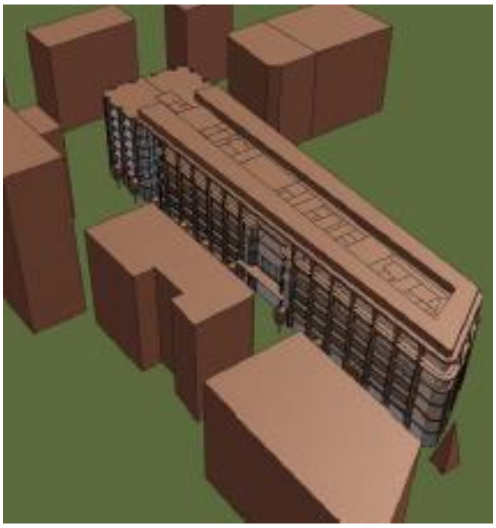
4. Pilot studies summaries and lessons learnt

Summaries of six pilot studies are reported in this section, chronologically according to the stage of the building development cycle when they were applied. At the end of the section, mention is made of over ten projects which were considered as pilots but did not materialise as such. The reasons for this are briefly explained to provide insight into the challenges facing DfP.

Pilot study 1: Early stage design to inform refurbishment (York House)

Project Overview

This pilot study, sponsored by British Land, covered the technical ingredient which seems to differentiate most strikingly between Australian and UK new office design practice: detailed dynamic simulation of HVAC systems and their controls. The subject is York House, a relatively recent mixed-use detached block in the West End of London, developed and owned by British Land and completed in 2006.



British Land occupy half the office area for their own headquarters. The building is managed by their wholly-owned property management business Broadgate Estates. The aim of the study was to explore the issues involved in applying “advanced” simulation, and to do so on an existing building with comprehensive energy metering that enables a model to be calibrated against highly granular data.

The scope of the study during the available time window of the pilot programme was to develop and validate a detailed and comprehensive model of the office elements of York House, produce a predicted LER for the building and compare this with a conventional LER based on meter data. Further work beyond that reported here will capitalise on this foundation, firstly to use the model to support further optimisation of the building’s operational control and secondly to inform future replacement / refurbishment of the M&E plant, when the model should be able to help right-size plant capacity as well as enhance energy efficiency.

This pilot study is believed to be a pioneering example in the UK of the use of NABERS-style advanced simulation on a commercial office. The work was undertaken by Built Physics Limited with practical support from British Land and Broadgate Estates.

About York House

York House is a 6/7 storey concrete frame building with glazed curtain walling designed by EPR Architects and located between Seymour Street and Bryanston Street in West London. British Land occupy about 45% of the building, facilitating the gathering of detailed information for the pilot study about how that portion of the building is used. The ground floor incorporates retail as well as office space and the office reception, the eastern end is residential and the basement provides plant rooms and car parking; this study looks at the office areas only, about 8,440 m^2 NLA.

HVAC is a 4-pipe fan coil system with roof-mounted AHUs providing tempered fresh air to the rear of the fan coils. The AHUs are fitted with inverter drives but operate in constant volume mode delivering 1.2 $l/s.m^2$ fresh air throughout the building. Some individual systems exist serving equipment rooms or high density spaces, including a level 3 auditorium space which has a VAV AHU. There are two chillers and four boilers, both sequence controlled and with primary and secondary pumped circuits.

Metered energy data and base building rating (LER)

The pilot study involved some forensic work to be able to collect robust base building energy data to generate the building's LER, reinforcing the perspective that obtaining investment grade base building ratings for existing UK commercial offices can require a detailed audit. The LER had to be calculated by summing utility supplies contracted by the landlord (three separate electric utility meters and one gas meter), subtracting sub-metered energy passed through to tenants for their light and power and then adding back on 'tenant supplements' (the base building services energy that is recorded under tenants' meters), specifically in this building the electricity for fan coil motors. The fan coil motors electricity use had to be 'professionally estimated', as allowed by the LER rules, if less than 25% of the total. It amounted to 128,000 kWh/year, or 15 kWh/m^2 NLA, some 14% of total base building energy use. Areas of the building used for retail and residential purposes are excluded from the LER calculation (both the floor area and any energy use). In most cases they have their own utility meters, but some are supplied with electricity from the main utility meters, via sub-meters, and these amounts have to be excluded.

The LER for York House for the 2017 calendar year was found to be 4.0 stars. Applying the NABERS classification (see footnote in Appendix A.1), this is a 'Good' performance[11]. Previous work by Verco for the BBP indicates most existing commercial offices in the UK fall below 4 stars[12]. Nevertheless, a 4 star rating still leaves much scope for improvement: in round numbers, improvement to 5 stars would require a 33% reduction in energy intensity and reaching 5.5 stars, the minimum standard currently being proposed by the City of Sydney for new offices in the Sydney central business district, would take a 50% reduction from the current energy use.

Advanced building and HVAC simulation method

The core activity of this pilot study was to develop a model of the energy use in the office areas of York House, deploying the approach specified in the NABERS Energy Guide to Building Energy Estimation 2011. The modelling reported here was done using IES VE 2017, but simulations were also undertaken using EDSL TAS as a separate exercise to understand any differences in approach and results, although reporting on these differences does not form part of this case study.

The geometry of the building, including the external shading louvres and overhangs was accurately represented (see image at start of this summary). Adjacent buildings were also incorporated to ensure their over-shadowing effects were taken into account – during the year of measurement there were no buildings affecting the South façade of York House as the buildings on the adjacent site had already been demolished and the site cleared for redevelopment.

Zoning within British Land's demise was reproduced as close to reality as possible. Inaccessible demises were zoned with internal and perimeter office areas to account for their different thermal loads from external factors. Internal equipment and lighting loads through the year were calculated for British Land's areas based on observation and sub-meter data, and estimated for the areas in the inaccessible demises, following the NABERS guidelines.

The fabric details were also represented accurately, especially the critical glazing thermal bridging junctions which were modelled using finite element analysis. Built Physics considered the level of detailed information available for York House was very good, and in this respect reflected the situation that should exist when modelling a new building at the design stage. Furthermore, they believed the construction was of a high quality and well maintained, implying a minimal 'gap' between design and as constructed performance.

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[11] York House used considerably more energy when the building was first completed, but starting 2009-10, British Land paid attention to fine-tuning and controls improvement, and reduced landlord's energy consumption by a reported 32%.

[12] York House energy performance may not be typical of commercial buildings that are not subject to strict monitoring.

Using the IES Apache HVAC module, the HVAC systems supplying all office areas and other zones receiving heating and cooling were modelled in detail. Non-cooled zones such as core stairs and toilet facilities were simulated without a full HVAC model. Meters were generated in the software to map to actual meters to enable the model calibration process. Energy for lifts and hot water generation was calculated outside the dynamic model based on algorithms taken from CIBSE TM54 and Guide G. The biggest challenge Built Physics faced was understanding exactly how the existing controls operate and interact with different systems, and this was only overcome by spending a day on site.

Model results

Once the model was fully checked and deemed ready, a first run was undertaken trying to mimic a design stage situation where operational information is obviously not available, albeit the existence of the real building and knowledge of how half of it is used by the tenants arguably means this run was better informed than a fully blind design stage situation where tenant fit-out is an unknown. The result gave a base building rating of 4.5 stars. The main difference from the metered data was for the annual chiller energy (actual 30 kWhe/m^2, simulated 13 kWhe/m^2) and this persisted when variants were tried including using the NABERS standard internal gains data for the British Land demises and applying a different weather data set, more representative of central London.

Modelling details were double-checked for the chiller control methodology, minimum part-load operation, sequencing, condenser fan power and operation and primary and secondary circuit operation and control. An off-axis scenario that brought the simulated chiller energy into line with the actual involved the lighting in the building being continuously on during unoccupied periods. It was conjectured this might be happening due to security patrols entering the offices on a regular basis. This demonstrates that real building operation will never follow the idealised performance assumed in a model, and corroborates the approach adopted in Australia whereby designers allow for some contingency (of the order of 0.25 star) in modelled performance above the NABERS target rating.

Conclusions

An advanced model including HVAC simulation of the base building services at York House has been able to reproduce the actual energy use with satisfactory accuracy. Two specific advantages of this approach are the ability to understand plant capacity requirements more robustly and to represent reliably the impacts of part-load operation on energy efficiency. In general, the pilot study has demonstrated the ability of advanced simulation to predict actual base building performance, the 'holy grail' for designers asked by developers to give assurances about performance outcomes in a market where tenants might have signed up for a tenancy on the basis of a specified base building rating.

Built Physics will be continuing this work, using the model to understand opportunities associated with changing HVAC control strategies at York House and alternative plant options if and when replacement and upgrade is undertaken. The model may also be used to explore other scenarios, such as higher or lower internal loads, periods with voids and worst-case climate change scenarios. It will also be able to examine the overshadowing impact of the large tower that is about to be built on the site to the South of York House.

Pilot study 2: Detailed design (245 Hammersmith Road)

Project Overview

This pilot was for a large (27,000m² NLA) office building in the borough of Hammersmith and Fulham in London, and was offered for participation in the Independent Design Review and Advanced Simulation components of the pilot programme. The project has had a long gestation due to external commercial factors, with the result that much of the design was more than a year old at the time of review. The project is being developed by Legal & General Properties who sponsored this DfP pilot study. The principal MEP design consultant is Hoare Lea.

Pilot study activities: simulation

The initial data provided for the project included an early simulation (without detailed HVAC modelling) following a TM54 approach with expected conditions of use. The model itself was briefly reviewed and showed significant issues with simultaneous heating and cooling that pointed to potential errors in the simulation. The model was updated before the pilot kick-off meeting and re-reviewed at the time of the independent design review.

Although the 'TM54' simulation for the building went beyond the Part L compliance approach by virtue of applying expected rather than standard conditions of use, the core model lacked detailed representation of the HVAC system and controls and was thus considered by the DfP team to be unsuitable for post-construction performance prediction[13]. A second round of simulation applied advanced simulation processes to the open-plan office spaces, using the IES Virtual Environment v2016 Apache HVAC software module. An initial report of model results was issued based on hours and intensity of use used for design purposes (BCO Guide to Specification). A second iteration was undertaken using values for the density of people and intensity of equipment loads that were considered more representative of what the building is likely to experience in operation. This advanced modelling was undertaken on a self-funded basis by Hoare Lea[14] with a cost estimated at £18k up to July 2017 on completion of the initial runs of the model described above.

The review of the simulation identified some limitations in the accuracy of representation of operation, but assessed the simulated NABERS Energy base building rating (using Melbourne as the climate zone) as being approximately 13% better than 5 stars; in practice this would be expected to yield a post-construction rating of 4.5 to 5 stars, which is around expectation for a new building. Based on the simulation outputs, the predicted total base building energy use equates to 5.2 stars on the LER scale. A compendium of some of the energy performance results produced by the advanced simulation is shown in Figure 4.2.1.

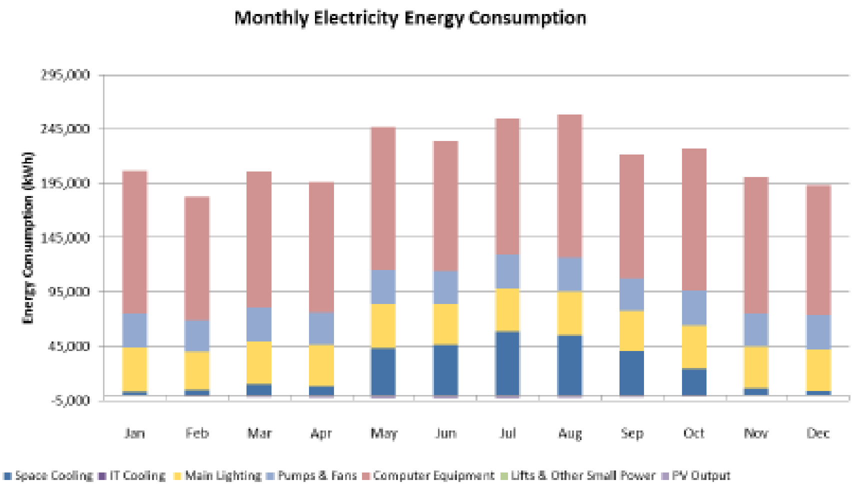
The DfP pilots core team examined the differences between the results from the three versions of the modelling, as shown in Figure 4.2.2. The earliest results are from the corrected TM54 model, whilst the more recent two (red and green columns) incorporate full HVAC simulations with different scenarios for lighting power density and intensity of equipment use. It can be seen that despite a nearly 40% reduction in internal gains in the last run (green column), cooling energy is relatively unaffected (it drops by less than 4%). Heating energy rises also only modestly, by 11%.

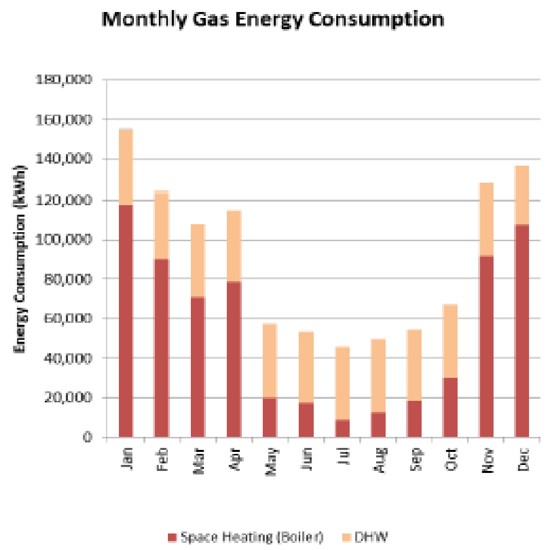
[13] See explanation in Appendix B of the shortcomings of the TM54 approach for energy efficiency performance prediction

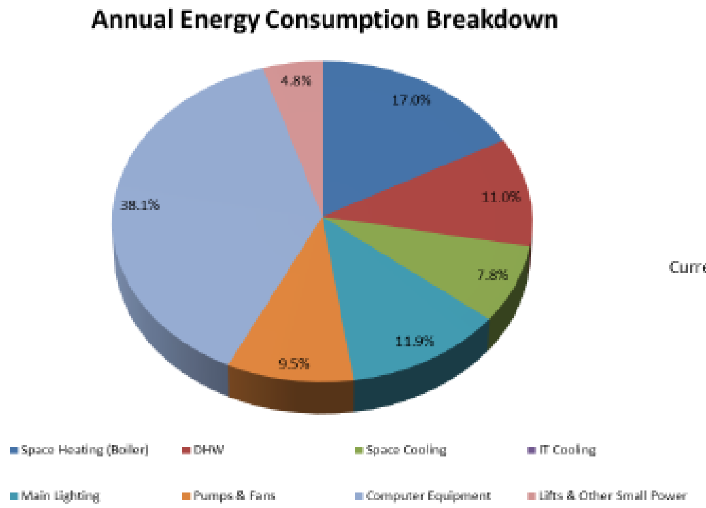
[14] When the pilot study was initiated, the developer hoped to be able to fund the advanced simulation as a means to underwrite a proposition that they would offer prospective tenants a cap on the energy costs element of the service charge. This proposal was shelved in the wake of the result of the EU Referendum.

Annual Energy Consumption Estimation

Month	Space Heating (Boiler)	DHW	Space Cooling	IT Cooling	Main Lighting	Pumps & Fans	Computer Equipmen t	Lifts & Other Small Power	PV Output
Jan	117,547	37,222	3,468	0	40,432	31,731	131,092	0	597
Feb	90,150	33,620	4,699	0	35,635	28,460	114,041	0	896
Mar	70,855	37,222	9,936	0	39,289	31,472	125,454	0	1,659
Apr	78,720	36,021	8,383	0	37,690	30,381	119,771	0	2,503
May	20,251	37,222	43,669	0	40,432	31,731	131,092	0	3,057
Jun	17,526	36,021	46,272	0	37,690	30,381	119,771	0	3,231
Jul	8,803	37,222	58,971	0	39,289	31,472	125,454	0	3,315
Aug	12,589	37,222	55,039	0	40,432	31,731	131,092	0	2,669
Sep	18,382	36,021	40,831	0	36,548	30,122	114,133	0	1,988
Oct	29,953	37,222	23,810	0	40,432	31,731	131,092	0	1,310
Nov	91,779	36,021	6,053	0	38,833	30,641	125,408	0	781
Dec	107,699	28,762	4,236	0	38,147	31,184	119,817	0	465
Total	*664,255*	*429,797*	*305,366*	*0*	*464,848*	*371,037*	*1,488,216*	*185,976*	*22,469*







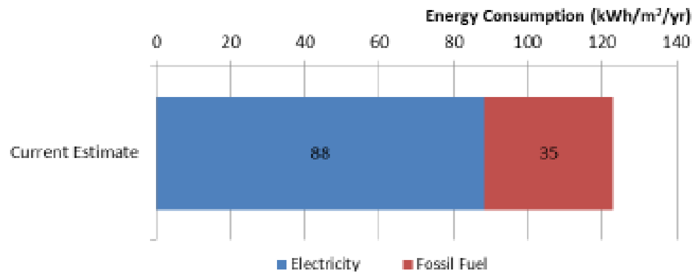


Figure 4.2.1 Results from advanced simulation modelling of pilot study no. 2

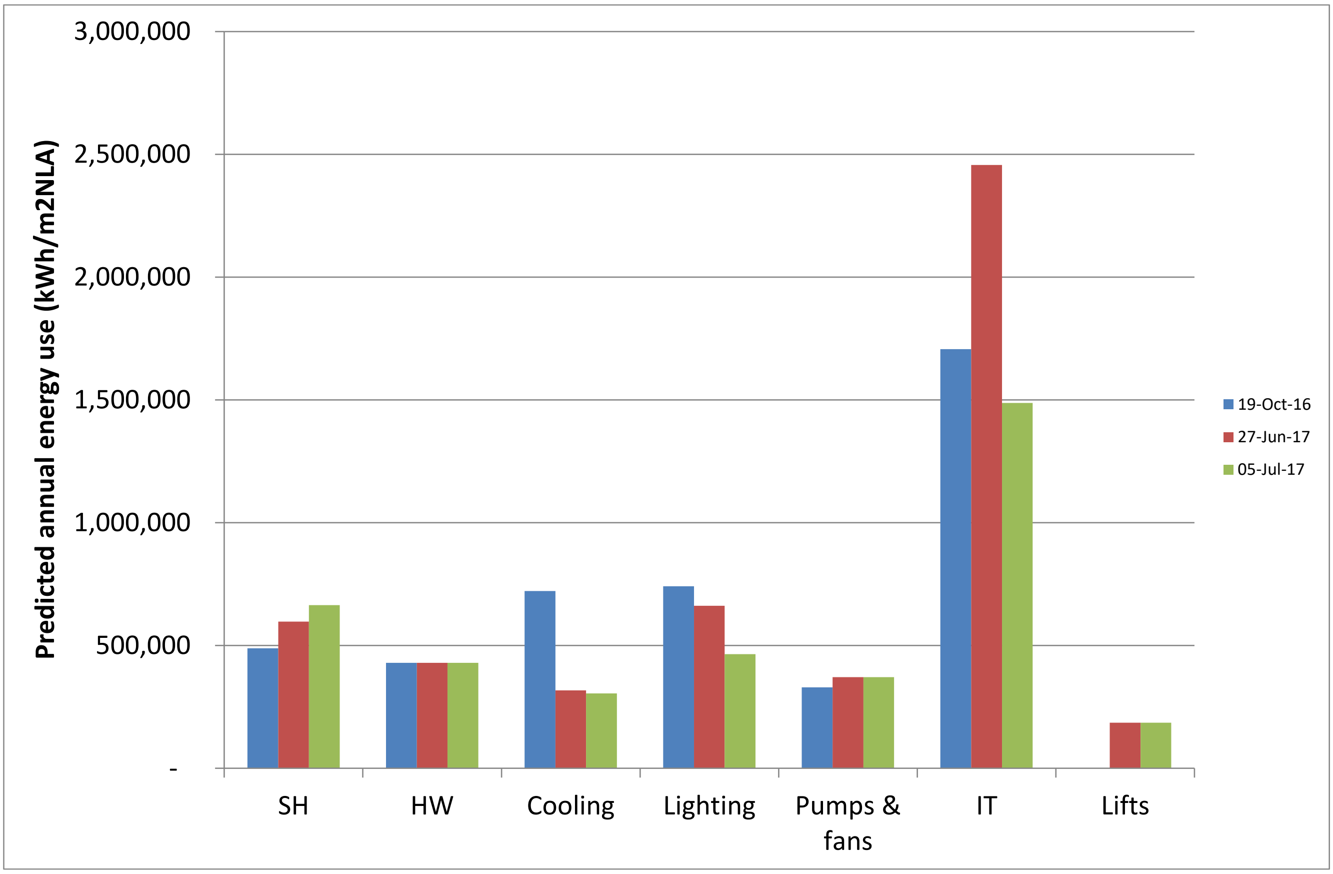


Figure 4.2.2 Results from 3 versions of modelling of pilot study no. 2

Overall the most notable finding apparent from comparing the results from the three different simulations is that the predicted overall base building energy use is very similar across all three runs (less than 5% variation). It did not prove possible for the advanced model to be reviewed by Energy Action's modelling experts, so it is difficult to reach conclusions about the suitability of that model for post-construction performance prediction.

The DfP core team considers the key issue here is how the results of simulation models are viewed in the UK compared with in Australia. The underlying driver for predicting a base building rating in Australia is to assure all parties that the target rating will be achieved when actual energy use is measured. This process is underwritten by both an onus on the designers to undertake off-axis scenarios to test the resilience of the rating to plausible variations in how the building will be used and confidence in the rating scheme's ability to account fairly for differences in how the building is actually used compared with the expected use.

The modelling results for this pilot have been presented in clear and concise graphics (Figure 4.2.1) with an inference for all stakeholders that these predictions are a plausible performance outcome. However, the absence of a formal operational performance target means that the necessary landlord services metering may not be put in place to measure the base building performance outcome. Furthermore, there is an assumption in the UK that predictions cannot be expected to be realised as measured outcomes, given that the actual conditions of use are unknown when the modelling is done and are bound to be different from those assumed. Critically, there is no base building rating scheme to conclude authoritatively if the outcome meets the set target. The risk is clear that design predictions will be treated as a vehicle for demonstrating that the design is energy efficient, with no expectation that the predicted results should be carried forward as realistic targets for performance in use.

Pilot study activities: Independent Design Review

The Independent Design Review identified that typical UK practices for the use of fan coil units and the presentation of the site in shell-and-core format presented significant barriers to the potential efficiency of the building. Fan coil units lack the ability to make use of cold outside air temperatures for winter cooling; the shell and core format leaves significant risks associated with design and control of air-conditioning on the floors[15].

The findings of the Independent Design Review were workshopped in detail with the design team. As indicated above, a large number of the design decisions were justified based on typical UK practice even where the deficiencies of the design were acknowledged. Prominent addressable issues related to the lack of measures to enable efficient turn down of central services and limited specification of control; the balance related to fundamental design parameters not open to change. The design team acknowledged the value of the IDR process at the time, although it is also noted that by the time the review was undertaken, the design decisions were largely under the control of Lendlease, the main contractor, who had had no involvement in the DfP process for this project.

Findings

Key technical findings:

- The use of shell-and-core fit-outs, as is common UK practice in at least the upper part of the office market, is a significant impediment to energy efficient performance outcomes. The use of fan coil units, which is closely linked to the shell-and-core practice, is also questionable in terms of its suitability as an energy efficient solution to air-conditioning in the UK environment.
- UK designers work within highly prescribed boundaries of industry expectation that are prejudicial to good efficient design; this has also to some extent created limitations on design thinking more generally.
- Simulation work conducted for this project showed some capability in the area of HVAC modelling. The lack of both a performance target and developer funding for the modelling costs militated against the simulation work taking centre stage in the design development.
- It is essential for DfP goals to be present in the original brief to ensure enforceability throughout the construction process.

Key process findings:

- The pilot study was drawn out over a long period and logistically struggled to have a strong influence in the design development. The chronology can be summarised as follows:

  Aug16 Release to DfP team of initial TM54 modelling

  Oct16 Release to DfP team of corrected TM54 modelling

  Oct16 Pilot project kick-off meeting

  Feb17 IDR workshop

  Jun17 Release to DfP team of first results from full HVAC model (design loads)

  Jul17 Release to DfP team of revised results from full HVAC model (expected loads)

  Jul17 Meeting to discuss advanced simulation results

  Jul17 DfP team issue findings from the simulation review with recommendations for model revisions

  Feb18 Close out meeting and effective end of pilot study

- As referred to above, the lack of funding for the simulation work reduced the opportunity (at least within the timeframe of the pilot study) for the modelling to be used to set the building up to

[15] The project also had provision for active chilled beams as an alternative for services on the floors, but the adaptation of the primary supplies to this was found to be problematic in the review.

perform in line with design intent and to produce a metering validation plan, so the expected base building performance could be monitored and verified against targets, once it is in operation. Under these circumstances, there is the potential for actual performance to fall short of the predicted 5 stars: the evidence from this pilot study corroborates concerns that design predictions not forming part of a full end-to-end DfP process are likely to give rise to a significant performance gap between predicted and actual base building performance.

- The DfP team offered to review the advanced simulation model if Hoare Lea were prepared to share it with Energy Action's modelling team. The offer was to review the modelling method against good practice approaches in Australia, where they have had 15 years of experience doing this type of modelling. It was suggested extra value could be generated for the building owners by possible enhancements to the model. The most obvious marketing pitch would be the ability to promote the building as one of the first in the UK to offer verification of base building energy performance. Hoare Lea did not take up this offer, citing a potential additional cost burden as a risk for them. Regrettably, this meant the study was unable to take advantage of one of the key potential values of the DfP pilots which was for UK practitioners to learn from the existing knowledge and experience of their counterparts in Australia.

Hoare Lea has indicated they plan to do at least one further run of the model taking account of the simulation review and its recommendations for model revisions. They were waiting for various uncertainties on design detail to be resolved by the main contractor who is allowed (under the terms of the contract) to select alternative equipment. The results from any further modelling were not available to the DfP team at the time of writing.

Key findings for the MEP engineers:

- Leadership is important (from client and consultants), to recognise the value of seeking to predict actual performance outcomes.
- More time is required for modelling, but this should moderate as modellers gain experience.
- There is a perceived need to know how occupants might occupy the building before attempting advanced modelling. However, this will become less daunting as M&E teams are required by their contracts to achieve targeted performance in use and are more exposed to how real buildings get used. Related to this is a difficulty for UK designers in the absence of a base building rating scheme to credit the fact that base building performance, with an hours corrected benchmark, gives results that are first order independent of the tenant profiles.
- Due to the emphasis on carbon in UK Building Regulations, the focus of UK designers can become blurred by whether their emphasis should be on energy or carbon. There is a need to focus on energy because carbon factors change over time and in any case energy efficiency helps to decarbonise the grid: the faster demand-side energy intensity is reduced, the greater will be the zero carbon-sourced proportion of grid supplies.
- A fundamental difference between the UK and Australia is the degree of landlord control over base building services in tenant demises which strongly impacts performance outcomes: better performance implies greater landlord control.
- Rule of thumb office loads in UK (BSIRA, CIBSE, BCO, etc.) are a lot higher than typical reality. In some cases, loads are half design values.
- Consultants will design to meet industry standards, so client and leasing agent buy-in is important if you are going to step away from this. There is also an important question of trust between client and consultant: engineers cannot be sued for over-sizing, but can be sued for under-sizing.

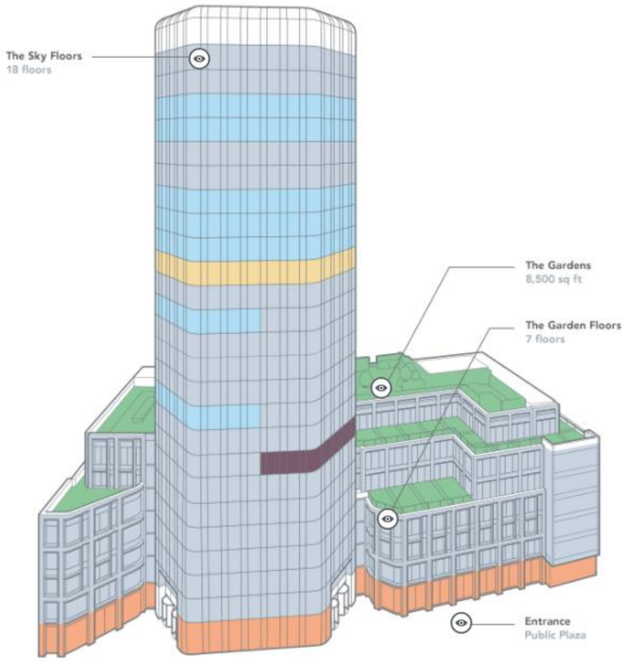
Pilot study 3: Detailed design (1 Angel Court)

Project Overview

Angel Court is a City of London office building of some 29,000m^2 total lettable space (office and retail) across 27 levels. Refurbishment / reconstruction of a 1970's building, and retention of the original structure, allowed its height to be retained in what is now a Conservation Area.

The project joined the DfP pilot programme when the building was well into its construction phase. The plan put forward by the MEP engineers Waterman was to undertake an advanced simulation and use the potential for the model's results to support tune-up during early occupation. It was also hoped to do a metering plan review, to set monthly operational targets for each sub-meter and to predict the base building rating (LER).

Stanhope, the developer, expressed interest to observe this exercise, but was unable to align it with engineering or marketing activities on site.



Building details

A 7-storey podium at the base (called garden floors) has some retail on the ground and first floors, and large-floorplate offices (1,722 – 2,487 m^2) on Levels 2 to 6. Rising above this from Levels 7 to 24 is a tower of offices (called sky floors) totalling 14,564 m^2, typically 814 m^2/floor. Levels 25 and 26 are floors for mechanical plant.

HVAC is fan coil (4-pipe on the perimeter) with efficient, variable volume DC fans. Fixed fresh air is supplied by four AHUs, each fully metered, two supply the podium and are in the basement, and two are for the sky floors and are located on the roof. There is no ability to isolate air from unoccupied spaces, other than manually. There are 3 chillers, 3 condensing gas boilers, CHP and a thermal store in the basement and 3 cooling towers on the roof with space provision for one extra chiller and cooling tower. There is also space for tenant supplementary plant on decks on the 7th and 26th floors. Supplementary tenant cooling requirements can reject their heat into the cooling tower loop.

Energy use is monitored by a dedicated system with multiple sub-meters. Hot, chilled and cooling water supplies to each tenancy have utility-grade meters. Tenants have separate lighting and small power meters. While landlord's electricity is comprehensively metered, the NABERS definition base building cannot be precisely measured, due to the fan coil unit fan motors being on tenant supplies.

Angel Court was designed as a low energy building with EPC rating 'A, BREEAM 2014 'Excellent' and 2010 Part L2A minimum requirements regarding CO_2 emissions surpassed by 25%[16]. It has efficient lighting (T5 fittings with daylight and occupancy sensing and PIR control), variable speed drives to reduce pump and fan energy, BMS energy monitoring to fully interrogate and optimise energy use, heat recovery on main ventilation plant to reduce energy use, high efficiency boilers and chillers and future capacity to connect into a district heating network.

[16] London Plan requires 35% for new build, 25% for a refurbishment.

Pilot activities

The project MEP engineering consultants (Waterman) originally committed to self-fund undertaking an advanced simulation, but realised rapidly that they lacked the in-house skills to do so. Their original response to this was to attempt to engage the services of their Sydney office, who have had experience in this as a result of working in the Australian market. However, as the Sydney office used different software to the London office, this proposal was dropped.

The advanced simulation project was subsequently sub-contracted out to IES's as a result of Waterman using the (Apache) HVAC model of the IES-VE program. At the time of writing, the IES team's model is being reviewed. It is intended that the model will be run for low, medium and high load scenarios, following the approach of TM54, to bracket the possible range of base building performance. It seems likely that the advanced simulation work will have served to inform the consultants of what it involves, but not achieve the original aim of taking them up the learning curve by doing it themselves. It seems unlikely that the simulation results will be mapped to sub-meters and used to tune up the building.

Findings

The key technical findings from this pilot were:

- There is a significant gap in the skills of the UK design consulting community with respect to the production of good quality advanced simulations with detailed representation of HVAC plant and controls.
- There are, however, a few specialists who are capable of providing this service. This position is similar to how the Australian market was 15 years ago.
- The somewhat simplified approach to simulation embodied in compliance approaches in the UK has significantly limited the level of understanding and skill in relation to HVAC simulation, to a level substantially behind that in many competing economies, especially those outside the EU, as discussed in section 3.2.

In a DfP context, the inability for the base building operational energy performance to be measured, rated and disclosed means that it is not possible to confirm whether the low energy features included in the design will achieve the desired outcome, provide little feedback to the designers of what worked well and what didn't.

Pilot study 4: Post occupancy monitoring (5 Endeavour Square)

Project Review

This DfP pilot is sponsored by Transport for London (TfL) and concerns 5 Endeavour Square, an office building of approximately 26,500m^2 across 11 floors in the Lendlease developed International Quarter in Stratford, London. The building was constructed from 2015-17 by Lendlease for Legal & General as owner, and with TfL as anchor tenant for all the office space. The accommodation provides office space for 3,000 TfL staff, break out spaces, an auditorium and a restaurant.

Handover was on 31 August 2017 and TfL occupiers moved into the building during October. TfL approached the project with a strong brief for environmental performance, but were unable to secure a performance commitment agreement from the developer.

Nonetheless, the building was designed for a high level of energy efficiency, including the following features:

- Passive chilled beam cooling system plus perimeter trench heating
- Heat recovery ventilation provided via a displacement system
- High performance building façade (floor to ceiling triple glazed with automated interstitial venetian blinds and a dehumidified ventilated cavity)
- Demand Logic automated fault diagnosis
- Full sub-metering with automated data transfer to TfL's SystemsLink portfolio automatic monitoring & targeting software system
- As part of the International Quarter development, the site receives chilled water and hot water from a district scheme that uses CHP and biomass to reduce the greenhouse gas emissions intensity of its energy sources.

Pilot study activities

The agreed pilot study tasks are:

- Independent Design Review (IDR) + simulation review
- Metering review and setting sub-meter targets
- BMS review and tuning assistance
- Monitoring and verification against targets
- Monthly tracking of the base building rating

The pilot study is continuing to mid-2019 to support controls fine tuning, energy performance monitoring and tracking of the base building rating during the first 18 months of occupation.

The DfP pilot's substantive involvement in the project commenced with an Independent Design Review. The design review identified a number of key items for consideration:

1. Opportunities to make chilled water and hot water flows variable temperature
2. Opportunities to introduce variable flow outside air
3. Opportunities to use variable pressure control
4. Weaknesses in the specification of LED lighting systems and lighting commissioning processes generally

The first three items in this list reflect a general trend across most of the pilots that UK designs appear to rarely make provision for the fact that building occupancy and loads are highly variable and as a result are an opportunity and risk for efficiency. It is noted that the design review was conducted around the time of the commencement of building occupancy, so there was little opportunity for it to influence design. TfL has commented that many of these features are included in their Head Office Standards, but were varied out by the Cat A construction team on this project. The fourth item reflects a common weakness in lighting specifications generally, as the rapid change in lighting technology and advancement of controls has moved ahead faster than the relatively conservative pace of standard specification development has been able to adapt; this is not a uniquely UK issue.

Given the nature of the first three findings, an important second stage of the DfP project was the review of the Description of Operations for the HVAC control system. In a mature DfP process, this would have occurred at a time prior to practical completion of the construction phase and would have been an input into the design of the control system. However, in a manner typical of a non-DfP project, the Description of Operations was not generated or made available as a document for review prior to programming; it was made available as post-hoc documentation of works completed[17]. It is notable that the documentation that was provided came in the format of a single 1.3 Gb 5,000 page pdf document, which suggests that this was intended as a close-out document for the record rather than an active document for review. The Description of Operations review found similar issues as per the design review with respect to the lack of allowance for variable service provision throughout the design in general, and recommended a range of control changes to reflect this. At the time of writing, the response from the controls contractor has not yet been provided; there is some degree of contractual tension as to whether further tuning works are treated as defects or as additional work, which may be a delaying factor.

A further factor in this project has been the role of simulation. Two relatively detailed simulation studies were undertaken by AECOM. One was produced to answer the “exam question” of whether the decision to change from a façade with brise-soleil and 900mm spandrel to a fully-glazed closed cavity façade with automatic blinds would use more or less energy. A second was commissioned to estimate the likely energy performance in use at handover and for the following 40 years - anticipating weather differences produced by climate change. This second was labelled a TM54 model but it went beyond the normal remit of TM54 by including simulation of the HVAC using IES Apache HVAC, with air flow rates over the chilled beams informed by CFD analysis. The IDR questioned whether the HVAC system was modelled adequately to produce robust predictions for use in early operation monitoring and verification (M&V), especially the controls (to some extent reflecting the lack of known detail as to intended control). At the time of writing, the pilot study is examining options to make the TM54 simulation more useful for the provision of post-construction targets at sub-meter level.

General Findings

The key technical findings from this pilot are:

- The design, while generally high efficiency, lacks provision for efficient turndown of core services in response to variable thermal and occupancy loads.
- While HVAC commissioning processes were well specified, lighting commissioning processes were weakly specified and have been the cause of some post-occupancy issues.
- TfL were unable to secure a contractual obligation for the building to achieve the energy performance goals it had for the building.
- It is essential for DfP goals to be present in the original brief to ensure enforceability throughout the construction process.

[17] It is noted however that the documents contained within the Descriptions of Operations package suggest that materials would have been available considerably earlier than they were made available for review.

Pilot study 5: Refurbishment from design to post occupancy (Worple Road)

Project Overview

The Worple Road DfP pilot project is located in Wimbledon, London, and involves the refurbishment of a mid-scale (3,700m²) commercial office owned by Nuveen Real Estate.

The building has been owned by Nuveen since 2004 and existing tenants had vacated the building prior to the refurbishment by March 2017.

Nuveen has energy performance data for the building prior to it being emptied which should provide a useful baseline for a before vs after analysis.

The project uses a Mitsubishi variable refrigerant flow system for air-conditioning throughout, as is common for smaller projects. It achieved a B rated EPC and BREEAM Very Good at planning stage, which has subsequently been improved to BREEAM Excellent.

Pilot study activities

The Worple Road DfP pilot study was submitted by Nuveen for the pilot programme as an end-to-end DfP process, although it was agreed too late in the development's contractual process to set an operational performance target.

The refurbishment works contract is due for completion in March 2019 and will offer up to 8 tenancies (2 per floor on 3 floors plus a single tenant on the ground and top floors), although it is conceivable it will be let to a single tenant. Cat A or B fit-outs will follow the refurbishment contract, indicating the earliest full occupation could be around October 2019, but may not be until early 2020. The pilot study will monitor performance for 12 months of full occupation.

Independent Design Review

The Independent Design Review identified opportunities and risks associated with sensor location and airflow within the office spaces, as well as issues with the provision of constant rather than variable outside air flow. It was also identified that the proposed metering arrangements would not be compatible with the measurement of a NABERS-style base building rating. No simulation was provided for review because at that stage no modelling had been undertaken - the project was still in the process of seeking planning for adding an extra floor, the step which would trigger the need for a compliance model to satisfy Building Regulations.

In response to the design review, the project team is considering upgrading metering to enable measurement of the base building energy use, addition of CO_2 control to the outside air supply and measures to improve lighting commissioning.

Most interestingly, Nuveen have suggested using this site for a case study into the relative overall occupancy costs of a landlord-operated HVAC system versus systems maintained by each individual tenant. This has the potential to be influential in the discussion of this critical issue.

Performance simulation

The refurbishment has recently secured planning consent to include an extension of the building's floor area by building an extra floor into the roof, and the design team is committed to simulating the building performance, but this work was not complete at the time of writing. The simulation work is being done with the EDSL-TAS dynamic simulation and will be used to identify post-construction performance targets by sub-system and to test the economic viability of the CO_2 control measure.

Project Findings

The key technical findings of this pilot are:

1. The use of return air sensing appears to be commonly dictated by aesthetic architectural requirements, and yet has the potential to significantly impact upon occupant comfort and system efficiency.
2. The application of VRF design for this project appears to be well suited to the application.
3. The small scale of the building does lend itself towards a NABERS-incompatible metering and management configuration, with all responsibility for HVAC being passed to the tenants. However, this makes it likely that maintenance will be more costly and the operational outcomes for the building as a whole will be poor, given small tenants have few resources with which to manage air-conditioning.
4. UK designers have a strong tendency towards the provision of fixed outside air, to the detriment of efficiency. Even though the use of heat recovery reduces the thermal energy penalty of this, the heat recovery also contributes to increased fan energy that is highly sensitive to modulation.

Pilot study 6: Post occupancy monitoring

Project overview

This DfP pilot, running from April 2016 to February 2018, covered the period of initial operation of a mixed-use development by The Crown Estate. The building commenced on site in spring 2011 and was completed in March 2014. 3,100 m^2 of new retail space at basement, ground and part first floor sit below office floorplates totalling 9,000 m^2 NLA across six floors.

The building is fully air conditioned, with 4-pipe fan-coil units. A ground source heat pump provides heating and cooling in addition to conventional chillers and gas-fired boilers. The building achieved a BREEAM Excellent rating.

The building services designer was Watkins Payne Partnership, working with architect AHMM. The main contractor was Mace. The building is managed as part of The Crown Estate's Regent Street portfolio by Regent Street Management Direct. The pilot study itself was led by Arup working directly for The Crown Estate. The following is a summary of Arup's case study report.

Pilot study activities: introduction

The main objective of this pilot study was to strive to ensure that during the early operation phase of this new development it was set firmly on a pathway that was achieving its energy efficiency potential. This task began as a technical exercise in meter data analysis, intensive fine tuning of controls and ensuring the operation of the building followed the design intent. As the study proceeded, it became clear that to meet the objective, it was also necessary to tackle the challenge of establishing energy efficiency monitoring, improvement and reporting as an accepted part of the building manager's remit.

The DfP concept of monitoring and targeting a measured base building performance is new to the UK market and, as a consequence, if it is to be done well, it is likely to create the need for facilities management staff to develop new skill sets. But it is equally important to recognise that the underlying problem in current practice is also a failure to ensure everything is in place to enable monitoring and targeting to be done easily by the FM team. The sub-metering requirements in Part L may be a clear signal to developers that a continual measurement of energy use when a building is in operation is a good idea; however, the requirements fall a long way short of being sufficient to ensure that a metering system installed in compliance with regulations is capable of being put to any use whatsoever, let alone used to drive meaningful energy management activities.

Pilot study activities: monitoring & targeting

As part of The Crown Estate's Development Sustainability Principles, all major commercial development projects are required to have a design stage operational energy performance estimate, calculated using the CIBSE TM54 methodology. This requirement was introduced in the later stages of construction of this pilot study building, and thus the model was produced after the design was completed in this case. The design stage model was produced by Watkins Payne Partnership.

The first task of the pilot study was to compare base building measured performance against the predictions of the TM54 model. The immediate challenge tackled by the pilot study was that the installed energy metering system was originally designed for compliance with Part L and CIBSE TM39 (2009), not specifically to enable base building benchmarking / rating:

- There was no process set out at the design stage for calculating the end use energy performance breakdown (i.e. mapping individual meters to end uses).

- As-built schematics did not show all meters and there was no meter schedule or referencing system
- The eSight energy management system (EMS) uses references which were not replicated on the schematics.

The pilot study highlighted that if operational energy consumption is to be targeted by building managers, then **specific measurable KPIs like the base building rating need to be defined during design, and supported by a comprehensive set of metering O&M information that uses common referencing across documents, schematics and the EMS**.

As the pilot study proceeded, it revealed there were issues both with the collection of sub-meter data and with the recorded data for a number of meters, indicating potential calibration problems. Two key reasons for the problems were identified:

- The building uses a pulsed data EMS. There is no data storage in the system, so loss of communications for any reason means that the data for that period is also lost. More recent buildings use high level communications protocols such as BACnet or MODbus, which are more robust and allow for storage of data during communications interruptions.
- Meters are not treated as maintainable assets, and as such there is no programme of maintenance or calibration checks. Manual meter reads are taken monthly for fiscal meters, but not sub-meters, so there is no method of checking the EMS data.

Operational performance was initially assessed based on the period June 2015 to May 2016. The actual energy use results, expressed using a CO_2 emissions intensity metric, are shown in Figure 4.6.1, compared with the low, medium and high scenario estimates predicted by the TM54 analysis.

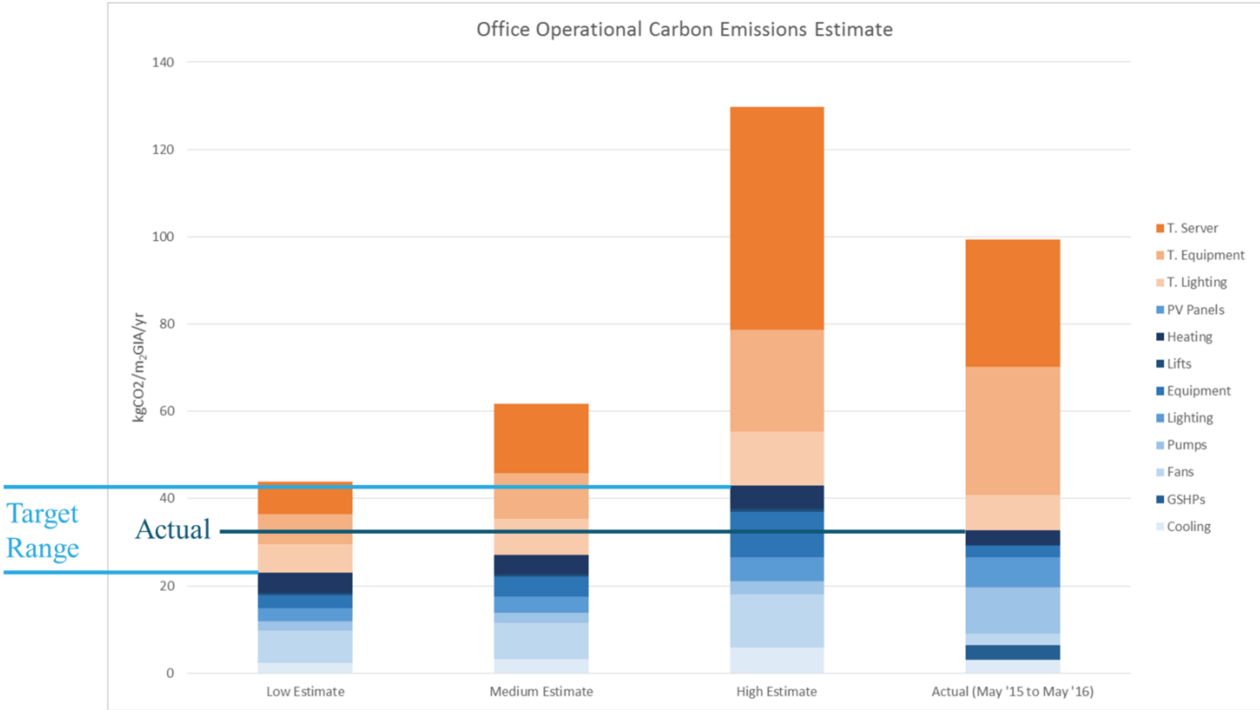


Figure 4.6.1 Operational Performance compared to Design Estimate (base building in shades of blue)

Figure 4.6.1 shows that, for the analysis period, the performance of the base building systems was approximately mid-way between the low and high TM54 estimates, and 32% above the median estimate. The tenant energy consumption (sub-metered electricity demand) was 80% of the TM54 high estimate. However, this style of TM54 analysis has an inherent shortcoming in that it is clearly not comparing like with like. If the TM54 approach is used simply to caveat in advance the possible range for a building's annual energy consumption, it is but a small achievement if the actual consumption falls within the extremes of the low and high usage scenarios.

A more insightful purpose for TM54 would be to try to understand whether the actual consumption is in line with where the model predicts it should be. This would enable deviations between expected and actual use to be identified and investigated, faults in control diagnosed and then potentially rectified. To do this robustly, one should be prepared to compare measured values with predictions on a like-for-like basis. This would entail a re-run of the model, applying the actual conditions of use, such as the hours and intensity of use and the weather over the year of measurement, so the boundary conditions for the prediction are aligned with those for the measured performance. Then the differences between the two can be assigned to plant efficiency and operational control issues.

A third objective, and arguably the priority, is to assess the building's energy efficiency. This requires a base building rating scheme like the LER (or NABERS) which takes into account the actual usage of the building. A more intensively used building should not necessarily be penalised for a higher absolute energy use.

The pilot study team helped identify and resolve issues described above related to the documentation of the metering system and its reliability. Nevertheless, data gaps were not totally avoided and it was not possible to track the LER accurately. An indicative value for the annual energy use of Landlord systems was calculated at 117 kWhe/m^2 NLA which translates into an LER of around 3.5 stars[18], as illustrated in Figure 4.6.2. **Robust meter data collection, correct calibration and an effective programme of maintenance of the metering installation is essential for the DfP process.**

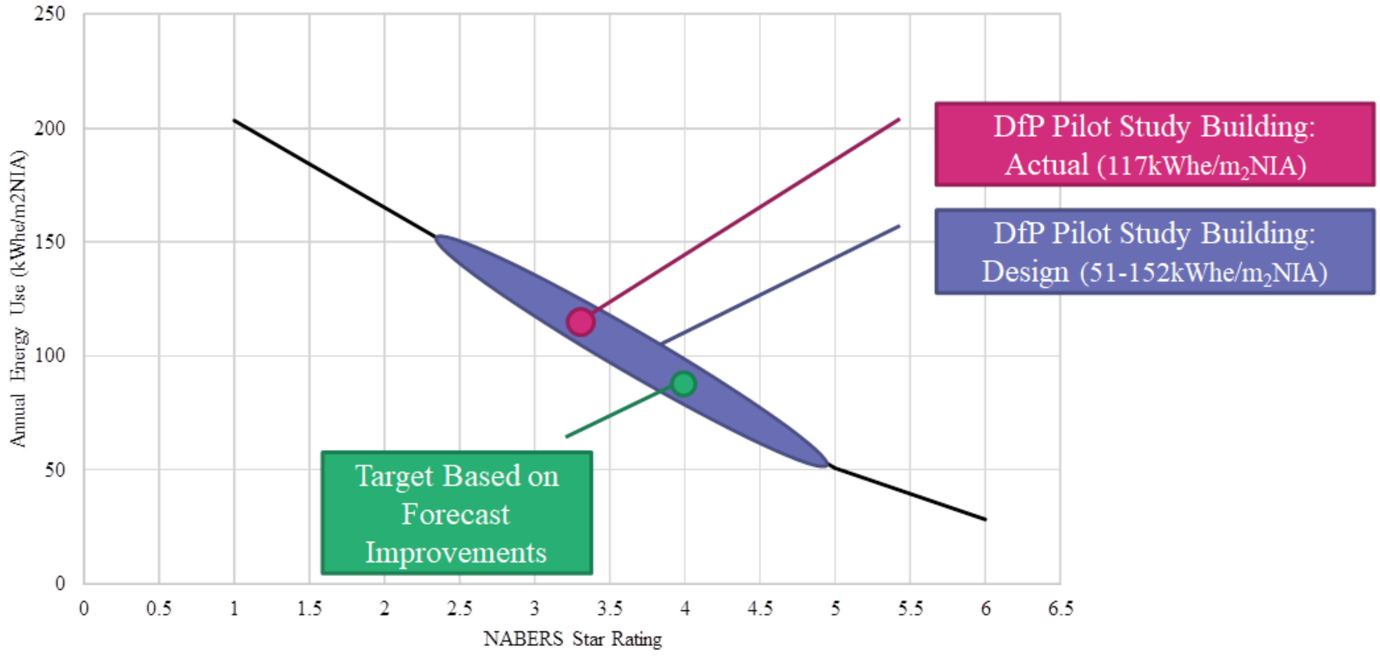


Figure 4.6.2 Indicative base building performance of the pilot study building on the LER scale

[18] NABERS, on which the LER is modelled, categorises 3 stars as "Average" and 4 stars as "Good" (see Appendix A).

Pilot study activities: improvement diagnosis

As well as working to improve the reliability of and understanding of the energy data being collected from the sub-meter system, the pilot study team scrutinised the BMS to identify control issues and, part way through the study, a Demand Logic system was installed, and deployed to give automated fault diagnosis. The main potential options for improvement identified by these means were:

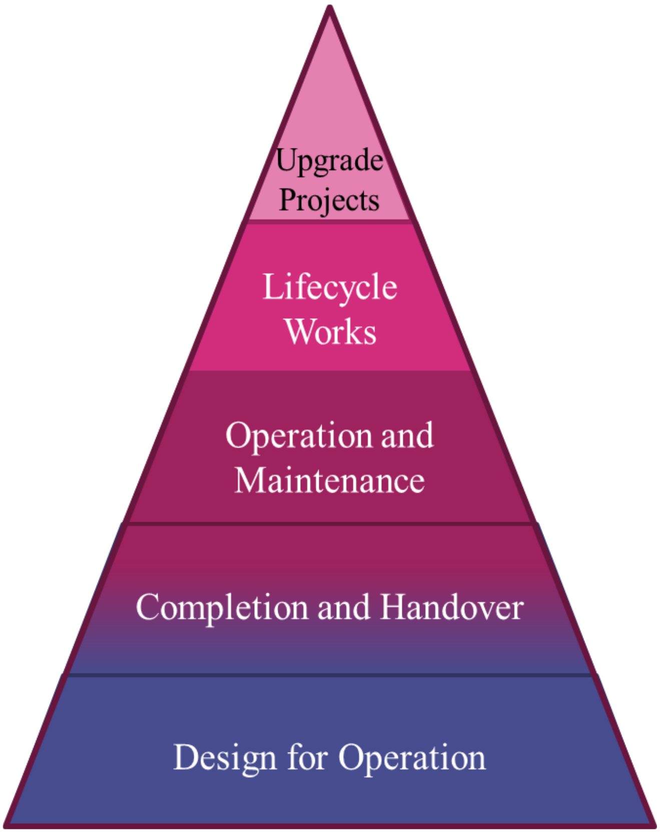
- Some main plant running 24/7 e,g, pumps & chillers
- AHU dynamic volume control dampers time schedule not set to shut when floor unoccupied
- Fan-coil units operating excessive hours e.g. 4 am to 10 pm
- Fan-coil units poor control e.g. in heating mode during warm weather in summer

The combined potential impact of correcting all these shortcomings was estimated to be worth about 0.5 stars on the LER scale, taking the building to around 4 Stars, if successfully implemented.

Building Performance Hierarchy

Arup's case study report on this pilot study sets out the challenges from their perspective in implementing the DfP process successfully. Arup encapsulated the technical challenges involved in delivering good building performance outcomes in a "Building Performance Hierarchy". For a building to deliver good performance in operation, all the layers of the hierarchy need to be in place, i.e.:

Building Performance Hierarchy



A building must be designed to be operated effectively. This means data on performance needs to be readily available to the FM team; and controls interfaces need to be appropriate to the maintenance skill set, easy to use both for operators and building users.

Construction and commissioning need to be completed effectively, both for base build and fit-out. Commissioning, particularly of the BMS and EMS, must be done without delay. Care must be taken to prevent tenant fit-out works adversely affecting base building operation.

A process of continuous commissioning needs to be undertaken in the first 1-2 years of operation and completed within the defects liability period, in order to identify any residual defects, engage with the base build contractor on the issues identified and to optimise operational settings.

Maintenance activity needs to respond directly to building performance data, using it to identify problems and with the flexibility to allocate resources on that basis. Maintenance activity needs access to sufficient resources of an appropriate skill level for the building systems in question.

An appropriate lifecycle maintenance programme requires good condition-based maintenance in order to divine the appropriate plant replacement point. It is necessary to look beyond standard like-for-like replacement, and requires a long-term plan aligned with performance objectives. Plant replacement/upgrade projects can be an effective way of improving performance, but will normally only represent good value once all the lower levels of the Building Performance hierarchy are in place.

“Normalising” building performance optimisation

The standard approach to maintenance in the UK is based on an “Input Specification”, as defined in the industry standard maintenance specification, SFG20. This defines a series of regular tasks required for different types of equipment. Maintenance is always under cost pressure, so the incentive for maintenance companies is to employ the cheapest labour to do the specified tasks.

There is no commercial incentive for maintenance companies to value performance, and so little incentive for maintenance staff to engage with performance improvement. In some cases, there is a clear disincentive: the provider pays some or all of the reactive maintenance costs within a fixed fee structure, therefore the more reactive works are undertaken, the lower the contractor’s profit margin.

More proactive portfolio owners, such as The Crown Estate, address performance improvement as part of an overarching sustainability agenda, which is fully or partly outside the standard maintenance contract, but this is not the market norm.

New approaches based on data analytics (including energy and BMS data analysis) have the potential to re-connect clients with the performance of their portfolios, helping to identify the performance improvement opportunities that exist. Performance-based maintenance offers the best opportunity to drive performance improvement, but needs good quality performance data to support it and to incentivise contractors to invest in staff with the right skills to make the improvements required.

Commercial considerations

In situations where property management is undertaken directly by the asset owner, it is relatively straightforward to ensure the right skills are in place, and to set up incentives to reward performance. In the more conventional out-sourced model, where a Managing Agent is contracted to manage a building or portfolio, creating the correct incentives can be more difficult. There are general levels of expectation around maintenance (hard and soft), but these are seen as supporting the commercial outcomes (rental rates, voids, service charge and customer satisfaction). Maintenance quality needs to be added to this list because it is a good proxy for both comfort and energy performance. Importantly, this would also create an incentive to up-skill building or facilities managers in energy management, and help energy performance become a core requirement. Energy performance KPIs (such as the base building rating) need to feature explicitly in a Managing Agent’s contract. This would then allow for alignment of positive incentives throughout the operational supply chain.

Other buildings considered

An additional 14 buildings were assessed for potential inclusion within the pilot programme, however, were not taken forward for variety of commercial, resource and technical issues.

5. Benefits of DfP for different stakeholders

The pilot studies have underlined the need for DfP: the successful pilots showed that there were things that could be done to make physical improvements in buildings while the unsuccessful pilots show that there is a problem to be answered in terms of the industry's practices. The table below shows how multiple stakeholders can get benefits through engagement with DfP.

Stakeholder	Benefits of DfP (and base building ratings)
Investors	Operational base building energy efficiency is a metric of interest to investors targeting lower carbon portfolios, for example in response to investor indices such as the Carbon Disclosure Project and GRESB, and more generally the Financial Stability Board's Task force on Climate-related Financial Disclosures (TCFD). Base building ratings would fill a vacuum in Europe for a metric which can be used by, for example, green bond issuers to qualify assets on the basis of their operational energy use and carbon emissions. The lack of a comparable metric for performance in use is a 'barrier to investment' in the UK market. Based on the precedent in the Australian market, investors can target office buildings with better base building ratings in the knowledge they should produce higher yields, through higher income returns and stronger capital growth. This is because better rated buildings are seen as better quality buildings, and command rent premiums occupiers are willing to pay.
Developers	Right-sizing plant capacity through the advanced modelling of the design advocated by DfP can reduce building costs and more than offset the extra costs of the modelling and other DfP processes. Credible predictions by advanced simulation at the design stage of base building operational ratings enable building efficiency to become a signal of good design, rather than the present reliance on feature-driven 'bling', and this can save developers significant capital costs. DfP ensures a new office building will operate at its energy performance target level. It thereby enables developers to offer occupiers pre-lets for space with the in-use energy performance (building quality) they want. It also means the building can compete with rated existing buildings, once these start to become common. In a crowded space for sustainability metrics, both soft and hard, a base building energy rating is a directly measurable hard metric, and can be secured by a developer with support from supply side stakeholders under their control or influence (like the contractor, managing agent and building manager). The potential impact of base building energy performance on asset value and yield would make the base building energy rating a core business KPI for developers. DfP helps manage the risk and potential liabilities of product 'mis-selling' in the form of 'over-promising' on performance which the current procurement system cannot deliver. DfP offers developers a more assured pathway towards the fulfilment of their own corporate objectives related to carbon emissions, and the ability to respond to investor demands for greater transparency (as referenced above).
Landlords	Base building energy performance is under the control and/or influence of the landlord and is a hard metric that can be used to attract tenants and justify rent premiums For the same overall cost to occupy, the landlord can improve rental value when the outgoings on utilities are lower. DfP buildings will be much more resilient to obsolescence as a consequence of energy performance.

	DfP buildings are more likely to sustain and enhance asset value and reduce risk of 'discounting' during the transaction process due to a lack of information or perceived absolute risk. DfP buildings are more likely to attract and retain good quality occupiers. This puts the landlords of DfP buildings in a better position to capitalise on the importance of closer relationships with their customers (occupiers) and gives landlords the ability to deliver a building that meets their customers' expectations and their corporate commitments.
Leasing agents	A base building energy rating will provide leasing agents with a hard sustainability metric which occupiers may perceive as a surrogate for building and indoor environment quality, as well as ticking their corporate climate change CSR policies.
Transactional agents	DfP and a more general context in which base building ratings are obtained and disclosed would provide transactional agents with accurate and comparable data.
Valuers	Valuers have been seeking a measurable sustainability metric for many years to complement design based environmental metrics like BREEAM and/or displace discredited energy performance metrics like the EPC. DfP effectively provides them with market based, consistent and comparable metrics of actual performance, which is exactly what valuers can use to play their part in market transformation.
Managing agents	As the market for DfP develops, managing agents will be keen to compete on their ability to achieve target base building energy ratings across their portfolios. A key benefit of DfP will be its ability to provide clear and specific briefs and metrics to managing agents to manage the buildings in line with specific performance outcomes. This enables the managing agents to focus on performance outcomes, resulting in process efficiency (e.g. needs performance based maintenance rather than PPM), skills development (e.g. commissioning and BMS) and to enable them to manage buildings in line with occupier expectations.
Facilities managers	DfP should make it easier for facilities managers to offer effective performance based maintenance: the means to do it will be built in to designs. Knowledge that managing agents will pay for performance based maintenance will encourage FM organisations to recruit staff with the necessary skill sets. This will enable FM organisations to meet their customers' expectations more transparently and thereby develop stronger and longer term relationships with them.
Occupiers	Occupiers are increasingly focused on ensuring that the space they occupy is smart and promotes occupant well-being. In the current environment, detractors argue that high performance may be achieved by service deprivation. In reality, the gap between simulation and reality is driven by poor operational practices that waste energy while not generating any positive comfort outcomes; efficient buildings save that energy while delivering the same or better comfort. A Project Agreement commits the signatory from the outset to achieving a specific base building energy performance verified by measurement. This lends certainty to occupiers signing a pre-let that the building will live up to its promises. A more energy efficient base building will reduce occupier utility costs. Savings will offset potentially higher service charges arising from performance based maintenance. DfP enables greater transparency about energy costs and offers opportunities to fulfil corporate commitments transparently.
Main contractors	The ability to deliver buildings with their target base building rating will enable contractors to differentiate their offer on the basis of a hard sustainability metric. The DfP process will help contractors manage the risk of delivering a building that does not perform as expected, a result that could be considered by some as a 'defect'.

M&E contractors	Many aspects of DfP will need to be delivered by M&E contractors. Those keen to progress up the learning curve will be able to differentiate their abilities and evidence their success through hard metrics.
MEP consultant engineers	MEP consultant skills lie at the heart of the technical aspects of DfP. Those embracing this new approach should be able to promote this in the market, both to win new work and to attract and retain the most talented engineers, who will relish using innovation and their knowledge and understanding of HVAC systems and controls to produce better performing buildings, verified by hard measurements.
Software developers	DfP should hugely expand the market for advanced simulation and reinforce the positive role of software in improving the energy performance of actual buildings by first creating a virtual building which can reflect accurately the energy usage of a proposed building, under expected and plausible conditions of use over a year.
Modelling practitioners	The use of advanced simulation software by skilled modellers is central to DfP. Modellers keen to go up the learning curve will be able to offer new services to a market seeking the best practitioners, rather than the cheapest route to compliance.
Control engineers	Good control is essential to achieving better base building ratings. DfP will reward those control engineers keen to embrace a new regime with a focus on controls which operate as intended, and are judged by measured performance outcomes.
Energy consultants	DfP will raise the profile of building energy efficiency, increasing the market for energy consultant services, as advisers and accredited base building rating assessors. Base building ratings will give energy consultants a hard metric to demonstrate their abilities in tuning up the energy performance of existing buildings. Similarly, they can act as an enabler for low cost M&V in energy performance contracting.
Energy managers	Energy managers will welcome new assets into the portfolios they manage if they have a prescribed energy performance which DfP ensures will turn into a reality. Base building ratings will transform the prestige of the energy manager's role, raising its profile to a business critical level for property companies.
EMS / M&T supplier	DfP will provide further justification for better quality EMS and M&T systems, potentially driving innovation and reinforcing the market for added value features. Vendors of automatic fault diagnosis (ADF) systems will get another reason to convince building owners and landlords to deploy their technology.
Government	DfP can help government focus the design of new construction on base building operational ratings. If DfP starts to be adopted in the UK's regulatory framework, in the same way as Australia is planning to introduce it, government would empower the industry's attention to refocus on performance outcomes. DfP will contribute to the UK's Industrial and Clean Growth Strategies: improving energy productivity, reducing carbon emissions and increasing energy security. It can help deliver Paris Agreement outcomes, something the current system is failing to do. DfP enables the commercial real estate sector to deliver better buildings, helping the UK to compete credibly as a location of choice for businesses in an international market that will be increasingly driven by the Paris Agreement on climate change. Support for DfP can help government demonstrate policy action towards: • high level international climate commitments and leadership. • the commitment to halve the energy consumption of new buildings by 2030 • responding to the substantial concerns raised by the Committee on Climate Change about the UK staying within its 5th carbon budget (2028-2032).

6. Next steps

Rationale for developing a fully-fledged scheme

The DfP initiative has been very successful: the initial feasibility study confirmed the potential for introducing DfP into the UK market with no challenges being insurmountable, and the pilot projects have demonstrated that the application of DfP can have significant benefits.

The DfP pilot programme is formally coming to a close in July 2018 and the question is whether a fully-fledged scheme could be established in the UK. The key drivers for establishing a scheme are:

- There is increasing awareness that regulatory drivers are not delivering the kind of 'step change' required to improve the operational energy efficiency performance of UK office buildings.
- Disclosure and transparency concerning actual performance in use is increasingly being required by investors and official bodies concerned about the risks of climate change.
- The confirmation (from the pilot studies and Australian data) that far better performing buildings are possible, and that this would have clear benefits in terms of asset value and customer (occupier) engagement.
- Increasing consensus across major industry bodies that a greater focus on performance in use is required and that the DFP approach can deliver this.

The experience from the pilot studies underlines that it will take time to develop a fully functioning scheme in the UK, and that a 'transition phase' is necessary to enable:

- DfP infrastructure to be established
- the scheme to be fine-tuned for the UK market, building on outcomes from the pilots
- a phased uptake amongst industry leaders, enabling leaders to help shape and test the scheme, limiting the risk to early adopters
- the DfP project team to build upon existing engagement from industry, gain deeper industry buy-in to the scheme and help build industry momentum

What is meant by a fully-fledged scheme

To provide context for the proposed next steps, this section identifies the components of an ecosystem which might constitute a scheme enabling DfP to be implemented in the UK. The key elements are:

- An ‘official’ base building rating method with a set of Rules for assessors applying the rating method and a process for adjudication of the rules and collation of case law and FAQs
- An administration body to manage receipt of Project Agreements and completed ratings, QA of ratings and accreditation of assessors
- A governance structure providing independent and authoritative oversight of the scheme and its administration, and enabling the scheme to evolve and the Rules be revised over time
- Capacity building arrangements which enable the UK industry to learn the skills needed to implement DfP effectively
- Market development: a plan that sets out how to promote the DfP scheme to key stakeholders

Building the market – DfP Pioneers

The concept of a DfP Pioneer has been created to describe a developer organisation which is enthusiastic about the DfP approach and prepared to commit to adopting DfP on some of its major new development projects during the transition stage.

Why we need pioneers

There are three key underlying reasons to believe so-called DfP Pioneers are needed to kick-start the establishment of a fully-fledged scheme:

1. **Creating a market**: Demonstrating to the wider supply side that clients for new construction are serious in taking this on and will create a market for DfP services

2. **Taking the initiative**: Industry needs to act first to create a critical mass of activity before legislators will be convinced to get involved. A long-term aim for DfP would be for government to mandate performance based metrics for property. Pioneers can create the impetus for a rating scheme to be established. Once it is up and running, government is more likely to look at mandating its use. By approaching the measurement of performance in use in this way, the market will have a rating scheme that reflects industry needs and is developed by the market, rather than having a regulated approach developed by the government which does not always understand the finer intricacies of the commercial real estate sector and how to drive improvements in performance. Pioneers will be seen as 'leaders' in the market, setting the direction of travel and driving the rest of the industry to follow.

3. **Avoiding fragmentation**: In the absence of a government-led scheme, pioneers can support a pathway towards a national scheme that is credible and underpinned by appropriate protocols to protect its integrity. This will incentivise the whole market to play by the same DfP rules. A harmonised approach can spur innovation and improved performance outcomes through healthy peer group competition. The alternative could see DfP left to individual market actors to adopt it in ways they see fit; such fragmentation would not produce the same drivers for improvement as a harmonised approach.

   A consistent way of measuring performance and having a credible system for verification across the market is a critical element of transparency and disclosure that will enable the market players to be compared objectively and fairly with one another. Increasing disclosure requirements (e.g. TCFD) and voluntary benchmarking initiatives (e.g. GRESB) lay bare the lack of a harmonised approach in Europe and the UK for accurately reflecting performance in use. Potential DfP Pioneers are already committing to such voluntary initiatives and committing to creating a national approach to DfP would demonstrate there is 'teeth' to these commitments by providing an independent, credible and verified approach to performance in use.

What actions are pioneers asked to commit to

There are two aspects to the pioneer role;

1. Making a commitment to adopt DfP on certain new development projects, in order to establish a growing market for DfP services. This might manifest in, for example, a specific property fund with a ‘green’ remit committing to a minimum base building operational performance standard for all their new office developments in the UK eg 4.5 stars LER. Such a commitment implies these projects would follow the full DfP process described in section 3 of this report, on the basis that if they didn’t, the target is unlikely to be achieved and the commitment would be seen to be hollow.

2. Participating in an industry steering group which will drive the transition phase. It is foreseen that a new DfP Executive Board comprising all the DfP Pioneers would take over from the current Board.

7. Conclusions

Why is design for performance needed?

The UK commercial office market targets theoretical performance to comply with Building Regulations. Furthermore, at present, an energy performance certificate (EPC) rating, determined by a theoretical calculation, is used to communicate an existing building's energy efficiency in the UK market. The effect of this regime is a 'design for compliance' culture prevails, and empirical evidence suggests the EPC rating correlates only very weakly with actual operational energy use. A direct consequence is the existence of a well-documented and large 'Performance Gap' for new commercial offices in the UK[19] [20].

By stark contrast, evidence from the Australian commercial office market shows a focus on performance outcomes, supported by a scheme to rate the operational energy efficiency of the base building (NABERS[21]), has been transformational in improving the energy efficiency of assets in the market. Importantly it has also become a KPI influencing investment decisions for existing and new buildings, sales and purchases. Data has confirmed that buildings with better energy efficiency ratings on average enjoy lower voids, increased rents and enhanced asset values, thereby producing higher income and capital yields. The underlying reason is a better rating becomes a marker of higher building quality.

For new build offices, developers in Australia sign up to 'Commitment Agreements', a process which involves a target performance outcome being specified from the very beginning of a new building development process, a relentless focus on performance throughout the design, construction and early operation phases and a commitment to rate the base building operational performance after a year of full occupation. It was conceived to ensure new offices could operate at their target energy performance levels. Commitment Agreements enable new buildings to compete with rated existing buildings using the same metric, and empower occupiers to sign up to pre-lets for space with the in-use energy performance (building quality) they want.

The immediate manifestation of the above contrasting approaches is the very high energy intensity of UK prime offices compared with their counterparts in Australia. Up until recently, this position has been invisible: performance targets are rarely set, performance outcomes are rarely measured in the UK. But investors are pushing for greater transparency and disclosure which could expose new assets to risk, given the problem has now been revealed. And in any case, more efficient buildings offer substantial co-benefits in terms of a better working environment, and in Australia have been proven to offer better financial returns. DfP should be pursued because it produces better buildings fit for the 21st Century and benefits all stakeholders - the size of the prize is huge from a core business financial perspective for property owners, as well as for energy efficiency and climate.

What are the key findings of the pilot projects?

The pilot projects have enabled the DfP Board and project stakeholders to understand whether the practical process and benefits of DfP identified in the earlier Feasibility Study can be borne out in reality. Whilst the pilot studies have a number of limitations (e.g. the scope of application of DfP being restricted by timing to specific 'phases' within the development life cycle), they have provided a sound evidence base to enable a thorough examination of the technical, market and cultural opportunities and challenges of implementing a DfP approach in the commercial office market. These can be summarised as follows:

[19] Austin, B, The performance gap – causes and solutions. Green Construction Board – Buildings Working Group, 2013.
[20] UK Green Building Council (UKGBC), Delivering Building Performance, May 2016 https://www.ukgbc.org/wp-content/uploads/2017/09/UK-GBC-Task-Group-Report-Delivering-Building-Performance.pdf
[21] National Australian Built Environment Rating System

Technical: The DfP approach aligns energy use with demand, resulting in multiple efficiency benefits.

The current 'Design for Compliance' mentality in the UK means that the technical specification and delivery of offices in the UK does not accurately reflect the energy demand and services required by occupiers. The project pilots demonstrated that a Design for Performance approach requires a much greater focus on building design and services calibrated for demand and this ultimately delivers multiple efficiency benefits.

- The preponderance of shell-and-core design in the premium office market leads to major issues in efficiency. The DfP pilots:
    - Confirmed that responsibility and authority for plant operation is often divided between landlord and tenant and that specialist expertise is often required to establish how controls operate and interact. This represents key challenges in establishing accountability for energy efficiency, but also often places the tenant as the building managers, without the appropriate skills to deliver efficiency and limited agency to influence base build operation.
    - Questioned the use of fan coil units in terms of their suitability as an energy efficient solution to air conditioning in the UK environment.
    - Highlighted market challenges, particularly in relation to larger tenants wanting to have more control over HVAC.
- Commercial offices in the UK are designed predominantly to service a 'top-hat' usage profile throughout a building rather than to serve actual occupancy on an as-needed basis. The DfP pilots:
    - Corroborated the fact that many systems are not designed to respond efficiently to changes in demand, different operating hours or the presence of voids. These are factors of first order importance in achieving operational efficiency.
    - Demonstrated that advanced modelling that includes HVAC simulation and the use of off-axis scenarios can reproduce the actual energy use with satisfactory accuracy. This takes additional time and costs, but specific advantages of this approach are the ability to:
        - understand plant capacity requirements more robustly
        - represent reliably the impacts of part-load operation on efficiency
        - enable alternative plant options to be considered if and when replacement/upgrade is required.
- Central visibility of all HVAC system controls is a pre-requisite for efficient building operation and thus essential if a good base building rating is desired.
- Metering configuration plays a critical role in being able to delineate and measure energy in a way that makes accountability for energy consumption transparent, an important enabling factor in improving energy efficiency. The DfP Pilots demonstrated that metering strategies that align with DfP principles can provide much greater visibility and accountability for energy performance.
- The process of undertaking an Independent Design Review has proved to have significant benefits, providing an independent analysis of projects to help identify specific interventions that can improve the performance of the building to enable it to meet its targeted performance.
- The findings of the two pilots involving post-construction work suggested that the philosophy of continuous service availability has led to poor practices in commissioning and operation that are highly wasteful. The pilots demonstrated that the DfP approach enables services to be calibrated to demand and the commitment to fine tuning and commissioning can secure energy efficiency in operation.
- There are differing opinions as to whether the 'measure' of building performance should be based on carbon or energy. The DfP focus on energy helps to deliver better buildings and decarbonise the grid by reducing demand side energy intensity.

Industry Culture & Skills: DfP provides an antidote to the Design for Compliance culture & fosters the skills required to deliver better buildings.

A general finding of the pilot studies (and one expressed in some of the comments of developers in the close out questionnaire) is that institutional issues will take time to turn round. The performance consequences triggered by procurement practices, split responsibilities for HVAC control, lowest-cost driven maintenance, etc. will be exposed by measuring performance outcomes. This may lead different stakeholders to examine the overall costs of occupancy depending whether the landlord or tenant maintains plant in tenant demises. In due course, this may encourage consideration of other solutions, including the Australian model whereby the landlord takes full responsibility for all base building services.

Driven by the existing regulatory regime, the Design for Compliance culture is embedded within standard industry practice, standards and guidance, Design for Performance shifts the focus to performance outcomes which can secure the delivery of targeted performance and in doing so enables the supply chain to focus skills development on delivering better buildings.

- Designers appear heavily constrained by “normal industry practice” even where these practices are directly leading to poor efficiency outcomes. The DfP pilots illustrated that focusing on performance outcomes could result in different design solutions and that many designers would benefit from the post-occupancy feedback loop.
- In general, HVAC is treated as being of secondary importance in the regulatory framework, as its detail is not addressed in EPCs. The DfP pilots:
    - Confirmed that:
        - Skills for the enhancement of HVAC efficiency have not been fostered within the design industry.
        - There is a lack of skill in the industry in the advanced modelling required to optimise general building services.
        - HVAC design is well behind that in other developed countries, such as Australia and the US.
    - Evidenced that there are only a small number of individuals capable of providing an advanced modelling service in the UK and that upskilling in this area would be essential for the implementation of Design for Performance.
- The DfP pilots demonstrated that contractors are not held to account for failing to deliver a performance outcome and are therefore not incentivised to ensure construction quality beyond compliance and formal completion. The DfP ‘Commitment Agreement’ process would ensure that performance outcomes are incorporated within contractual requirements, but aligning this with accountability for performance will be challenging, especially in the early period of adoption of a Design for Performance approach.
- The DfP pilots confirmed that commissioning processes are weakly specified and often truncated in order to meet development delivery schedules. The pilots also demonstrated that the commissioning and fine tuning of buildings is critical to their chances of achieving the targeted outcome and that the DfP process would support this.
- The DfP pilots concluded that performance based maintenance contracts for managing agents and facilities managers are likely to produce the best chance of achieving the target base build rating. Meters should be treated as maintainable assets and the task of meter data collection and processing should be included in the requirements of the maintenance contract.
- The DfP pilots highlighted that leasing agents need to be aware of and ‘bought-into’ the concept of DfP for it to be valued and communicated effectively to prospective investors and occupiers.

Client Commitment: The commitment to a performance target is critical to driving a Design for Performance approach.

Finally, but crucially, the lack of performance outcomes in clients' briefs reverberates across the supply chain. Many of the DfP pilot studies were at Stage 4+ in the development process and therefore DfP consistent performance targets had not been originally set in the client brief. So, whilst many of the pilot studies identified changes that could be made to deliver better buildings, not all of these changes could be implemented as the targets were not incorporated within the contractual arrangements with the supply chain. The DfP approach can help in acknowledging the value of accurately predicting performance outcomes, setting expectations appropriately and securing these outcomes.

Achieving a target is a collaborative endeavour like a relay race. The pilot studies show that DfP is a feasible new approach but presents many challenges. One of the key findings is how activities in earlier stages determine success at later stages and the converse: challenges at later stages often have their root causes in choices made earlier. The main contractor must probably take greater responsibility for ensuring every party involved in delivering the building recognises their contribution to activities which follow their inputs. Engendering such a collaborative mentality may take a significant adjustment in the context of existing fragmented procurement routes, construction practices and supply chains.

The pilots demonstrated that the existence of a performance target would have been a key 'enabling' commitment and should be set in the early stages (Stage 1 or 2) to ensure that the performance outcomes are embedded within the supply chain contracts and that these are reflected in the whole life cycle of the building from design through to operation.

What needs to be done to kick-start DfP projects in the UK?

The DfP and pilot studies have demonstrated that there are strong drivers and a coherent rationale for establishing a scheme to support Design for Performance. This report details the building blocks that need to put in place for this to happen including:

- Leadership from key players in the market - a cohort of pioneers that commit to following the DfP process and set target operational ratings at the start of new projects.
- A scheme infrastructure needs to be developed that reflects the specific nature of the UK market, including careful consideration of the rating scale and the rules/guidance to ensure they are fit for purpose.
- Market Development to provide visibility within the market place and enable those adopting DfP to have their approach acknowledged and valued in the market.
- Governance structures to protect the integrity of the scheme, enable its continuing development and to advocate for wider adoption.
- Capacity Building to enable the industry to develop the skills to deliver Design for Performance.
- Engagement with a wide range of stakeholders to ensure that the DfP approach is embedded within existing standards.

Although many of those participating in the DfP pilots cited barriers to change, very few considered these to be insurmountable. Furthermore, frustrated by the deeply entrenched Design for Compliance culture, a plethora of initiatives that are based on design intent and poorly performing buildings, developers see Design for Performance as an exciting new vehicle to create better buildings - there is a strong consensus among leading practitioners in support of a change to Design for Performance.

Appendix A. Australia's success story and how the UK compares

Appendix A 1. What has been achieved in Australia?

Some 15 years ago in Australia, "base building" energy ratings[22] had started to influence investment decisions for existing and new buildings, sales and purchases. The scheme that measured and verified this base building performance was called the National Australian Built Environment Rating System or NABERS. Some of the key steps have been:

- 1999: New South Wales introduced a voluntary system (the Australian Building Greenhouse Rating, ABGR), to measure and benchmark the energy use of existing office buildings. This developed into the NABERS national scheme.
- 2002: Commitment Agreements were conceived for developers to ensure new offices could operate at their target energy performance levels and enable occupiers to sign up to pre-lets for space with the in-use energy performance they wanted.
- 2004: State governments started to set minimum standards for space they occupied. New South Wales took the lead in March 2004, when they decreed their existing owned buildings and tenancies had to be rated by the year end, should attain 3 star base building by July 2006 and new leases should require 3.5 stars from 2006[23]. They also required 4 stars for major upgrades and 4.5 stars for new buildings[24]. Other States gradually introduced their own minimum standards.
- 2006: Federal Government mandated, for spaces that it occupies, 4.5 star base buildings for new buildings, major refurbishments and new leases over 2,000m^2. Most States have since ratcheted up their requirements to the 4.5 star level for all their stock over 2,000m^2. In the same year, the Property Council of Australia introduced minimum NABERS base building energy ratings into their definitions of new offices: 4.5 stars for grade A, 4 stars for grade B.
- 2010: Federal government introduced the Building Energy Efficiency Disclosure Act, to mandate disclosure of Base Building ratings on sale or let of office premises >2,000 m^2 NLA.
- 2011: NABERS extended the top of their scale to 6 stars, stating 5 stars represented excellent performance, and 6 stars market leading[25]. The new 6 star level was set by taking a theoretical 7 star level as zero emissions and applying a 50% reduction in the emissions at 5 stars. Similarly, 5.5 stars is a 25% reduction from the 5 star level.
- 2012: the energy performance bar for grade A offices was raised: to 5 stars for new buildings and to at least 4 stars for existing buildings.
- 2017: the threshold for mandatory disclosure was reduced from 2,000 m^2 to 1,000 m^2 NLA.

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[22] Base building energy covers the following energy end uses; sub-meters should be provided to measure the energy consumed by fuel type in supplying each of these building central services:

- heating, domestic hot water, cooling and ventilation e.g. to a BCO Guide specification*
- common-area lighting and power (including lift lobbies, plant rooms and common-area toilets)
- vertical transportation, e.g. lifts and escalators
- exterior lighting, exterior signage provided by the building owner for the benefit of office occupiers
- generator fuel where it serves central services
- car park ventilation and lighting, where internal or external car parks within the legal boundaries of the site are provided for occupier use.

*supplementary HVAC services to a tenant's energy-intensive areas including server rooms, dealer rooms and laboratories should use energy off the tenant's meter, not the landlord's HVAC.

[23] Plain English star level descriptions: 1=Poor, 2=Below average, 3=Average, 4=Good, 5=Excellent, 6=Market leading.

[24] http://arp.nsw.gov.au/m2004-04-greenhouse-performance-government-office-buildings-and-rental-properties

[25] https://www.thefifthestate.com.au/articles/nabers-energy-goes-6-stars-as-most-of-the-industry-moves-on/

A Feasibility Study published by the Better Buildings Partnership (BBP) in May 2016 confirmed that, in the commercial office property market in Australia, better base building operational energy performance has become aligned with investor, developer and occupier interests. Over the last 15 years, this has driven a systemic change in design, construction and operation of office buildings, with innovation flourishing across the supply chain. As a result, base building services in today's *new* buildings in Australia use on average half the energy they did when measurements started in 1998, and the best one fifth. The nexus of financial and property industry interests has also driven a remarkable uplift in the base building energy performance of the *existing* stock in Australia (see Figure A1).

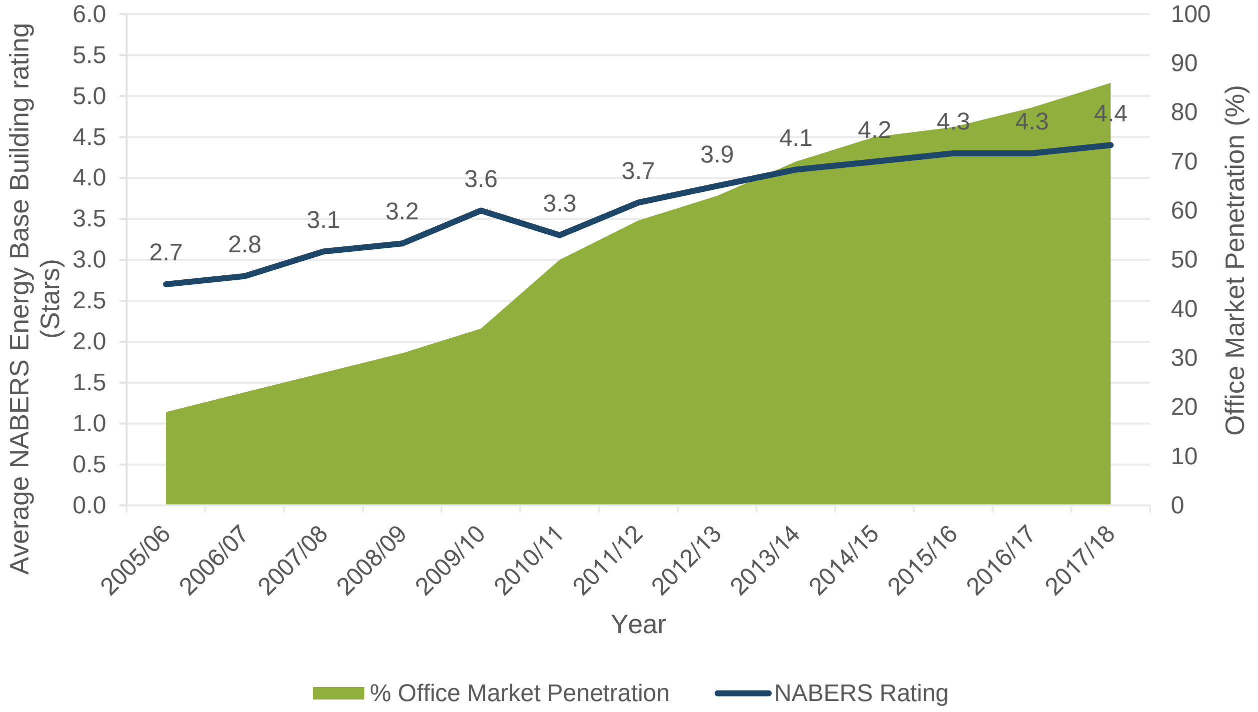


Figure A1 Growth in rated commercial office floor area and improvement in the existing stock average base building energy rating from 2006 to 2016 [Source: NABERS, OEH[26]]

The context for Figure A1 is that when base building ratings were initiated in 1998 (on a voluntary basis), a scale from 1 to 5 stars was set using empirical data to position the average performance at 2.5 stars. The blue line in Figure A1 shows that by 2006 the average rating had crept up to 2.7 stars (right hand scale). By then some 3 million m^2 of commercial office floor space had a rating (the blue-filled area on the graph and left hand scale).

Momentum was boosted in 2007 by an Energy Efficiency in Government Offices policy requiring office buildings leased by the Commonwealth government to be a minimum of 4.5 stars. By 2010, the average rating had climbed to 3.6 stars, a 24% improvement on the 2006 position.

In 2010, policy makers had sufficient confidence in the approach to mandate disclosure for sale or let transactions, which widened the empirical data from a voluntary cohort of buildings. Not surprisingly, the overall effect was a reduction in the average rating over the next year to 3.3 stars as poorer performing buildings were obliged to lodge their rating data, as well as those that had been doing so voluntarily.

However, the hiatus in average rating improvement was short-lived and within a couple of years the market average was exceeding its previous record high and indeed grew continuously every year, reaching 4.2 stars by 2016. Over the ten year period from 2006-2016, the improvement from 2.7 to 4.2

[26] https://www.nabers.gov.au/publications/nabers-annual-report

stars represented a 41% reduction in energy intensity for the whole of the rated stock, which by then had climbed to 16 million m^2 of commercial office floor space, an almost complete penetration into the overall market for tenancies over 2,000 m^2.

In 2017[27], the mandatory disclosure requirement was extended to tenancies over 1,000 m^2. It will be interesting to track the impact on the stock average rating once it includes these smaller tenancies which can lack the economies of scale supporting energy management activities in larger buildings. With the allocation of floor space in the market highly skewed to larger buildings, it seems unlikely this step will undermine the upward march of the headline statistic for the overall average rating.

In the context of tackling the energy trilemma[28], the scale of these improvements is striking. But the market transformation in Australia is being driven by commercial interest: investors and developers get better yields from better rated buildings because occupiers associate them with better buildings[29]. Statistics demonstrate that occupiers stay in better rated buildings longer - voids are lower - as shown in Figure A2a. Occupiers are also willing to pay higher rents for better rated buildings, so income return is higher, as shown in the left hand set of data in Figure A2b. Better rated buildings also produce stronger capital growth (middle set of data in Figure A2b).

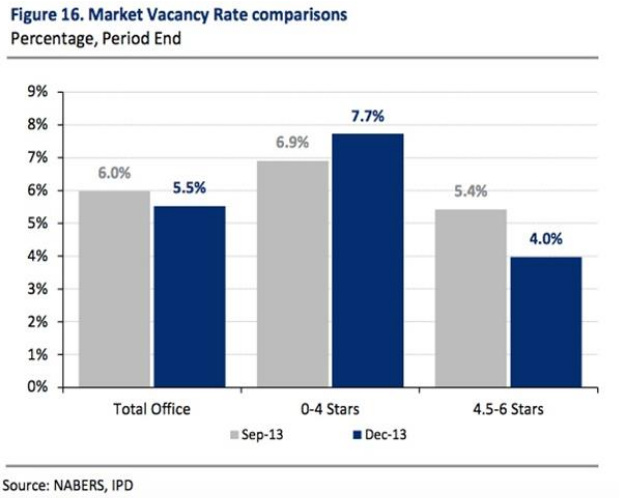
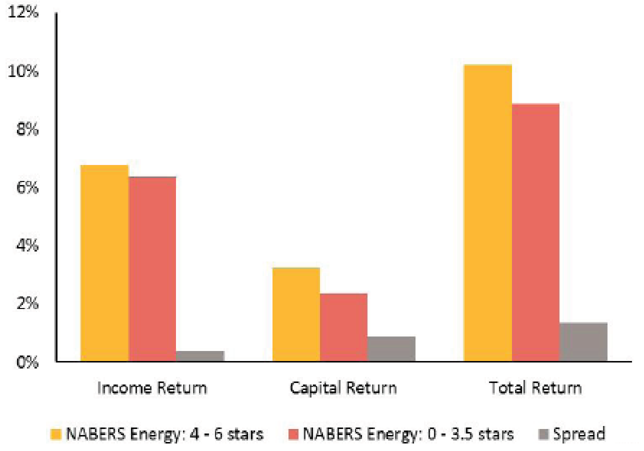


Figure A2a Offices with higher NABERS Energy ratings have lower voids[30]



Source: The Property Council/IPD Green Property Index, MSCI, March 2015

Figure A2b Offices with higher NABERS Energy ratings deliver stronger financial returns[31]

The Government's role has been to develop and operate an online public rating and disclosure platform, create infrastructure for independent and authoritative ratings to be produced by accredited assessors and to lead by example by setting minimum ratings for the space it leases. Once the rating had become established in the market, government was moved to make performance disclosure mandatory. It is apparent that technical innovation usually needs policy intervention to extend market take-up beyond early adopters. But the experience in Australia demonstrates how performance transparency can be powerful in driving improvement, both at the top and the bottom of the efficiency scale: there are no mandated minimum energy standards.

[27] NABERS Annual Report 2017-18, Version 1, 30Sep18.

[28]Climate change, security of supply and affordability (minimising energy costs)

[29] The underlying logic is that a better rating is associated with a building that has been better designed, better constructed, better commissioned and better operated and maintained

[30] IPD / Department of Industry NABERS Energy Office Market Analysis, Figure 16, December 2013

[31] The Property Council/IPD Australia Green Property Index March 2015

Appendix A 2. How does the UK compare?

By contrast with Australia, sale and let transactions in the UK are informed by the EPC[32], a theoretical calculation which does not reflect real performance and so gives limited insight to decision makers. Full compliance with Building Regulations Part L2A does support a direction of travel which should make it possible to measure the performance outcomes for all the energy uses regulated by Part L2 - using sub-metering which has been mandated for new buildings since 2002. However, there is no requirement, nor a pervading culture, for a comparison to be made between the measured outcomes and the predictions made at the design stage, let alone for this to be disclosed to stakeholders. In many respects, it is perverse that there is no guidance suggesting this would be a useful purpose for the metering system[33]. The absence of such a requirement means this comparison is almost never made and it prevents policy makers getting the evidence for the ratcheting up of Part L2 requirements that has occurred roughly every 5 years since energy efficiency regulations were first introduced for commercial buildings (offices and shops) in 1976. And it prevents a light being shone on the notorious performance gap between the predicted and measured values for regulated energy end uses.

This failure to use evidence which could be collected from equipment installed to comply with regulations to tackle the performance gap is especially stark in a building with a single occupier, where all sub-meter data can reasonably be expected to be collected at a single central point. In multi-let buildings, the Part L2 metering requirements are less well aligned with the objective of quantifying the energy performance gap. Individual tenants might not install their own sub-metering system for their own energy use. But even if they did, this data on energy end use breakdown would not normally be made available to a landlord, making it difficult to aggregate whole building energy use for each category of regulated loads and creating a barrier for making a comparison with the predictions at the design stage.

Unlike in Australia, the UK does not have a mentality of designing for measurability, a key feature of DfP. The best empirical evidence available for commercial multi-let buildings is collected by the BBP from its members. This data enables a comparison to be made between metered whole building energy intensity and the building's EPC grade (see Figure A3). The data suggests a limited correlation – the median energy intensity values do get better (lower) as grade improves, but there's so much variability that this marginal trend is of limited statistical significance.

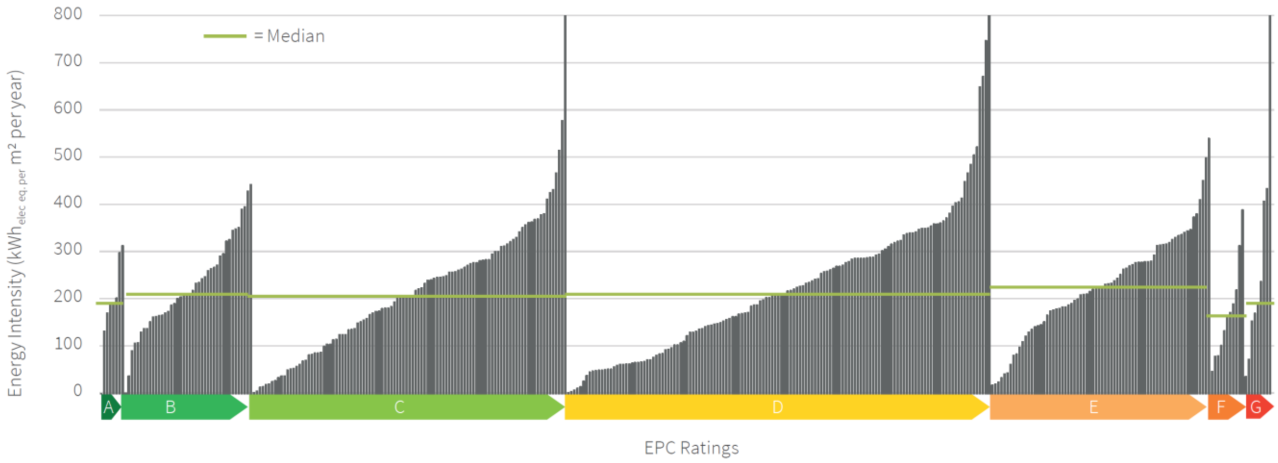


Figure A3 Comparing whole building energy intensity for buildings with different EPC grades
[Source: Real Estate Environmental Benchmark Update, Better Buildings Partnership, 2017]

[32] An Energy Performance Certificate (EPC) is used to rate the energy efficiency of both new and existing buildings.
[33] DCHLG currently has little jurisdiction beyond construction. NABERS has evolved into a complementary role with Code in Australia; but it has not (yet) become part of Code and Code cannot mandate operational performance outcomes

The UK's new building construction supply industry is notoriously fragmented, a position often cited for poor energy performance outcomes. It is true that responsibility for energy efficiency is often taken initially by the building's MEP designers, for example through production of a new development's energy statement; then passed to the appointed Design & Build contractor to implement. Once the shell-and-core is completed, it is then handed over again to a whole new set of businesses to deliver a placeholder Category A fit-out until spaces are let and subsequently the Category B fit-out desired by each tenant. However, new building procurement in the Australian market is not materially different in these respects, and yet because the energy performance outcome is a critical KPI for the developer, in Australia the baton is not dropped at each handover point in the energy efficiency relay.

It is material to note that both jurisdictions share the aim to provide the market with relevant information about the energy performance of a building at the moment of a property transaction, when the data can inform buying and letting decisions. But their approaches could not be more different (see Figure A4).

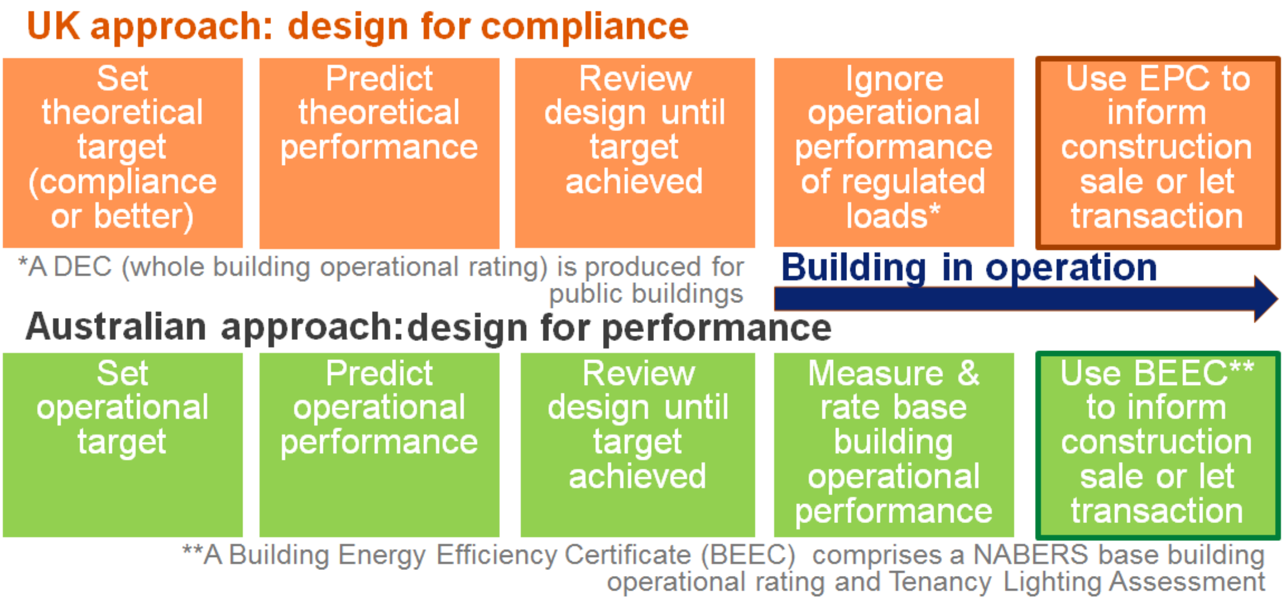


Figure A4 Comparing how the markets in the UK and Australia are informed about building energy performance at the moment of a sale or lease property transaction

The alternative representations of a building's energy efficiency in each country for the purpose of market transparency (theoretical 'asset rating' vs measured 'operational rating'), gives rise to the idea of considering the different approaches as if they were medicines being prescribed to treat a disease in a medical blind trial. After at least 10 years of each jurisdiction applying their different 'medicine', how have the two respective cohorts of patients (buildings) responded to the treatment they received. The DfP feasibility study delved into the data to determine what, if any, differences there were in outcomes in the UK and Australia.

To make the comparison on a like-for-like basis, the energy performance of buildings in London and Melbourne were plotted on the same graph, where the x-axis is the NABERS 1 to 6 star scale and the y-axis is the measured base building energy intensity (see Figure A5). Although there are significant differences between Melbourne's climate and London's, this factor would not be enough to drive dramatic variances in annual energy intensity. For much of a typical year in each climate, the weather in London and Melbourne is similar. Melbourne tends to have much hotter peak summer months, requiring more cooling energy, but this is compensated by milder peak winter months, requiring less heating energy.

The black line on the graph in Figure A5 shows the relationship between base building energy intensity measured in units of kWh of electricity equivalent[34] (kWhe) per m^2 of net lettable area per year and the 1 to 6 stars NABERS scale for the State of Victoria where Melbourne is the State capital. The scale is linear from 1 to 5 stars with a 38 kWhe/m^2 NLA bandwidth. Base building energy must be < 204 kWhe/m^2 to get on the scale with a 1 star rating. 5 stars is at 52 kWhe/m^2 NLA. 6 stars is at 26 kWhe/m^2 NLA, ie half-way from 5 stars to net zero. Half stars are available between the integer values – official ratings are rounded down to the nearest half star rating.

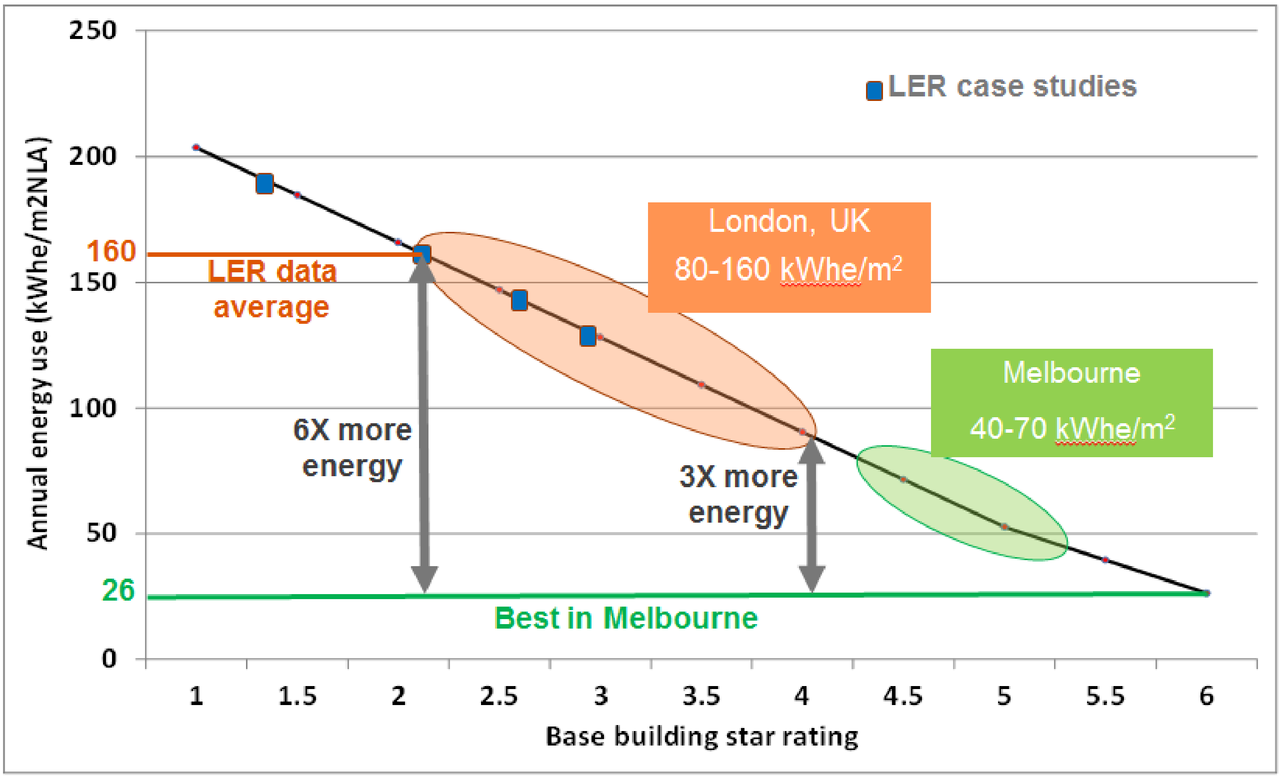


Figure A5 Base building performance of new offices in Melbourne and London compared.

The graph illustrates a reality in which new office buildings in Melbourne are never worse than 4.5 stars, and a significant proportion achieve 5 or 5.5 stars. Two have actually achieved 6 stars, confirming this level as market leading. In terms of base building energy intensity, this places new buildings in Melbourne in the range 40-70 kWhe/m^2/yr, with the best at 26 kWhe/m^2/yr.

The average base building energy intensity of 160 kWhe/m^2/yr for London offices shown in Figure A5 covers data collected for 85 assets by Verco in 2013[35]. Because base building energy use is not specifically measured, this bulk data quality was recognised to be weak. To address this concern, detailed energy audits were undertaken for four of these assets, with the findings written up as case studies. The results for these case studies were scattered around the average level, giving confidence in the average value, which was also anecdotally corroborated as plausible by individuals with everyday

[34] To calculate the kWh of "electricity equivalent" of total energy use, kWh of electricity are added to kWh of any fuel multiplied by 0.4 and kWh of hot or chilled water delivered to the building multiplied by 0.5. The kWhe metric enables timeless, international comparisons of a building's energy performance, and facilitates intrinsic building energy efficiency to be rated, independently from local, regional or national grid factors. Furthermore, with electricity often / usually the dominant energy carrier for commercial offices, kWhe has the enormous merit of using unity as the weighting or intensity factor for electricity – thus a unit of electricity retains the same value independent of the building's location around the globe, or the timing of the period for which the analysis is being undertaken.

[35] See Technical Note at end of this section.

exposure to data from office building portfolios. This exercise was done as part of work to develop and test a Landlord Energy Rating (LER) scheme for the BBP[36].

With base building energy use not generally measured in the UK, it was estimated, probably optimistically, that the energy intensity range for new buildings in London might be 80-160 kWhe/m^2/yr. The conclusion is that the most efficient new office buildings in London are three times more energy intensive than the best in Melbourne, whilst the least good in London are using over six times more energy than the best in Melbourne. With no visibility of actual base building performance outcomes, it is no coincidence that the base building energy efficiency of new UK commercial offices compares so unfavourably with that for their counterparts in Australia. Harking back to the medical trial, the patients in Australia have fared very well, whilst those in the UK remain critically ill.

What proves that climate is not the critical factor is the data for base building energy intensity for Melbourne offices in 2002. Back then, the average rating was 2.5 stars or about 150 kWhe/m^2/yr. It can thus be seen that the least good new buildings in Melbourne are now using less than half the average in 2002, whilst the best are using six times less. The differences in today's outcomes between London and Melbourne are clearly being driven by the huge improvements that Melbourne has achieved in the last 15 years, not climate differences. The EPC has not driven corresponding improvements in the operational energy performance of the UK's commercial office buildings. However, Australia's experience suggests that with the right drivers, the energy use of base building services in new UK offices could typically be halved, and best practice four to five times lower

Following reports on the performance gap by the Green Construction Board in 2013 and UK Green Building Council in 2016, the UK property market has woken up to the potential of buildings which perform as intended and to the risks with those that don't. The ability to demonstrate that energy efficient operation can be achieved in new buildings, can help to identify exemplar pathways for deep retrofits of the existing stock, on a trajectory towards net zero energy in operation.

Technical note on the LER scale

A core principle of the NABERS rating scheme is to set the mid-point of the rating scale at the median level, based on empirical data for the sector concerned. In Australia the top of the original scale was at 5 stars, so when NABERS was beginning the median energy intensity was aligned with 2.5 stars.

The LER scale aims to follow the same principle. By extrapolation to net zero energy, it effectively has a 7-point scale with a mid-point therefore at 3.5 stars. The unadjusted annual energy intensity of 3.5 stars on the LER scale is set at 105 kWhe/m^2. This was calculated to achieve consistency with the whole building benchmarks for DECs, the median levels for which have now been corroborated by empirical data from about 3,000 office buildings in England and Wales. The base building figure is based on a calculated bottom up split of the DEC benchmarks between base building and tenant.

When establishing the LER scale, it was agreed by the BBP's LER steering group that it should be aligned with DECs rather than set to create a special base building benchmark for the BBP members' assets in London. The reasons why the average base building energy intensity of the London offices examined for the LER (160 kWhe/m^2) is so much higher than that of buildings with a DEC include:

- The cohort of 85 buildings belonging to BBP members from which data were collected for LER research is top end, multi-let prime office in central London.

[36] In 2012, BBP commissioned Verco and the UBT to develop the LER, a NABERS-style energy rating scheme for UK offices. Its application on about 85 buildings exposed challenges with the configuration and sub-metering of *existing* building services systems. This led BBP to focus on the concept of base building performance agreements for *new* buildings, where it was potentially possible to design out the obstacles to a harmonised investment-grade rating presented by the variability of engineering services and sub-metering configurations encountered in the existing stock.

- Many public sector offices are single occupier, smaller (median floor area 3,000 m^2 GIA) and less complex buildings, many without full air-conditioning.

It's no surprise that larger, more complex, multi-let buildings with full air-conditioning have base buildings using 50% more energy.

The question arises whether the LER scale should be revised to reflect the realities in the UK's prime office sector, and this will be further examined during the DfP transition stage. The implication of aligning the LER scale with the median for prime commercial offices could be to increase the band width from 30 kWhe/m^2 to 40 kWhe/m^2, so the scale mid-point at 3.5 stars moves to140 kWhe/m^2. Two immediate disadvantages of doing this would be:

- For existing offices, this would place the average public sector office at 4.5 stars, and many at 5 stars, implying they have good to above average efficiency.
- Increasing the bandwidth for each half-star improvement (from 15 to 20 kWhe/m^2) makes it more difficult to improve a rating and in particular reduces the granularity available as the trajectory moves towards zero.

Appendix B. The role of simulation

There are essentially four levels of energy modelling available for non-domestic buildings in the UK:

i. Building Regulations Part L compliance using SBEM (a monthly calculation): predicts regulated energy use, assuming NCM standard occupancy and conditions of use. The Part L method is not intended to produce an absolute prediction - compliance is achieved by demonstrating sufficiently better theoretical energy efficiency relative to a notional reference building of the same geometry and given energy efficiency attributes.

ii. Building Regulations Part L compliance using a dynamic simulation model, as above but mandated for larger and/or more complex buildings. This type of model has a more detailed representation of the building and uses a time step for the simulation of an hour or less.

iii. CIBSE TM54[37] which sets out "*to evaluate operational energy use accurately at the design stage*". There are two significant differences between TM54 and the Part L compliance method:

    a) The predictions of the regulated energy uses (HVAC, hot water and lighting) deploy profiles for operating hours and intensity of plant and equipment which are bespoke to the individual building being designed, in contrast to the standard profiles that must be used for Part L calculations. However, the underlying model to predict HVAC loads is typically based on the same approach as the Part L compliance model, deeming simultaneous modelling of the HVAC system unnecessary[38].

    b) TM54 makes plausible estimates for the 'unregulated' energy uses in the building, such as lifts and escalators, small power loads, catering, server rooms and other plant and equipment.

iv. "advanced simulation" following the process used in Australia and defined in the NABERS Commitment Agreements Handbook for estimating NABERS ratings Version 1.1, February 2019. It aims to apply realistic levels of occupancy and hours of use, and is based on dynamic simulation of the HVAC plant and controls simultaneously with the dynamic thermal modelling of the building which generates the heating, cooling and ventilation loads to be met by the building services plant. It expects alternative HVAC system design and sizing might be examined and requires 'off-axis' operating scenarios to be considered. Advanced simulation focuses on predicting energy use by HVAC plant: boilers and other types of heat generator for space heating, chillers for space cooling, fans for ventilation and pumps for circulating fluids. The energy requirements for other base building energy uses, such as hot water, lighting, small power and lifts, are usually calculated outside the simulation model.

Project Agreements would require this level iv advanced modelling of the HVAC system to be undertaken.

The two fundamental underlying shortcomings of the TM54 approach are:

1. The acceptance of dynamic modelling that does not cover the detail of the HVAC system and its controls inevitably undermines the reliability of the predictions.

[37] CIBSE Technical Memorandum 54: Evaluating operational energy performance of buildings at the design stage, 2013

[38] TM54 section 7.11 paragraph 2 states: "*A more detailed DSM, which includes the system design, can be built to calculate the energy use associated with heating, cooling, fans and pumps. This should provide a better representation of what would happen in reality. A detailed DSM requires considerably more time to build and has far more inputs. The cost and time associated with such an undertaking may well be prohibitive. Therefore,* ***the methodology set out in this document [TM54] proposes a simplified approach***."

2. The principle of predicting low, medium and high operational energy outcomes as a spectrum to cover the unpredictability of how unknown tenants might occupy and use a building may offer developers some certainty on the range of their utility costs, but does nothing to indicate the energy efficiency of these scenarios. In practice, this reflects on the lack of a base building rating scheme in the UK which makes suitable allowances for occupancy (voids) and a building's hours of use.

The NABERS energy rating scheme in Australia (and the LER, its equivalent in the UK) do give extra allowances for longer hours of use when benchmarking base building energy use[39]. A well-controlled and efficient building should achieve a similar rating whatever the hours of use. The base building approach by definition excludes the direct first order impacts of the energy use of tenants for small power and lighting. There may be second order impacts, such as increased cooling loads and reduced heating loads for a higher density occupier, but experience in Australia indicates these have only a minor effect on the base building rating.

In Australia, the performance-focused version of the TM54 approach would be to set the 'Medium' scenario at the design stage with the conditions deemed most likely for the building concerned and to check that the rating under this scenario is predicted to meet the target. Then to simulate as off-axis scenarios plausible low and high hours and intensity of use and to check that the target rating should also be achieved under those conditions too. This approach gives confidence to a developer that a new building and its HVAC system and controls should achieve the target rating, de-risking the potential unknowns about who the tenants will be, and irrespective of how tenants will use the building.

By contrast, the TM54 approach in the UK, in the absence of a base building rating, seems to be simply caveating in advance the range of expected consumption with low, medium and high usage scenarios, which can vary across a factor of 3 in whole building energy use, making for a very forgiving target. Although one can then demonstrate that the measured actual performance lies somewhere between these predictions and imply the performance outcome is therefore in line with design predictions, this begs the question of how efficiently the building is performing.

To apply design for performance principles, one should be prepared to compare actual with measured on a like-for-like basis. This would entail applying all the actual conditions of use in a re-run of the model, including the weather over the year of measurement, so the boundary conditions for the prediction are identical with those for the measurements. Then the differences between the two can be assigned to plant efficiency and operational control issues.

[39] The NABERS whole building rating also makes allowances for the density of occupation (number of workstations in the building) which the methodology for its UK equivalent (DECs) does not (due to the challenges and extra costs of doing so).

Appendix C. Close-out survey

A close-out survey from participants in the pilot studies programme was undertaken that comprised 12 questions: the first 9 sought participants' views on the specific learning from each pilot whilst the last 3 focused on the key challenges and benefits of seeking to apply the Design for Performance approach in the UK. 14 pilot study participants were asked to complete the whole survey whilst a further 17 pilot study programme stakeholders (mainly members of the DfP Executive Board) were asked to complete just the last 3 questions. The results are given below.

PILOT STUDY SPECIFIC QUESTIONS (Q1 to Q9)

Q1 Prior to participating in the pilot, were you aware that there is a large energy performance gap between design intent and actual post-construction outcomes?

Mode for responses: Slider 0 to 100 [0 = not aware; 100 = fully aware]

Average score 93 (10 responses)

Q2 Following your participation in the pilot, how important do you consider this performance gap to be?

Mode for responses: Slider 0 to 100 [0 = not important; 100 = very important]

Average score 97 (10 responses)

Q3 Do you have any additional comments relating to awareness and importance of the energy performance gap

Mode for responses: Text box

- Awareness needs to be raised by improving availability of in-use performance data and its presentation to all players that can make a difference, preferably across portfolios.
- Needs to be linked with commercials and well-being in the working space. Value appreciation and attractiveness of the (office) asset to both occupiers and investors
- It can only really be addressed through complete public disclosure of whole building performance to give it credibility and deal with important systemic issues like poor design, poor construction, poor commissioning and poor compliance enforcement.
- I wonder whether we (as an industry) could become better at differentiating between: - the gap between how a building performs and how it is meant to perform; and - the gap between how people think it is meant to perform, and what is actually intended; the performance gap is sometimes used to describe the difference between Part L and actual regulated energy use; I think this might be confusing, because Part L is not meant as a prediction... Here the issue is more with the lack of proper assessment or prediction of performance, not the performance of the building itself
- Improved knowledge of the issues for the commercial real estate market on this topic
- I think that new builds need to be treated like energy performance contract refurbishments. The use of IPMVP to compare modelled performance to actual performance and taking in to account the changes between modelled assumptions and actual usage is vital to allow contractors the confidence to sign up to the guarantees.
- I have thought for some time that closing the performance gap is a significant decarbonisation opportunity for the UK property sector. DfP has the potential to play a pivotal role in making this change.

Q4 Independent Design Review: What would you consider the three key findings of your pilot to be?
Mode for responses: Text box

- Metering and wiring not arranged to extract base building
- Opportunities not taken to optimise design
- Advanced thermal modelling takes more resource
- The gap between design and actual
- Design approach to 4 pipe fan coil HVAC needs to be thought through in advance
- The horse had bolted on several opportunities
- The lack of attention currently paid by HVAC designers to control strategy
- Landlord alterations costed at £ 50k were not approved; tenant alterations and extra meters would also have been required as part of fitout spec.
- BREEAM process could not influence design
- It takes time to review operational assumptions
- The interest from landlords to engage further
- Always on heated/chilled water systems have inherent efficiency limitations
- The BMS had not been commission witnessed by the designer
- The lack of detailed HVAC modelling
- District heating/cooling/CHP energy not easily monitored
- contractual arrangement could not influence design
- It is important for the client to take leadership
- The importance of actual performance measurement certification/audits
- accurate and reliable metering is key to DfP success
- The air handling design was poor
- Poor documentation of control and metering commissioning
- District heating/cooling/CHP was operated by third party who could not step up to the plate because it was not in their spec.
- Most of the ideas talked about were indeed proposed or requested (we have implemented them before) but a combination of SBEM only compliance modelling and inflexibility prevented them from being considered, along with simplistic M&E design
- Occupant changes to 24/7 usage on some floors are hampering performance

Q5 Advanced simulation: What would you consider the three key findings of your pilot to be?
Mode for responses: Text box

- Advanced simulation not done, but ... a/c zoning not well suited to likely space planning
- Developer refusal to implement operational modelling requiring tenant to self-fund at a late stage
- It takes more time / money
- Again the gap between actual vs design
- Meaningful simulation requires dynamic HVAC modelling
- Lack of transparency on modelling information or use of BIM
- It requires specialist skills
- The opportunity to recognise remediation actions
- Metering commissioning was incomplete and therefore comparison to targets difficult
- Meaningful simulation requires accurate controls modelling
- Used only as a compliance tool

- It needs to be explained to the client
- Helps formulate space and layout arrangements
- Meaningful simulation requires accurate representation of building use (use of each space, occupant density, hours, etc)
- I am not sure we have actually learned anything
- I'm still uncertain whether simulation tools currently available can accurately model the real performance and therefore IPMVP techniques may be required to allow model results to be compared to actual performance

Q6 Post-construction monitoring and targeting: What would you consider the three key findings of your pilot to be?

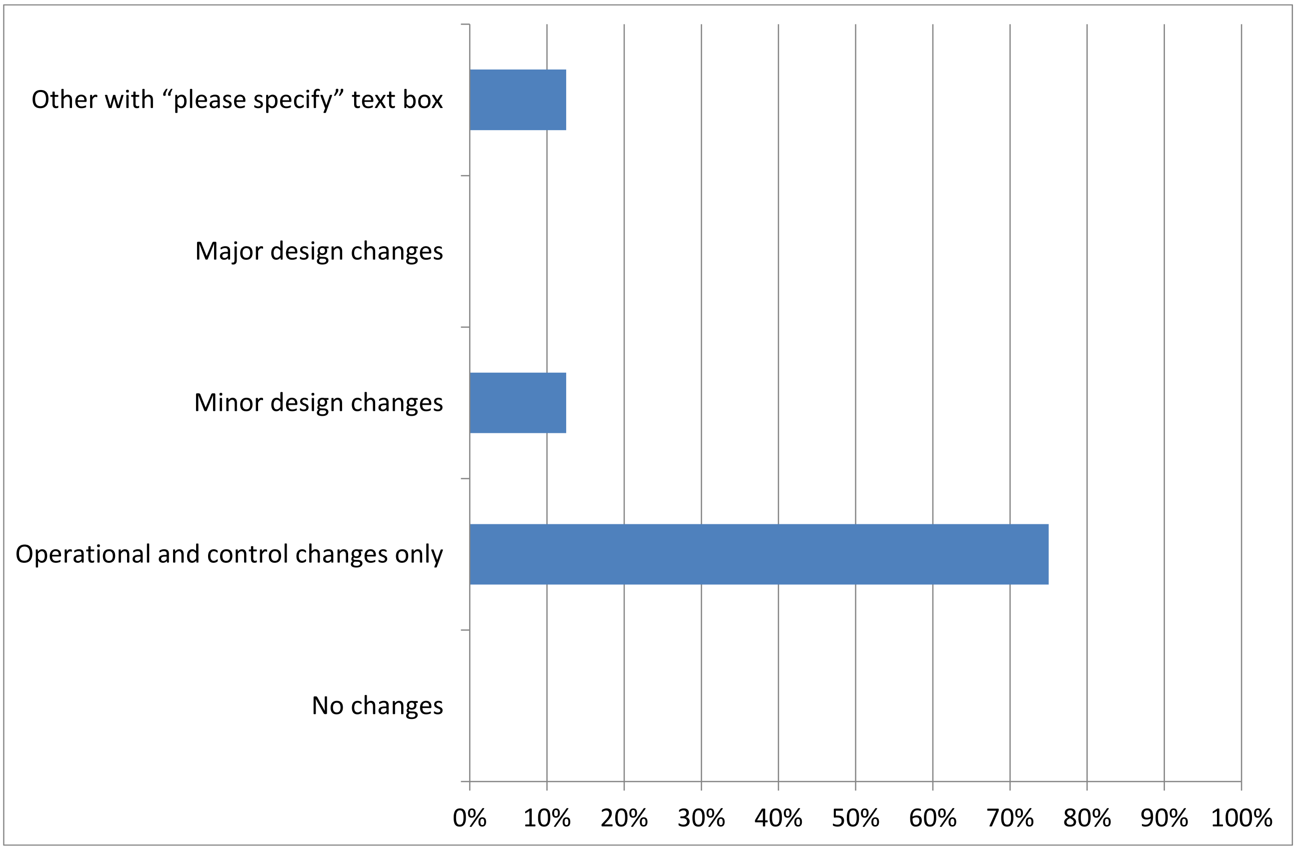
Mode for responses: Text box

- Structure, contracts and disjointed nature of teams means design and build is dysfunctional and not producing a system
- Need to keep the contractor in place for commissioning and rectifications
- Consider how data from AMR system will be captured and tabulated vs target data to get the system easy to operate and use
- The barrier to useful insights from poor controls & metering commissioning & documentation
- Quality of energy performance data is critical to the DfP process
- It's a bit early for comments on this, but contractor would not commit to Soft Landings
- Need to involve facility managers from the design/construction phase
- physical vs logged meter data checks are always essential to ensure data integrity
- The barrier to useful insights from inconsistent labelling of same object across different documents
- Quality of energy data in this case was not sufficient to support detailed performance analysis
- We have great opportunity for this with precedent of other buildings and robust targets
- The importance of actual performance measurement to better manage space
- The complexity added by multiple parties all with some responsibility (Landlord, tenant, developer, M&E contractor, BMS contractor, commissioning manager, landlords agent, developers agent, FM provider
- Overall energy performance improvements were identified but there were initially barriers to implementing these due to lack of resource in the maintenance supply chain
- Poorly commissioned and unfinished metering and BMS all make this difficult
- These findings are typical of our experience delivering post-occupancy evaluation for a range of clients

Q7 What scale of changes to the current pilot project design/operation are you planning to make?

Mode for responses: Multiple choice:

- *No changes*
- *Operational and control changes only/*
- *Minor design changes*
- *Major design changes*
- *Other with "please specify" text box*



[8 responses]; with 1 Other response: "No longer involved"

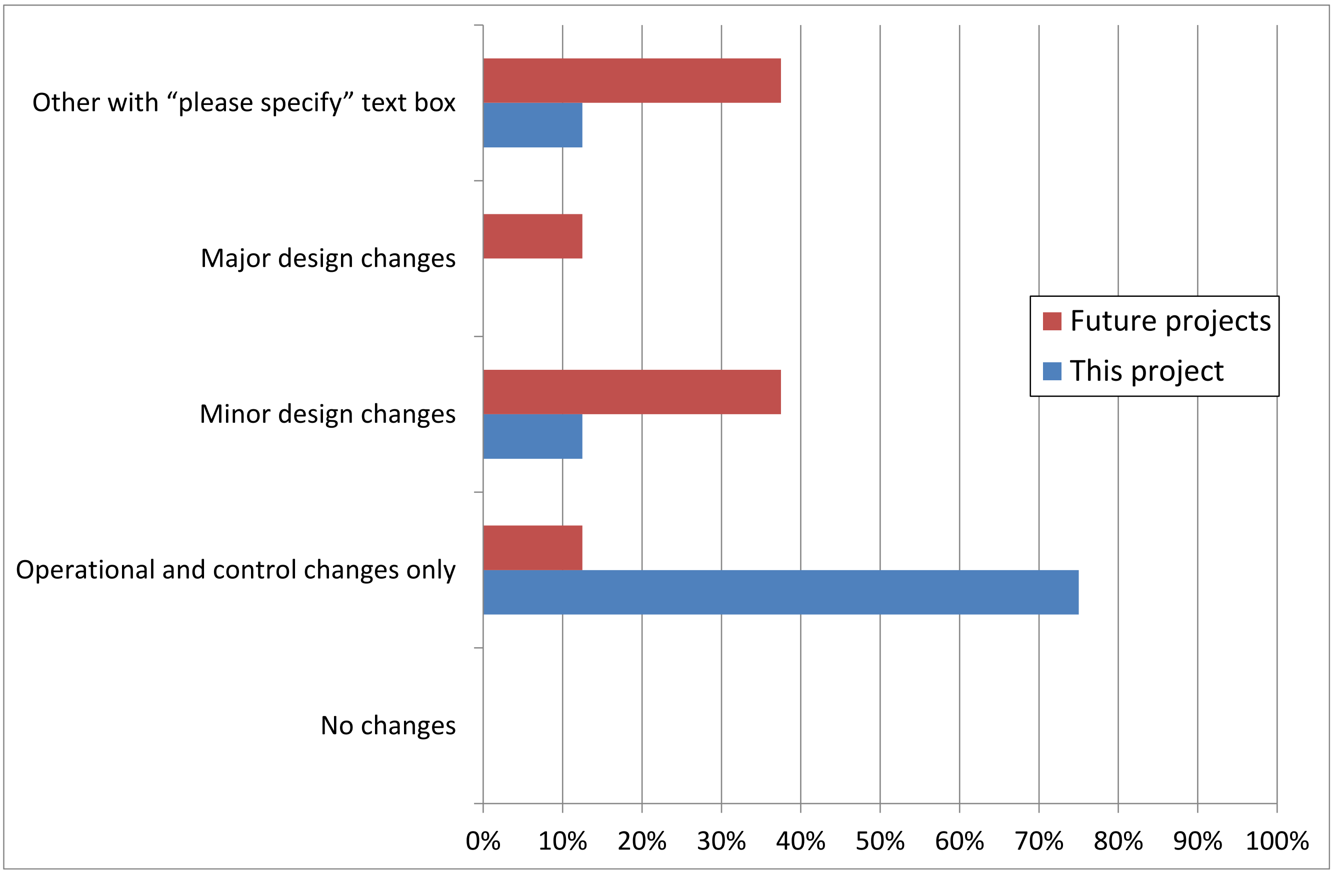
Q8 What have been the other benefits of adopting DfP on this project?
Mode for responses: Text box

- The importance of having to service and meter the base building separately at the very outset, particularly the segregation of landlord and tenant supplies of hot water, chilled water and electricity to DfP rules.
- Highlighted the deficiencies of compliance and standards regimes (CIBSE or BSRIA amongst others) to give clients what they are paying for.
- Shared knowledge
- Awareness and evidence gathering to pitch internally and externally
- Increased awareness of inherent energy efficiency shortcomings of current design/controls
- Influencing the contractor team and wider internal stakeholders that the base build delivered design was not working as designed
- Highlighting issues that suppliers can be held to account under existing contracts.
- The project has helped to enhance the client's understanding of the importance of good energy data quality.

Q9 Considering projects you are likely to conduct in the next 2-3 years, what changes do you expect to make to these projects as a result of what you have learnt in the pilot project?
Mode for responses: Multiple choice:

- *No changes*
- *Operational and control changes only/*
- *Minor design changes*
- *Major design changes*

- *Other with "please specify" text box*



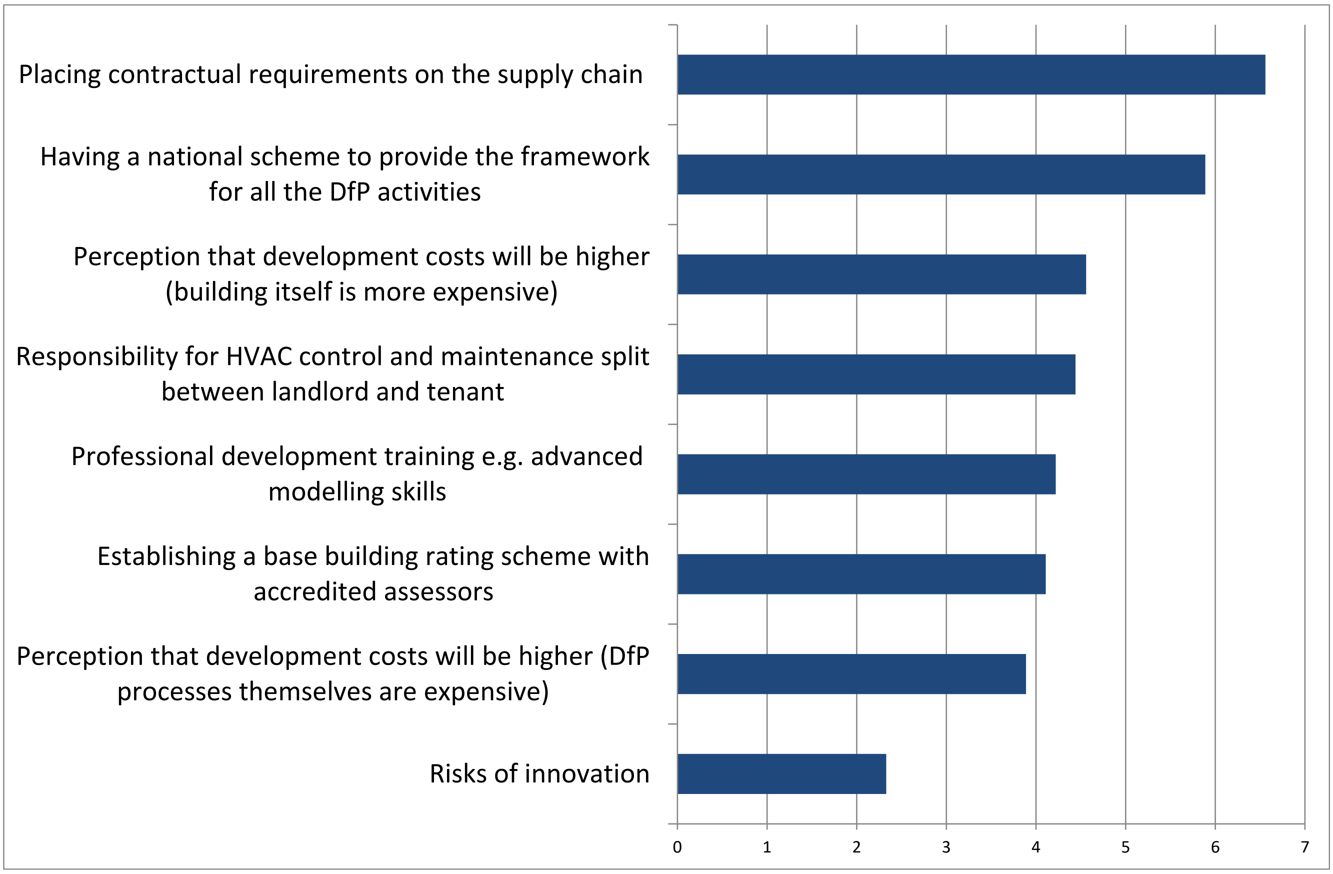
[8 responses]; with 3 Other responses:

- No continuing influence
- The pilot study highlighted all the things we have and were trying to do anyway - better design, more interaction, better BMS with earlier Des of ops, simpler metering, better modelling, use of soft landings, etc
- No more new build projects planned. All significant refurb projects will involve energy performance contracts to ensure guaranteed energy performance outcomes

MORE GENERIC DfP QUESTIONS (Q10 to Q12)
What do you think are the key challenges and benefits of the Design for Performance approach, based on your experience from the pilot studies programme.

Q10 What are the challenges associated with adopting DfP?
Mode for responses: Please rank the following in order of importance for the success of DfP

1. *Professional development training e.g. advanced modelling skills*
2. *Placing contractual requirements on the supply chain*
3. *Having a national scheme to provide the framework for all the DfP activities*
4. *Establishing a base building rating scheme with accredited assessors*
5. *Perception that development costs will be higher (building itself is more expensive)*
6. *Perception that development costs will be higher (DfP processes themselves are expensive)*
7. *Risks of innovation*
8. *Responsibility for HVAC control and maintenance split between landlord and tenant*



[9sponses]

Q11 How to tackle the challenge created by responsibility for HVAC control and maintenance often being split between landlord (central plant) and tenant (local distribution)?
Mode for responses: please give your perspective on the following solutions:

Follow Australian approach: landlord has full control of all HVAC services: Text box

- Is this correct: I thought NABERS favours tenants making their own arrangements for supplementary services (e.g. large server rooms) beyond base building's capacity.
- I agree
- Best approach
- Suspect this is the way to go for best outcomes
- very difficult to achieve given the current landlord - tenant market place and the way landlords have decided to reduce their risk/pain of having to run maintenance contracts. The general outsourced maintenance contract companies are also a significant problem
- Preferred approach. Single point of control. Tenants less likely to have expertise to manage efficiently.
- the market pull is in the opposite direction in the case of larger tenants, with tenants wanting to have more direct control over HVAC kit. DfP, even when fully implemented in the market, is unlikely to be a strong enough counter to market forces

Energy use by all HVAC plant is measured by landlord sub-meters: Text box

- If supplementary tenant services are supplied by landlord (e.g. chilled water to server rooms), shouldn't this be sub-metered and allocated to tenants.
- I agree - with visibility to stakeholders

- Could work too
- this would seem a basic starting point
- should be possible, but current FM/managing agent skill set does not sit well with meter readings and aM&T software usage, while the main construction teams still can't deliver working metering systems "out of the box" if ever!
- Essential. Even if landlord doesn't have full control. Can use data to engage with tenants.
- This should be universal good practice

Central visibility of all HVAC system controls is mandated by landlords: Text box

- Good idea, but might not include tenant supplementary services unless they share landlord supplies.
- OK -but see above
- Better than the above
- easiest and maybe best place to start?
- could help, but again takes FM upskilling
- Essential. Efficient control of main plant requires efficient control of terminal units.
- This should be universal good practice, but in some instances is contradicted by tenants wanting to take control of their own space for good operational reasons.

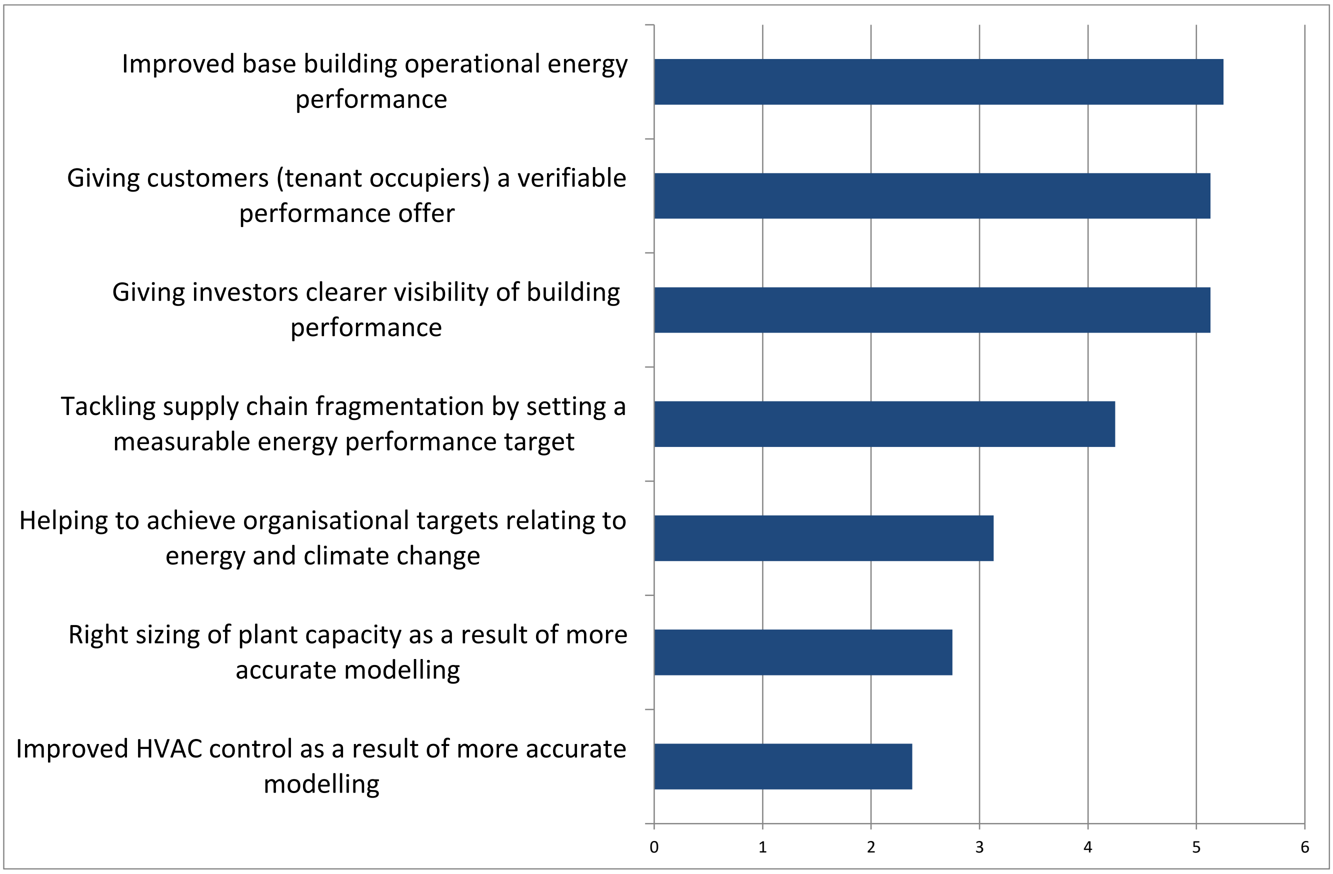
Other comments: Text box

- Problems might arise with landlord maintenance services contracts covering tenanted areas.
- Buildings would be simple as possible for tenants and avoid separate systems
- Landlord needs to be more involved in the whole process.
- it would be really useful to learn from the way that departures from "standard" assumptions are factored into NABERS, for example how contractual obligations on the landlord's cooling consumption take account of, say, increased tenant occupancy density
- BBP and Managing Agents Partnership should play a lead role to make the changes happen and demonstrate the good practice required to deliver DfP

Q12 What are the benefits associated with adopting DfP?

Mode for responses: Please rank the following in order of importance for the success of DfP

1. *Improved HVAC control as a result of more accurate modelling*
2. *Right sizing of plant capacity as a result of more accurate modelling*
3. *Improved base building operational energy performance*
4. *Giving investors clearer visibility of building performance*
5. *Helping to achieve organisational targets relating to energy and climate change*
6. *Tackling supply chain fragmentation by setting a measurable energy performance target*
7. *Giving customers (tenant occupiers) a verifiable performance offer*


Improved base building operational energy performance
Giving customers (tenant occupiers) a verifiable performance offer
Giving investors clearer visibility of building performance
Tackling supply chain fragmentation by setting a measurable energy performance target
Helping to achieve organisational targets relating to energy and climate change
Right sizing of plant capacity as a result of more accurate modelling
Improved HVAC control as a result of more accurate modelling
0
1
2
3
4
5
6

[8 responses]

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