DRIVING ENERGY EFFICIENCY SAVINGS THROUGH THE LONDON PLAN

BUROHAPPOLD ENGINEERING

DATA ANALYSIS REPORT
25/08/17

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BUROHAPPOLD ENGINEERING

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1. SUMMARY

Aim of Study

The Greater London Authority (GLA) London Plan is current under review and a new version is being written. The next London Plan will look to maintain the current target of a 35% reduction in onsite carbon dioxide emissions for residential and non-residential major developments. Zero Carbon will also be enforced for all development types, with the use of Local Authority offset payments, for emissions not abated through on-site measures. Research, including a study recently produced by BuroHappold (The future role of the London Plan in the delivery of area-wide district heating, 29/06/17), suggests that as a result of the changing carbon intensity of the grid and heat network carbon factors, the 35% onsite CO_2 reductions target will require a transition away from gas engine-CHP to other lower carbon heat sources and greater levels of energy efficiency.

Study Scope

As such, the scope of this study is to establish options for an energy efficiency (Lean) target, to be included in the London Plan. Consideration has also been given to how Lean performance correlates to other performance criteria, BREEAM, Fabric Energy Efficiency and PassivHaus. The GLA is seeking to develop appropriate targets for residential and non-residential developments along with an understanding of the technical and cost implications. Analysis has been undertaken by BuroHappold and Currie & Brown on two key data sets:

• Cases submitted to the GLA for planning permission from 2014, 2015 and 2016 tested under 2013 Building Regulations Part L (referred to as: GLA dataset)
• BuroHappold London Projects tested under 2013 Building Regulations Part L (referred to as: BuroHappold dataset)

The GLA dataset has been used to understand the current performance of various development types across London and to provide a macro picture of building performance submitted for planning under The London Plan 2016. The BuroHappold dataset has been used to understand the technical implications of varying performance, including the potential LEAN reductions beyond the Part L notional , considered the GLA Baseline, the specifications these require and the cost uplift to achieve this performance. Cost uplift is required for the London plan viability assessment on a £/m2 basis for Non-Residential and on a £ per unit basis for Residential.

The BuroHappold dataset includes both residential and non-residential modelling results on a block-averaged basis. The examples shown include final Lean results, as well as facade and systems studies to test the key parameters driving carbon performance. It also includes 'Push modelling' undertaken specifically for this study to understand the impacts of improving fabric and systems performance on carbon reduction and cost uplift for existing projects.
A third party peer review process was undertaken by AECOM. This review ran in parallel to the analysis, reviewing data assumptions and conclusions periodically as well as providing comments on reporting.

Outcomes

From the GLA data set, the median Lean reduction currently being achieved is 3.47% for residential, 11.6% for non-residential and 6.28% for mixed-use. Through analysis of all three datasets, it is deemed that a 'Medium level' 5% Lean reduction target for Residential and 10% target for non-residential would be technically feasible with a wide range of fabric and services specification. This would impact and improve the performance of 63% of residential and 42% non-residential applications.
A 'High level' 10% Lean reduction target for Residential would give added focus to locking in long-term carbon reductions through improved building fabric rather than shorter-life heat generation plant. This would raise the performance of 87% of the new applications coming forward. It would additionally be fill the gap left by reduction in the performance of Clean savings in the short term with an update the grid carbon factors. It would expect to reduce occupant bills £33/unit/year compared to a 0% policy target. Meeting the target will pose a technical stretch and buildability for many projects, and the industry may take a few years to raise performance to this level.A 'High level' 15% target for Non-residential would be technically achieve with good passive design and would align with BREEAM 'Outstanding' levels. This is considered a high target because it raised the majority of developments and it aligns with BREEAM 'Outstanding', which is considered the aspiration within the industry, with the GLA adopting a leadership role pushing towards BREEAM Outstanding energy performance. It would expect to reduce occupant bills by between £0.5/m2 - £1.4/m2 per year compared to a 0% policy target.
Cost uplift over Part L notional for these targets has been provided and financial viability, across five London Development Zones, will be tested by the London plan viability consultants.

2. STUDY METHODOLOGY

Methodology

Analysis has been undertaken by BuroHappold and Currie & Brown on three key datasets:

• GLA dataset - cases submitted to the GLA for planning permission from 2014, 2015 and 2016 tested under 2013 Building Regulations Part L
• BuroHappold dataset - BuroHappold Projects located in London tested under 2013 Building Regulations Part L
•Technology cost curves from Currie and Brown

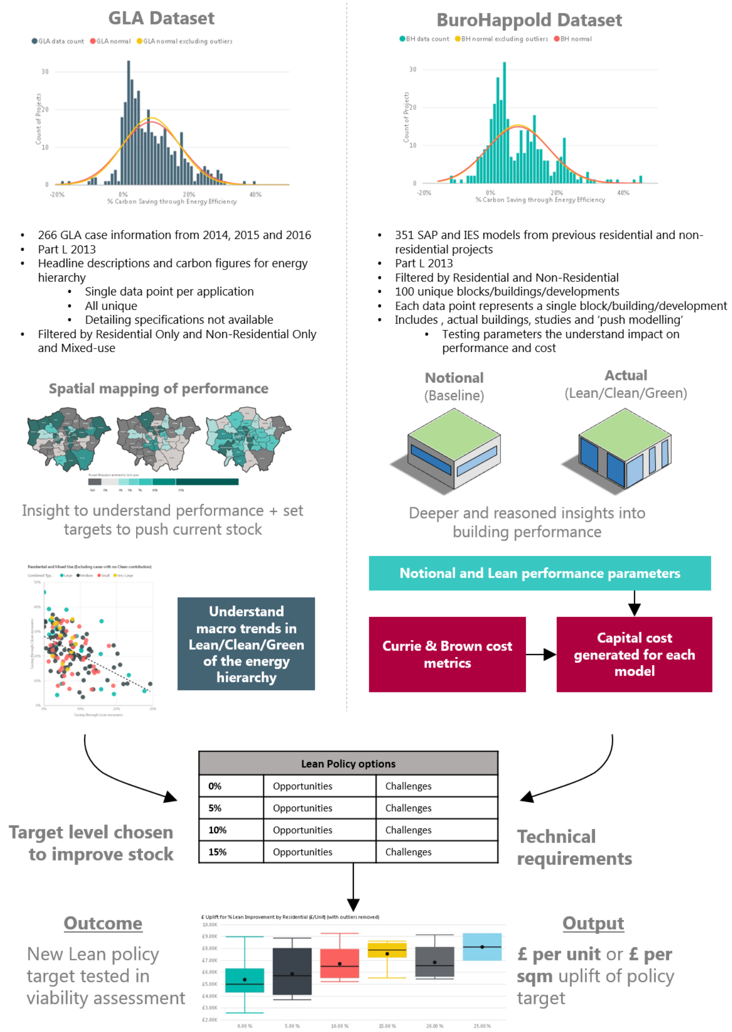
The GLA dataset has been used to understand the current performance of various development types across London and to provide a macro picture of building performance submitted for planning under The London Plan 2016.

The BuroHappold dataset has been used to understand the technical implications of meeting varying performance levels. It consists of energy models developed for BuroHappold projects within London. 100 unique blocks/buildings have been tested and 351 models generated from these with varying specifications. Incremental fabric and systems improvements have been made to many of the projects to provide a range of models across glazing ratios. The carbon reduction and capital costs of these models has been correlated to generate cost uplifts over each Notional within regions of performance.

The models required to generate these cost uplift are considered as a wide range of indicative ways to achieve the targets, however do not represent all permutations and is not exhaustive. A further study will be required on common building types to evidence fully how a target could be achieved across the building stock.

The Currie & Brown data has been used to generate estimates of the cost uplift to achieve different levels of performance on a £/m2 basis for Non-Residential and on a £ per unit basis for Residential. Both Notional and Actual buildings have been costed and the 'Cost Uplift' quoted is the difference between the two for each model/development.

Technical and cost implications of potential policy scenarios have then been evaluated, with cost ranges provided to the GLA's viability consultant. Third party peer review on this study has been provided by AECOM.



Footnote:

The Notional building referred to within this report is the Building created by the Building regulations Part L modelling as a comparator to performance. The notional dwelling/building matches the geometry of the actual dwelling/building. Glazing areas do vary however, with residential notional glazing area matches actual and topping out at 25% of floor area. Non –residential glazing area always being fixed at approx. 40% of external area. The notional building uses a fixed set of fabric and systems performance/efficiencies. These have been outlined in Appendix 4 of the main report for reference. Residential notional always uses an individual gas boiler and now cooling, however notional for non-residential matches the systems included within the actual building. The notional building results and GLA Baseline results are considered the same within the GLA energy hierarchy and as such are interchangeable within this report.

3. KEY FINDINGS

<u>What is the current Lean performance across London?</u>

From the GLA data set, the median Lean reduction is 3.7% for residential, 15.1% for non-residential and 5.8% for mixed-use. The average (mean) Lean reduction is 4.7% for residential, 2% for non-residential and 7.26% for mixed-use. Statistical analysis suggests that median is generally the most appropriate measure for this study. The Median Lean performance of those residential developments that did not connect to a communal/district heating systems is 7.5% reduction compared to a 3.4% reduction if Clean savings are identified. Additionally Non-residential developments achieve 8.17% with Clean savings and 17.83% without Clean savings.

<u>Is % reduction of Lean on Part L 2013 an appropriate measure of performance?</u>

Building Regulations Part L Carbon reduction has been chosen as an appropriate metric for an energy efficiency policy as it provides consistency with the rest of the GLA energy hierarchy (35% and zero carbon), in line with current Government regulations reducing compliance risk for developers and it is based upon relative target setting not precluding any building types specifically. Other metrics and their correlation with reduction beyond Part L 2013 have also been reviewing in this study, including Part L Fabric Energy Efficiency, Passivhaus and BREEAM (BRE Environmental Assessment Method) Energy Performance Ratio (EPR).

For Residential developments, there is a strong positive correlation between Fabric Energy Efficiency (FEE) and overall % carbon reduction suggesting that FEE could be as good a measure of performance. However the Part L Building Regulations FEE requirement does not consider any services or efficiencies of them. Therefore improvement in ventilation, or heating system will not affect the FEE result. For non-residential developments, BREEAM Energy Performance Ratio (EPR) has a strong positive correlation with % Lean reduction, therefore either target could be used. A 10% Lean reduction is in line with an EPR of 0.375 for 'Excellent' whilst 15% is in line with an EPR of 0.6 for 'Outstanding'.

<u>What are the cost uplift trends with % reduction?</u>

Analysis of the BuroHappold and Currie & Brown data sets shows that there is a positive correlation between residential % Lean reduction and cost uplift. Cost uplift over the notional building increases as % reduction increases. This is driven by the improved performance required from building fabric, ventilation and improved boiler specification. However, for non-residential there is a weak correlation between % Lean reduction and cost uplift. % Lean reduction can be heavily dependent upon building form, glazing ratio and 'good passive design' that balances glazing area, energy demands, consumption and resulting emissions. % Lean reduction has not been observed to be driven by the specification and performance values of any particular individual measure; rather, it is the combination of measures that influences performance. Cost uplift associated within Lean measures varies considerably as a result of differing building designs.

<u>What % reductions can be achieved and how can they be achieved?</u>

Three levels of Lean reduction have been assessed depending upon the level chosen

RESIDENTIAL

<u>LOW – 0%</u>

The base 'do nothing' position would be to maintain the GLA's current position as articulated in developer guidance but cement this through placing it more clearly in London Plan policy. The target is to meet Building Regulations Part L 2013 through energy efficiency alone. The expectation would be that, despite there being no increase in the Lean target, retention of the overall 35% carbon reduction target will continue to drive investment in a mix of Lean, Clean, Green measures and that the forthcoming higher carbon factors for gas engine CHP may provide pressure for greater Lean reductions, even without a specific lean target. Furthermore, the absence of a specific Lean target may increase developers' focus on the transition away from gas engine CHP to lower carbon heat sources. The challenge is that the current Lean target is typically being exceeded so the target no longer providing a stretch to developments.

4. KEY FINDINGS

MEDIUM – 5%

A 5% Lean reduction target is considered achievable and technical feasible with a range of specifications, as it can be achieved without the need for triple glazing or other strict requirements on performance of fabric and systems. 36.7% of GLA cases currently achieve this level so setting this target would raise the performance of two-thirds of projects and signal the need to focus on mitigating the impact of changing carbon factors. The challenge is the time and effort to enforce a relatively modest sub-target within the overall 35% carbon reduction. This target would not fill the gap left by the expected drop in Clean savings under 2016 SAP consultation grid carbon factors. Additionally this target level is under the Median performance of developments that do not connect to heat networks. This would suggest that a higher target would be required to actually improve performance going forward or even relax the performance of any projects already at this level.

HIGH – 10%

A residential target of 10% would represent a strong or stretch target. 13% of current cases achieve this therefore this would raise the performance of 87% of the new applications coming forward. A strong wording of the policy would look to rapidly improve the industry and a soft wording may look to drive the industry in the right direct, levels of energy efficiency closer to Passivhaus requirements. This target would give added focus to locking in long-term carbon reductions through improved building fabric rather than shorter-life heat generation plant. A 10% reduction would be Fill the gap left by reduction in the performance of Clean savings in the short term with an update the grid carbon factors. Savings will also be provided day one of a development occupation, unlike Clean savings that may only be provided when a low carbon asset is installed or a District heat network is connected. Finally reductions in demand to this significant level would provide real long term carbon reductions as grid decarbonisation or Low carbon heating systems are relied upon.

Meeting the target will pose a technical stretch and buildability for many projects, and the industry may take a few years to raise performance to this level. I could also increase the likelihood of detailed examination /discussion of applications on a case-by-case basis to agree the level that projects can reasonably attain. The lower heat demand could reduce the overall viability of low carbon heat networks and/or increase fixed standing charge costs to consumers.

NON-RESIDENTIAL

LOW – 0%

The base 'do nothing' position would be to maintain the GLA's current position as articulated in developer guidance but cement this through placing it more clearly in London Plan policy. The target is to meet Building Regulations Part L 2013 through energy efficiency alone. This acknowledges the variability of non-domestic stock and maintains the use of local borough BREEAM targets as the way to drive the market. The challenge of this approach is the absence of strong GLA policy to drive non-residential buildings since heat loads are often low and therefore not especially supported by low carbon heat networks.

MEDIUM – 10%

A 10% Lean reduction is considered achievable for most non-residential specifications. BREEAM Energy credit pre-requisites are driving to and beyond a 10% Lean reduction through the EPR ratings and the majority of Boroughs require BREEAM 'Excellent'. 58% of GLA applications are current achieving this target so it would raise the energy performance of 42% of projects including BREEAM 'Very Good' and some 'Excellent' buildings. The challenge is that this reduces slightly the flexibility of how to achieve BREEAM targets set by local authorities.

HIGH – 15%

A 15% reduction is being achieved in 46.8% of cases so a target at this level would raise the performance of 54% of projects. There is good evidence base that achievable in many cases however certain developments may find this a challenge due to a number of project-specific constraints. This is considered a high target because it raised the majority of developments and it aligns with BREEAM 'Outstanding', which is considered the aspiration within the industry. The high variability of non-domestic buildings means there will always be particular projects that will find it hard to meet the target. Nevertheless this would be a strong aspirational target to encourage investment and drive a section of the market less supported by low carbon heat networks. GLA would be adopting a leadership role alongside boroughs pushing towards BREEAM Outstanding energy performance.

5. POLICY TARGET OPTIONS

Three levels of LEAN reduction have been assessed depending upon the level chosen.

Residential					
Level	**Lean reduction**	**Technical comparator**	**Cost comparator**	**Opportunities**	**Challenges**
Low	0%	• Part L 2013 GLA baseline	London Counterfactual	• Retention of overall 35% carbon reduction target will continue drive investment in mix of Lean, Clean, Green and offset • Higher carbon factors for Gas CHP may provide pressure for greater Lean reductions, even without target • Absence of specific Lean target may increase focus on transition to lower carbon heat sources	• Current Lean target is typically being exceeded current target no longer providing a stretch
Medium	5%	• 37% current cases achieving • Lower than median without clean	Median of '5% - 9.9%' cost range	• Raises performance of two-thirds of projects • Generally achievable without significant technical change • Increases focus on the need to mitigate impact of changing carbon factors	• Time and effort to enforce relatively modest sub-target within the energy hierarchy • Does not fill the gap left by reduced future clean savings • Many projects, not connecting to DHN, already surpass this level
High	10%	• 13% current cases achieving • Close to Passivhaus levels; • Higher than median without clean	Median of '10% - 14.9%' cost range	• Stronger aspirational target to encourage innovation • Focuses on locking in long-term carbon reductions • Fills gap left by future reduced clean savings	• Technical stretch expected for many developments • Increases likelihood of detailed examination / discussion on case-by-case basis • May reduce viability of low carbon heat networks • Heading towards diminishing returns on investment

Non-Residential					
Level	**Lean reduction**	**Technical comparator**	**Cost comparator**	**Opportunities**	**Challenges**
Low	0%	• Part L 2013 GLA base case	London Counterfactual	• Acknowledges variability of non-domestic stock • Maintain local authority BREEAM targets as the way to drive the market	• Absence of strong GLA policy to drive non-residential buildings since heat loads are often low, hence Clean reductions often low
Medium	10%	• 58% current cases achieving; • Mid BREEAM Excellent	Median of '10% - 19.9%' cost range	• Raises the performance of 42% of projects • Generally achievable without significant technical change • Potential implementation mechanism through BREEAM • Raises the energy performance of BREEAM Very Good and some Excellent buildings	• Reduces flexibility of how to achieve BREEAM targets set by local authorities
High	15%	• 46% current cases achieving; • Just below median without clean; • Min for BREEAM Outstanding	Median of '10% - 19.9%' cost range	• Raises the performance of 54% of projects • Good evidence base that achievable in many cases • Strong aspirational target to encourage investment • Drives section of the market less supported by low carbon heat networks • Leadership role alongside boroughs pushing for BREEAM Outstanding	• High variability of non-domestic buildings means there will always be particular projects that will find it hard to meet the target

6. KEY FINDINGS CONTINUED

How could a new policy impact the GLA energy hierarchy?

The GLA case data shows a negative correlation between Lean and Clean performance in both Residential & Mixed (together) and Non-Residential buildings. There could be a number of reasons for this, including developers trading-off one part of the energy hierarchy against another. However it may also be the case that better Lean performance reduces heat demands and therefore reduces the impact of Clean heat sources.

On average if a Non-residential development has access to a Clean Heat Source, it achieves a 8.17% Lean reduction. Whereas without a Clean Heat source 17.83% is achieved. The median Lean performance for Residential projects is 3.4% for those connected to heat networks by 7.5% for those that are not. The median performance for Non-Residential projects is 7.1% for those connected to heat networks and 16.1% for those that are not. This suggest that developments that do not rely upon Clean savings are able feasibly and viabaly push Lean and Green performance to meet planning targets.

Analysis of the BuroHappold dataset shows that energy efficiency appears to be the least cost effective measure to reduce carbon emissions, and carbon offsetting the most cost effective. However it appears that a significant proportion of this cost is associated with just meeting Building Regulations Part L for project in London that are typically very different from the notional building used as a Part L baseline. No correlation can be found with % lean improvement and total offset cost, therefore it would infer that a Lean policy would not significantly increase overall offset cost.

Secondary consideration

Analysis of the BuroHappold models shows that % lean reduction increases with a higher G-value in residential dwellings, which could increase overheating risk. However analysis also shows that both 5% and 10% targets can be achieved with both low and high G-values and therefore this target can be achieved without compromising occupant thermal comfort.

Residential occupants could save between £15 to £25/year for a 5% reduction and £24 to £33/year on energy bills for a 10% reduction compared to the equivalent 0% Lean reduction, current policy, depending upon heating system. Non-residential occupants could save between £0.5/m2 for a 10% reduction and £1.4/m2 for a 20% reduction compared to the equivalent 0% Lean reduction depending upon heating system.

Correlation is observed between space heating and carbon reduction, particularly in residential buildings and, in general a 10% carbon reduction correlates with the Passivhaus performance level.

Analysis shows a strong correlation with the BREEAM EPR ratings and % reduction. Developments will most likely achieve between 5%-15% carbon reduction if BREEAM Excellent is required, which is present in the majority of Local Authority policy and guidance.

What is the expected Cost uplift for a new Lean target policy?

The cost uplifts have been outlined compared to the Building Regulations Part L Notional building, however this may not be considered typical or appropriate as a London Counterfactual case.

Current London median shows is shown on the cost uplift tables. This indicates which performance region the median Resi or Non-Resi development sits within. This is the point where 50% of the current applications currently meet. A hard or soft policy of this region would expect to influence the majority (over 50%) of developments in the future. London median Resi 0%-4.9% region and 10%-19.9% region Non-resi. This is without an energy efficiency policy, under the current London Plan. Therefore the viability consultant should choose whether to use the full cost uplift or difference between this figure and the cost of a chosen policy. Ranges have been provided based on upper, lower quartile of data sets as well as median cost, this outlines spread of datasets and a cost figures that can be chosen by the viability consultant.

Range of residential cost uplifts over notional (£/unit) for varying Lean % carbon reduction targets

LEAN % reduction Target	Notional	0%-4.9% (Current London Median in this region 3.7%)	5%-9.9%	10%-14.9%	15%-19.9%
Upper Quartile	£0	£6,300	£8,010	£7,920	£8,560
Median		£5,000	£5,710	£6500	£7,870
Lower Quartile		£4,350	£4,130	£5,550	£7,330

Range of non-residential cost uplifts over notional (£/m^2) for varying Lean % carbon reduction targets

LEAN % reduction Target	Notional	0%-9.9%	10%-19.9% (Current London Median in this region, 15.1%)	20%-29.9%	30%-39.9%
Upper Quartile	£0	£64	£59	£47	£57
Median		£35	£55	£37	£36
Lower Quartile		£20	£37	£32	£34

Next Steps and recommendations

- The models required to generate these cost uplift are considered as a wide range of indicative ways to achieve the targets, however do not represent all permutations and is not exhaustive. A further study will be required on common building types to evidence fully how a target could be achieved across the building stock.
- Analysis suggests that increasing G-value (closer to 1.0) will improve % lean reduction, however will increase overheating risk. A detailed study should be undertaken on the impact of G-value in typical dwellings on % lean reaction and Overheating risk in line with latest CIBSE and GLA guidance.

DATA ANALYSIS

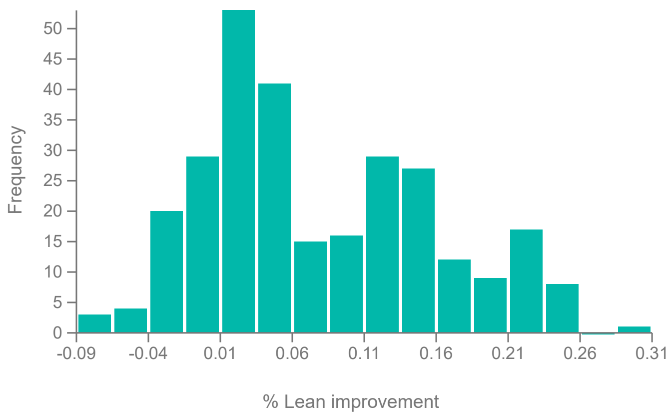
7. What is the nature of the data used for this study?

This shows a visualisation of the % Lean reduction split by Residential (and Mixed use) and Non-residential for the BuroHappold models and the GLA Cases received between 2014 and 2016. The histograms show that the BuroHappold modes occur at 1-4% reduction for Resi and 3-6% for Non-Resi. For the GLA cases the mode occurs at 0-4% for Resi and either 1-4% or 15-18% for Non-Resi.

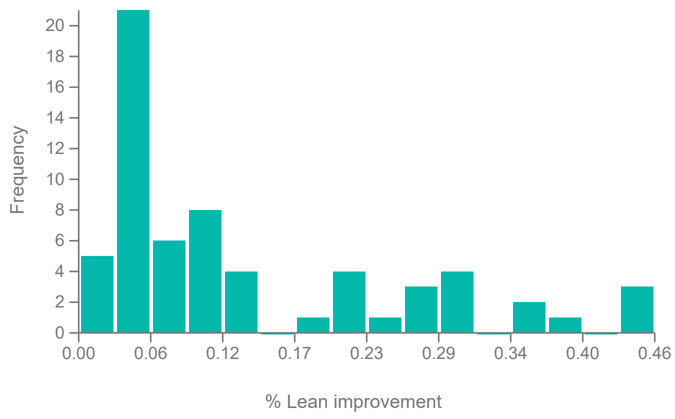
BuroHappold Lean Project Models
Number of project models **351**
Average Lean Improvement (%) **8.86%**
Median Lean Improvement (%) **5.88%**
Average BER or DER (kg CO2/m2) **55.51**
Average TER (kg CO2/m2) **59.35**

GLA cases between 2014 -2016
Number of GLA Cases **266**
Average Lean Improvement (%) **8.38%**
Average Lean Improvement (%) **6.45%**
Average Baseline Emissions (kg CO2/yr) **826**
Average Lean Emissions (kg CO2/yr) **760**

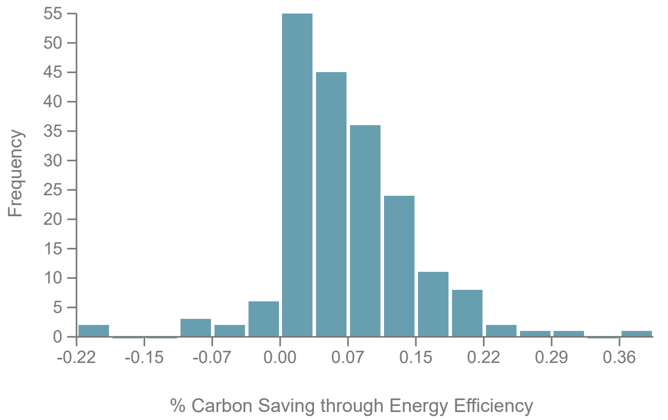
BuroHappold Residential Models - Part L 2013 Lean Improvement (%)



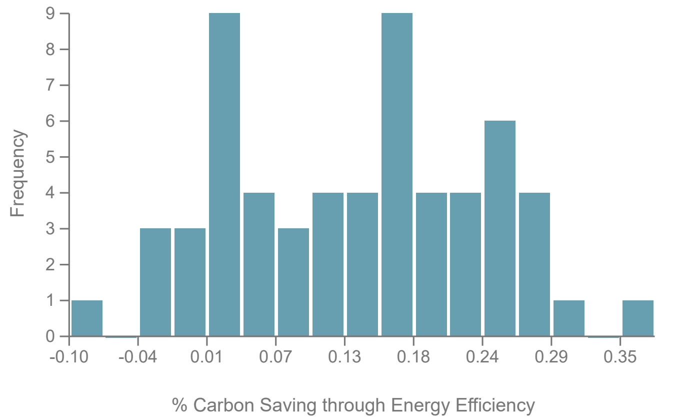
BuroHappold Non-Residential Models - Part L 2013 Lean Improvement (%)



GLA Resi and Mixed Use Cases Reviewed - Part L 2013 Lean Impr. (%)



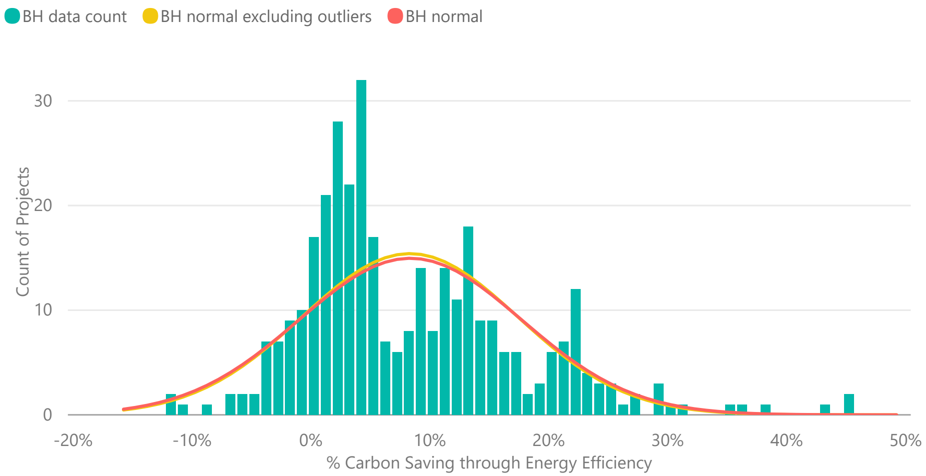
GLA non-Residential Cases Reviewed - Part L 2013 Lean Impr. (%)



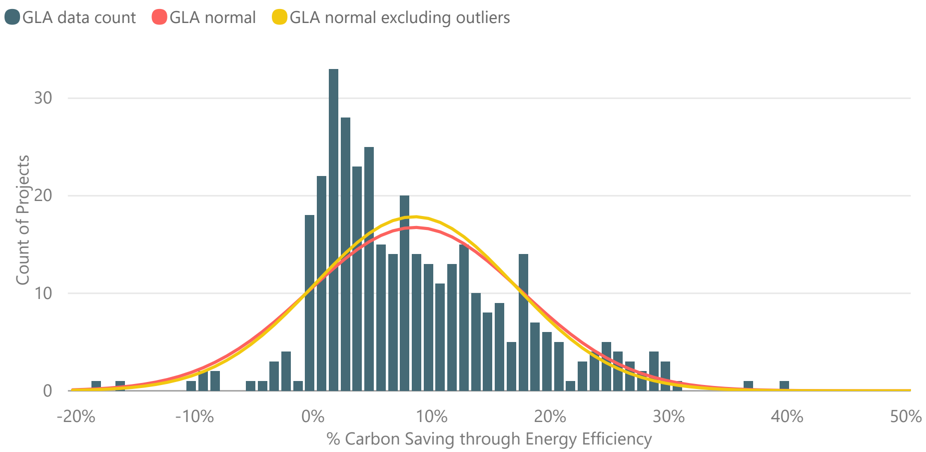
8. Investigating the normal distributions associated with both data sets

This comparison of the two data sets illustrates their relative distrubutions and the impact of outliers

Full BuroHappold dataset Lean % reduction by number of models (Resi and Non-Resi)



Full GLA dataset Lean % reduction by number of cases (Resi, Non-Resi and Mixed use)



The two data sets perform different functions. GLA data is used for high level analysis. It is used in preference to the BuroHappold data as it is a full picture of all relevant planning applications. The BuroHappold data is used where project specifications are analysed because this information is not present in the GLA data.

The plots on this page show normal distributions fitted to both data sets to understand the distribution of performance. This is used to understand the dataset and establish the relevent averages to use, mean/mode/median, when representing the dataset. In both cases the median, the middle value of a dataset, and mode, most frequent value in a dataset, occur at a lower % carbon reduction than the average (mean). This is because the pass/fail margin associated with a 0% carbon reduction skews the distribution. As a results of these discrepancies and the skewness of the underlying data it is suggested that the median, rather than the average (mean) should be used to assess typical performance. Median will be used in analysis going forward as result, and mean will be used where appropriate in addition, and stated as such.

The distributions shown with the yellow line on both plots show the normal distribution with outliers removed. In both the BuroHappold data and the GLA data the removal of the outliers has little impact on the location of the mean. this is due to the large sample size of the datasets as a whole, However when the datasets are split by residential and non-residential only varying patterns occur, see next page. This demonstrates the importance of sample size when interpreting data.

The tables below shows key metrics for both data sets. The Mann Whitney test for non-parametric data suggests that there is a 97% probability that these populations are the statistically similar.

BuroHappold data key metrics

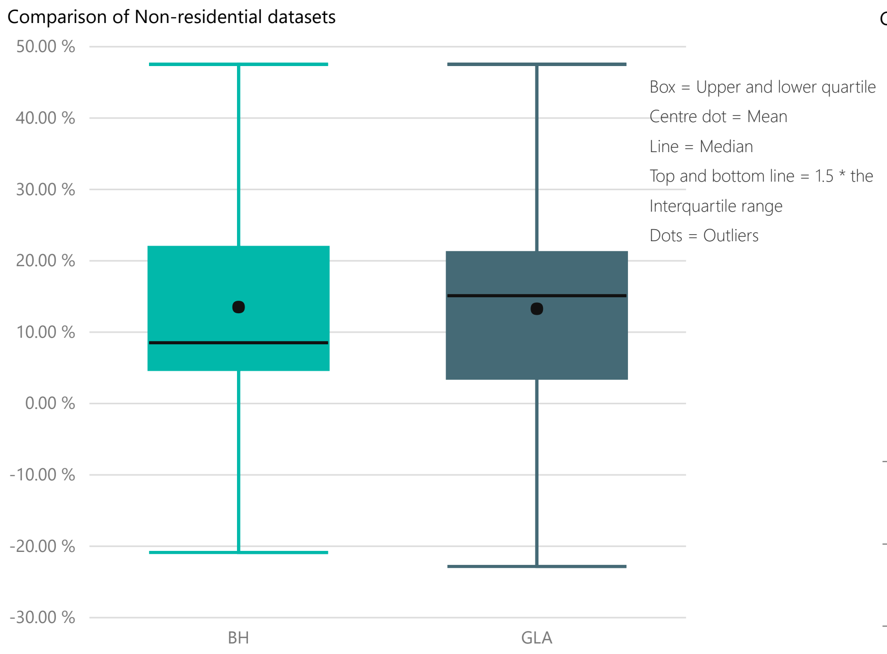
Resi/Non Resi	Average of saving from energy efficiency (%)	Median of saving from energy efficiency (%)	Standard deviation of saving from energy efficiency (%)
Non-Resi	13.52 %	8.52 %	12.53 %
Resi	7.82 %	5.44 %	8.13 %
Total	**8.86 %**	**5.88 %**	**9.36 %**

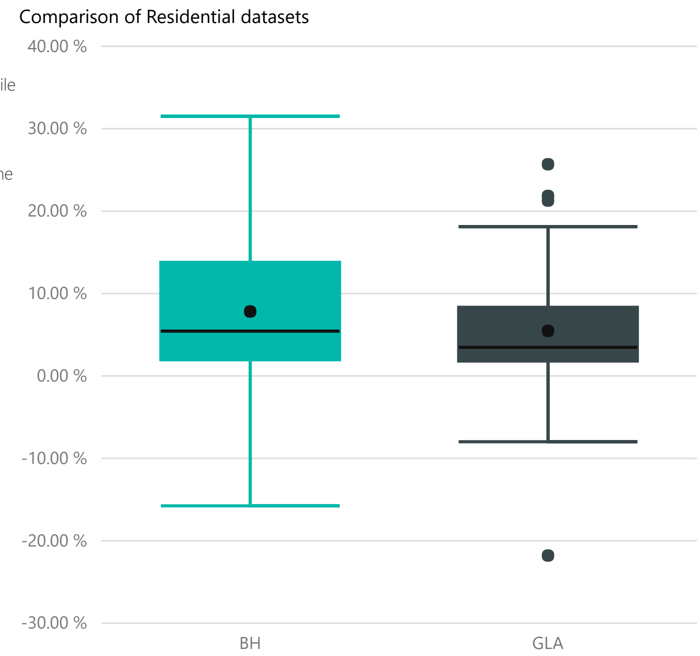
GLA data key metrics

Non dom/Dom/ Mixed	Average of saving from energy efficiency (%)	Median of saving from energy efficiency (%)	Standard deviation of saving from energy efficiency (%)
Mixed-Use	7.26 %	5.79 %	7.08 %
Non-Resi	13.28 %	15.11 %	10.18 %
Resi	4.74 %	3.70 %	7.34 %
Total	**8.38 %**	**6.45 %**	**8.42 %**

9. Understanding the relative distributions of the BuroHappold and GLA data sets

This comparison of the GLA and BuroHappold data sets shows that non-residential has statistically similar carbon savings. The detailed specifications of buildings in the GLA dataset are unknown, therefore it is impossible to know whether the buildings from both datasets are similar in other ways, without doing in-depth cost and energy analysis of the GLA buildings. The high level similarity between the datasets suggests that the in depth analysis of BuroHappold projects is applicable to the GLA data set. In addition, this comparison shows that, greater Lean savings are achieved on non-residential projects than on residential developments.





This suggests differences between the distribution of the datasets as a whole. This is relevant to the cost uplift analysis, in sections 29 -31, as this is the point in the study outputs where the two data sets are cross referenced. The cost uplifts are based upon BuroHappold modelling within regions of performance. The models required to generate these cost uplift are considered as a wide range of indicative ways to achieve the targets, however do not represent all permutations and is not exhaustive. For this study the costs uplifts provided show a range based on Upper, Lower quartiles as well as Median values to provide a range of costs if required. A further study will be required on common building types to evidence fully how a target could be achieved across the building stock.

The comparison of the non-residential data sets shows that the mean points of the GLA data and the BuroHappold data are very closely aligned, whilst the average (median) of the GLA data is somewhat higher. The Mann Whitney test (for non-parametric data) suggests that there is a 88% probability that these populations are the same.

In the residential data both the median and average of the Burohappold data are better performing than those in the GLA data. As in the case of the non-residential data the median shows a much closer match between the two data sets. This is because the mean will have been skewed higher due to the increased numbers of 'push' models created for the study. The 'push' models have been used to test the impact of more stringent specifications to improve carbon performance.

As a result, the Mann Whitney test (for non-parametric data) suggests that there is only a 2% probability that these populations are the same, this is increased to 19% when the lower outliers are excluded.

10. What proportion of current schemes achieve what level of Lean carbon reduction?

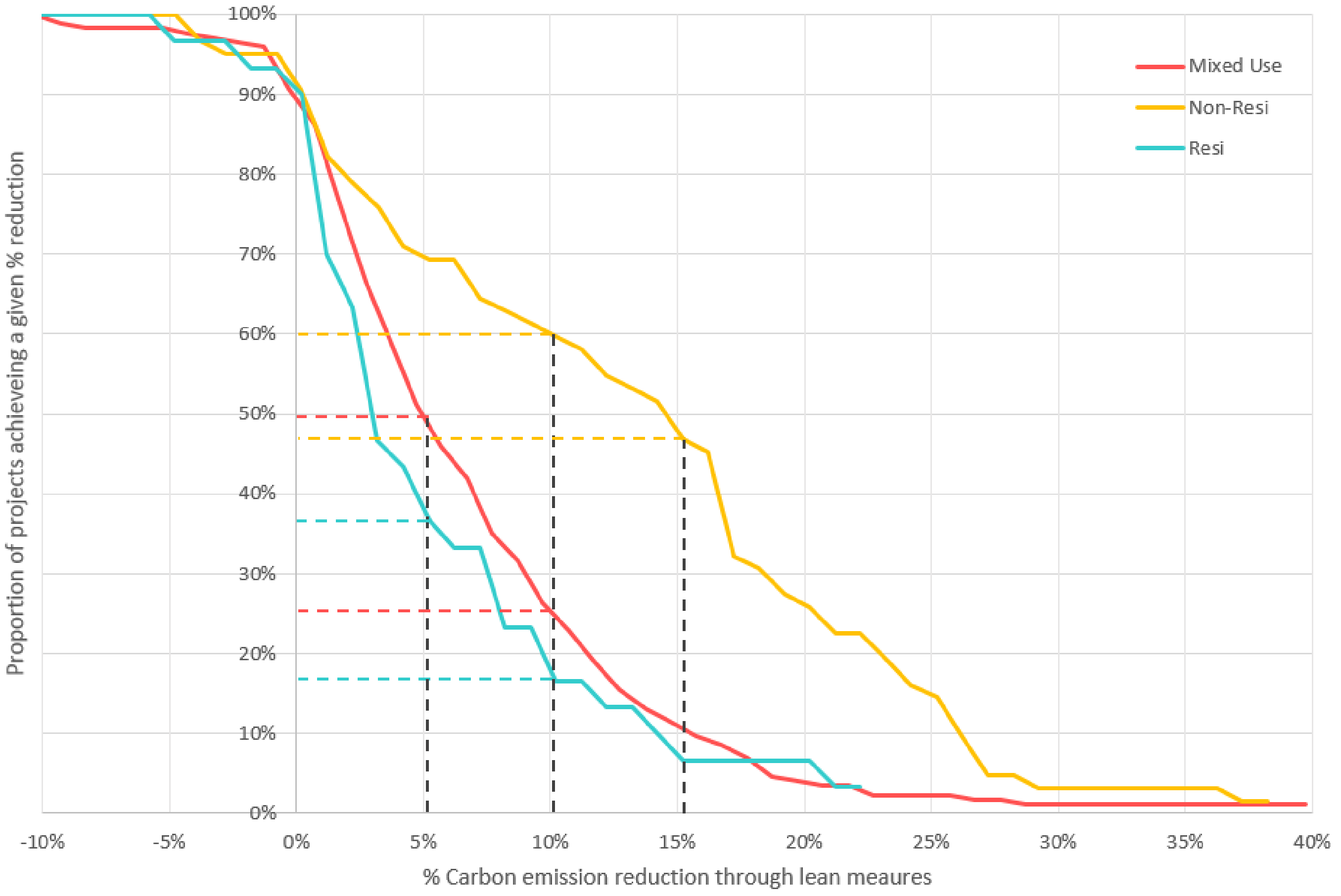
This slide shows the proportion of projects that are achieving any given % reduction in carbon emissions across all projects referred to the GLA under current planning regulations. The data is from the GLA dataset only and is used a a barometer of current performance within the rest of the study. The 50% percentile of each dataset on the graph approximates the median performance. Based upon the distribution analysis the median can be as an indicator of average performance and as such the this point is assumed to represent the 'typical' London performance for this development type.

Of current GLA residential projects 37% are already meeting a 5% energy efficiency reduction. A residential target set here would be expected to result in an energy efficiency performance uplift in 63% of residential developments, so making a significant impact on the majority of the residential new builds. This is balanced with the demonstration that this a consistently achievable target as over a third of projects already meet it.

The non-residential data shows that 58% of projects would already meet a 10% Lean reduction target. A target at this level would impact 42% of non-residential developments. This would again have a strong effect on many developments but is also clearly achievable in the majority of cases.

Mixed use schemes sit between non-residential and residential in terms of performance with 49% meeting a 5% reduction and 25% meeting a 10% target. It is assumed that the majority of the floor area in a mixed use scheme is typically residential. This suggests that the true proportion of residential schemes already meeting a 5% target is higher than the 37% shown so increasing the evidence to support the feasibility of achieving this level of reduction.

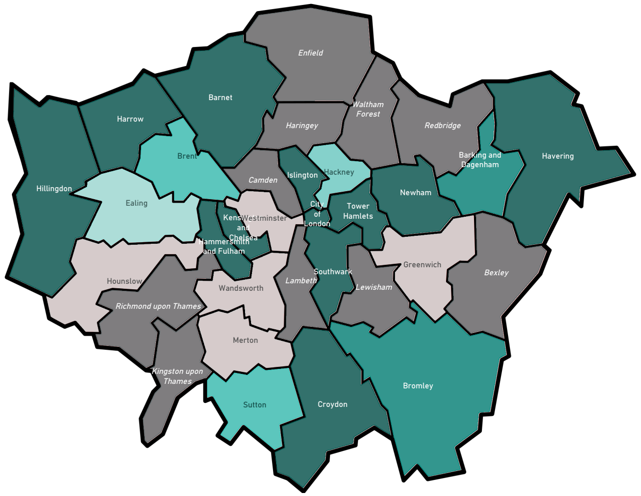
The data suggests that 11% of projects (across all space uses) are not meeting regulations through lean measures alone. This adds weight to the suggestion that there is a significant energy efficiency requirement in London associated with meeting Building Regulations.



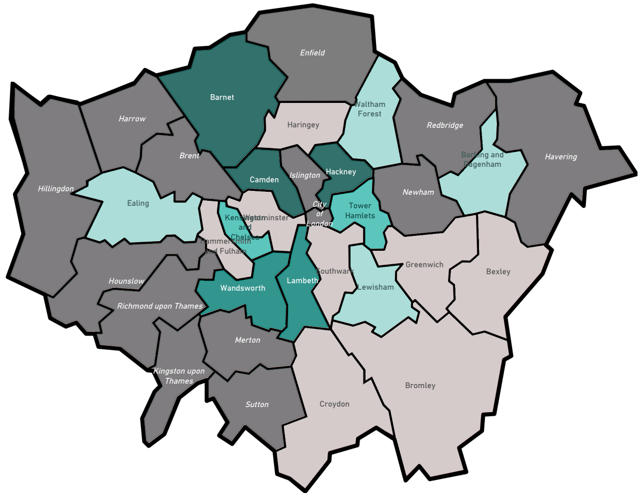
11. How are different London Boroughs currently performing on Lean Energy Efficiency?

The three maps show the % lean reductions for planning applications/cases received by the GLA under Part L 2013 from 2014, 2015 and 2016 considering borough and development zone. The maps shows Non-residential, Residential and Mixed Use developments respectively.

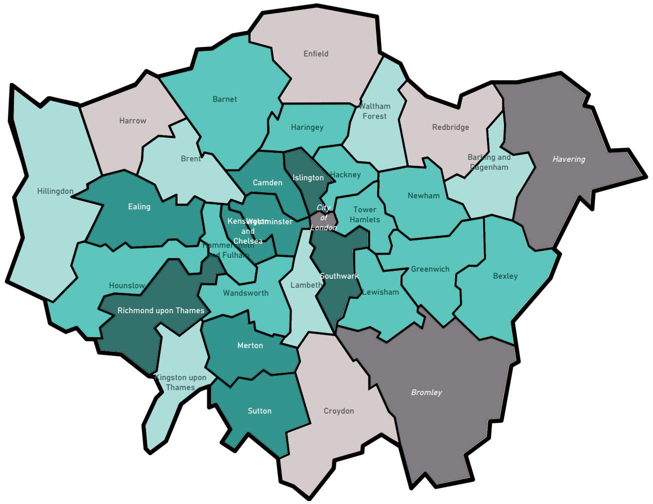
Median % Lean reduction by Non-Resi GLA cases by London Borough

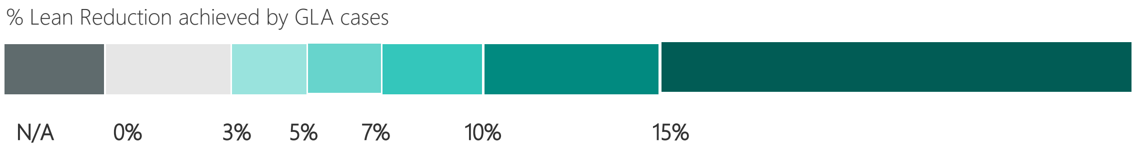


Median % Lean reduction for Residential GLA cases by London Borough



Median % Lean reduction for Mixed Use GLA cases by London Borough





The far left maps show that the majority of Non-Resi application's median % lean reduction received by the GLA show a result is higher than 15%. This is present in 12 of 23 boroughs, with 10 Boroughs not having Non-Resi only applications submitted. This does not seems to be a specific pattern or trend to the locations and % reductions, with both central an outer boroughs achieving above the 15% threshold. The central map shows Residential only applications. This map shows that high performance was achieved in Barnet, Hackney and Camden (+15%). Particularly low performance was achieved in Croyden, Bromley and Southwark, all less than 1% reduction.

Mixed-use applications make up the majority of applications submitted, 174 of 266. This map show a general trend that Central and South Westerly Boroughs perform best. Outer Borough, such as Croyden, Harrow, Enfield and Redbridge all perform low (<3%) compared to the other mixed use schemes. This may be due on high Resi to Non-resi proportions or other unknowns within these boroughs.

12. Which London boroughs are within each Viability Assessment Development Zone and what scales of development are seen across them?

The map shows the Development zone by borough used within the London Plan Viability Assessment. The Zones are named A - E and are correlated to development value, A being most valuable and E being the least

The viability assessment for the new London Plan will look at catorgised 5 development zones across London. This is to reduce the number of permutations to assess. The zones have been grouped by similar boroughs where development types and land value are similar. The Zones go from A to E, A being the most expensive to develop in.

The development zones are mapped and referenced going forward to understand if any trends are clear from a Development zone wide basis rather than on a borough basis. This is to allow an increased number of data points as well as ease of analysis for the viability assessment.

Applications have been additionally catagorised based on size, across four scales; Very Large , Large, Medium and Small. Both Non-resi, Resi and mixed use applications have a scale, Mixed-use is based upon the largest scale of either the Resi or Non-resi. The Scales are as follows:

Non Resi
Very Large >75,000 sqm
Large = 25,000 - 74,999 sqm
Medium = 5,000 - 24999 sqm
Small = 0 - 4,999 sqm

Residential
Very Large >1,500 Units
Large = 500 - 1,499 Units
Medium = 150 - 499 Units
Small = 0 - 149 Units

Medium scale is most prevalent across the zones and additionally Zones A and C have higher proportions of Large and Very Large applications compared to the other zones.

Viability Development Zone by London Borough

A B C D E

A count of Cases in each devlopment zone for varying scales

Viabilty Development Zone	Large	Medium	Small	Very Large	Total
A	16	38	21	4	**79**
B	7	42	23	4	**76**
C	12	18	6	5	**41**
D	6	30	14	1	**51**
E	5	8	4	2	**19**
Total	**46**	**136**	**68**	**16**	**266**

A count of Cases in each devlopment zone for varying scales

Viabilty Development Zone	Count of London Boroughs in Zone	£psm
A	7	14000
B	7	6500
C	7	5250
D	7	4000
E	5	2500
Total	**33**	**5250**

13. How do the London Borough and Development Zones perform across the Energy hierarchy?

The Matrix below shows three trends, Boroughs performing highest for Lean generally perform low in clean savings. The highest Clean saving boroughs perform lowest for Lean savings and 4 of the top 10 Boroughs for lean savings are in Development Zone A. However this may be due to higher proportions of Non-residential cases in these locations rather than a link to land value or build cost. The results are not weighted by scale of development and each development is weighted equally.

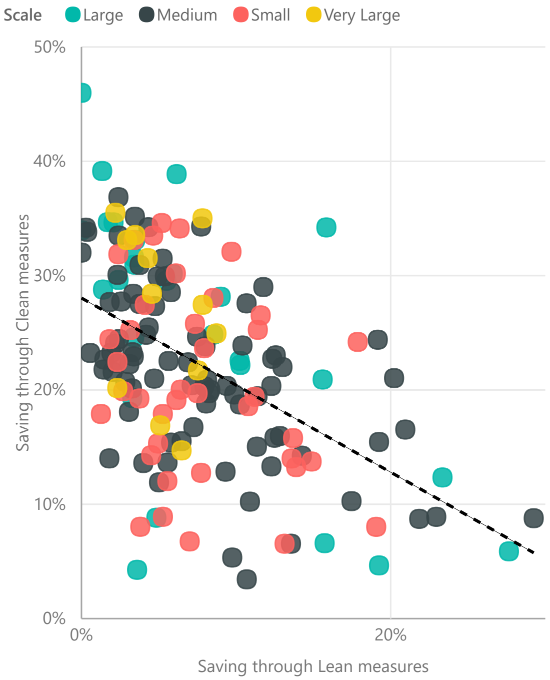
For analysis breakdown of development zones and of Residential and Non-residential see sections 15 and 16. For a breakdown by scale see Appendix 1 and 2.

London Borough	No. of applications	Viability Development Zone	£psm	Mean saving from energy efficiency (%)	Mean saving from CHP/DH (%)	Mean saving from renewable (%)	Mean Overall savings (%)
Redbridge	1	E	2500	1.85 %	0.00 %	33.15 %	35.00 %
Greenwich	7	C	5250	3.64 %	27.00 %	4.96 %	35.60 %
Kingston upon Thames	4	B	6500	3.94 %	25.15 %	2.38 %	31.46 %
Haringey	4	C	5250	4.18 %	18.85 %	6.24 %	29.27 %
Barking and Dagenham	6	E	2500	4.66 %	24.08 %	4.60 %	33.34 %
Enfield	4	C	5250	5.16 %	8.84 %	20.82 %	34.82 %
Merton	3	C	5250	5.41 %	14.01 %	10.25 %	29.67 %
Waltham Forest	6	D	4000	5.49 %	19.49 %	10.46 %	34.57 %
Bromley	2	D	4000	5.51 %	22.30 %	7.60 %	35.41 %
Bexley	5	E	2500	5.67 %	13.54 %	16.25 %	35.46 %
Wandsworth	20	B	6500	5.88 %	20.87 %	8.61 %	35.13 %
Newham	9	D	4000	5.91 %	22.15 %	3.52 %	31.03 %
Hounslow	13	B	6500	6.09 %	14.18 %	13.60 %	33.77 %
Croydon	6	D	4000	6.20 %	19.14 %	11.08 %	36.43 %
Lewisham	8	D	4000	6.48 %	21.15 %	6.88 %	33.90 %
Lambeth	10	A	14000	6.93 %	23.49 %	3.79 %	34.05 %
Brent	10	D	4000	7.19 %	22.51 %	5.75 %	34.95 %
Westminster	36	A	14000	7.41 %	15.88 %	8.29 %	31.40 %
Harrow	6	C	5250	8.17 %	18.70 %	8.00 %	34.87 %
Hammersmith and Fulham	4	A	14000	8.20 %	24.92 %	0.76 %	33.88 %
Sutton	3	E	2500	8.55 %	10.90 %	34.48 %	53.93 %
Hackney	10	B	6500	8.73 %	13.81 %	9.69 %	32.21 %
Ealing	18	B	6500	8.97 %	15.04 %	11.96 %	35.65 %
Barnet	9	B	6500	9.03 %	14.09 %	12.77 %	35.55 %
Kensington and Chelsea	6	A	14000	10.48 %	10.53 %	4.45 %	25.46 %
Camden	5	A	14000	10.55 %	5.12 %	14.00 %	29.66 %
Southwark	12	A	14000	11.49 %	17.42 %	4.38 %	33.26 %
Tower Hamlets	16	C	5250	11.74 %	19.91 %	5.78 %	37.33 %
Hillingdon	10	D	4000	11.74 %	5.35 %	21.72 %	38.82 %
Richmond upon Thames	1	C	5250	15.46 %	0.00 %	16.49 %	31.95 %
Islington	2	B	6500	19.99 %	10.10 %	3.01 %	33.10 %
Havering	4	E	2500	22.71 %	0.00 %	13.46 %	34.98 %
City of London	6	A	14000	23.77 %	4.19 %	2.48 %	30.44 %

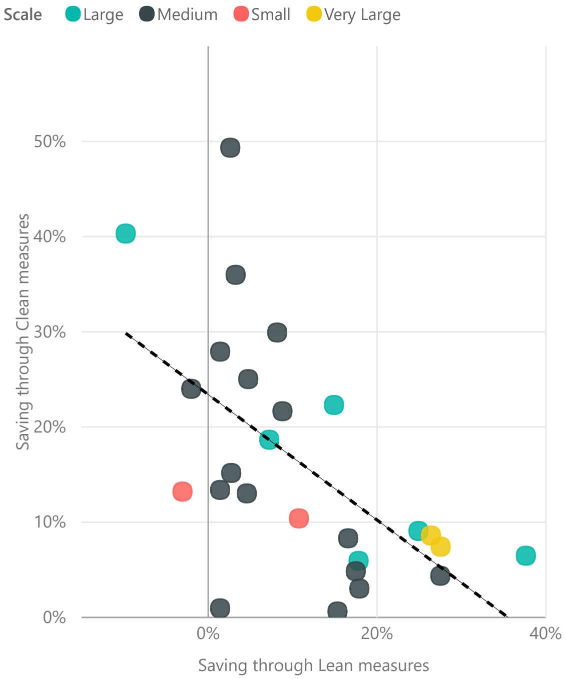
14. How do the Lean Savings Interact with other levels of the Energy Hierarchy?

This slide looks at the potential affect an energy efficiency target may have on the other levels of the Energy Hierarchy

Residential and Mixed Use (Excluding cases with no Clean contrib...



Non-Residential (Excluding cases with no Clean contribution)



The data for both the residential and non-residential developments shows some correlation (R2=0.29 and 0.35) and that increasing lean savings lead to decreased clean savings (gradient =0.7 and p<0.01 for both). One explanation for this is that a reduction in heat demand associated with good energy efficiency, will lead to a reduced use of the low carbon heat source and hence a smaller impact from clean measures.

The tables below, show a comparison between projects with an available district or communal heat source to connect to and projects without. Projects with district or communal heating achieve 7% less lean savings (p=0.001 that this difference would be seen by chance). This highlights the increased lean and green savings that are possible when there is no low carbon heat source.

This finding helps in the understanding of section 8 which shows several outer boroughs achieving the highest levels of energy efficiency carbon reductions. This may be because of the unsuitability of heat networks in these areas drives developments towards lean measures. Conversely, areas where district heating is viable tend to perform less well on energy efficiency. This may also be driven by a requirement to provide a certain level of heat demand to ensure the economics of the heat network.

An Energy Efficiency policy may help to reinforce this pattern of performance and push the cases further that currently do not have Clean savings. This i because the as the savings from Clean measures are expected to diminish if grid carbon factors are updated in line with the 2016 SAP consultation, see section 20 and 21 for more information.

Table of carbon savings for projects without clean measures

Non dom/Dom/ Mixed	Median of saving from energy efficiency (%)	Median of saving from renewable (%)	Count of Case No.
Non-Resi	17.83 %	15.20 %	35
Mixed-Use	8.64 %	19.63 %	24
Resi	7.49 %	20.08 %	6
Total	**12.84 %**	**18.61 %**	**65**

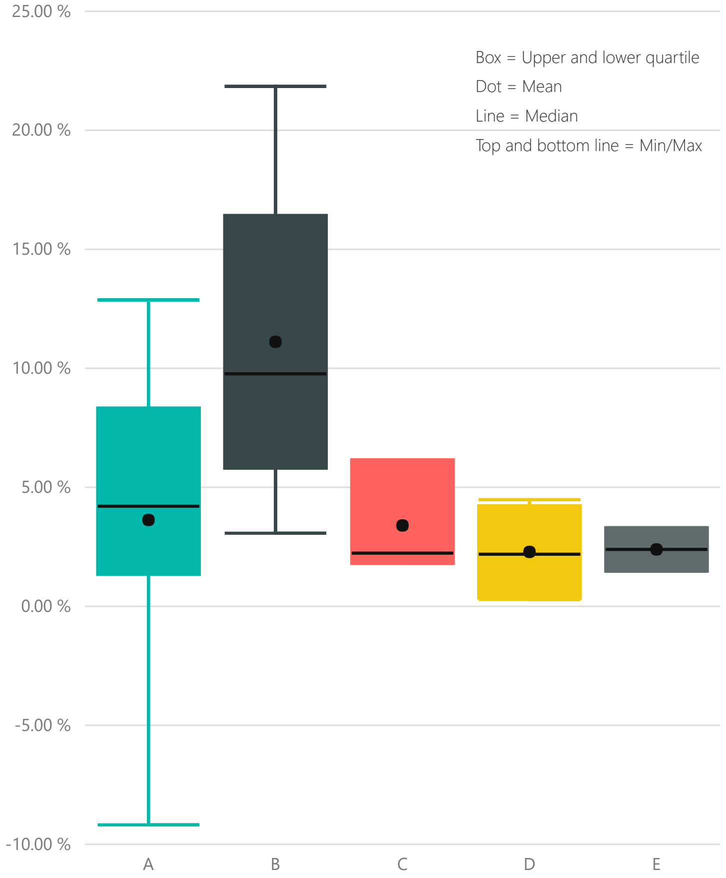
Table of carbon savings for projects with clean measures

Non dom/Dom/ Mixed	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Count of Case No.
Non-Resi	8.17 %	13.22 %	1.77 %	26
Mixed-Use	5.56 %	22.67 %	2.90 %	148
Resi	3.36 %	22.95 %	6.54 %	24
Total	**5.56 %**	**22.38 %**	**3.36 %**	**198**

15. Does development zone have an affect on the carbon savings from energy efficiency in residential schemes?

This page shows how the Residential GLA Cases will be effected by an energy efficiency target across the different development zones.

Variation in savings through energy efficiency in the different Development Zones



The average and median performance across all the Development Zones (except B) is worse than a 5% reduction. In all zones there is an approximately 20% saving being achieved through Clean measures (see table below), as previously discussed in slide 9 this may be contributing to the poor performance in energy efficiency. The reasons for the better performance in zone B are not fully understood although it may be linked to the typical architecture and typologies being built in these Boroughs.

There are a wide range of performances observed in zones A and B whilst the other zones are more tightly grouped. This may be a function of the smaller sample size in zones C,D and E or could be associated with a more consistent style of development in the latter zones leading to more similar energy savings being achieved. There is a general trend for the outer Development Zones to perform more poorly than those closer to central London.

Although there is a general trend towards poorer performance in the outer zones the actual variation (again excluding zone B) is minimal (between 4.3% in zone c and 2.4% in zone E). This suggests that there will not be a particularly negative impact of an energy efficiency target on any one Development Zone. However no cases in Zone D or E achieved over 5%.

Zone B performs significantly better than any other zone. It is not understood why this is occurring and a further detailed study into the building performance specifications would be required to do so. Analysis in this study, on BuroHappold models, suggests low air permeability and moving toward triple glazing may be required to meet these levels. Therefore a study to understand of how this has been achieved feasibly and viably on a zone wide basis is therefore recommended.

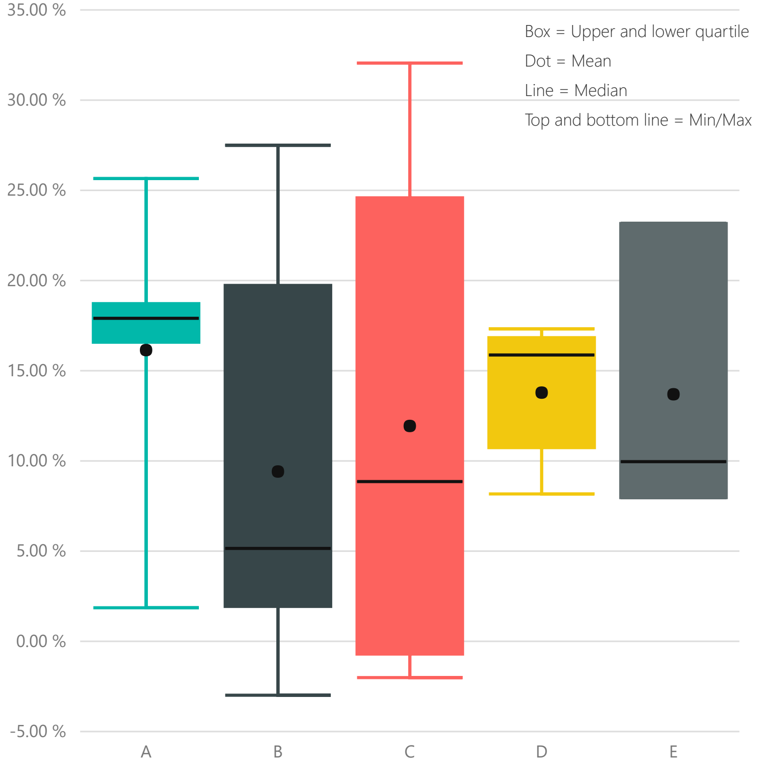
Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Average of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
E	2	2.39 %	2.39 %	22.98 %	7.43 %	32.80 %
D	6	2.57 %	2.34 %	21.96 %	11.29 %	32.92 %
A	9	3.42 %	1.85 %	20.00 %	7.17 %	35.00 %
B	8	9.77 %	9.56 %	18.75 %	8.38 %	35.37 %
C	5	4.35 %	6.03 %	22.35 %	11.30 %	42.93 %
Total	**30**	**3.70 %**	**4.74 %**	**21.87 %**	**7.70 %**	**35.02 %**

See Appendix 1. for a breakdown of project performance by scale

16. Does development zone have an affect on the carbon savings from energy efficiency in non-residential schemes?

This page shows how the Non-residential GLA Cases will be effected by an energy efficiency target across the different development zones.

Variation in savings through energy efficiency across the different Development Zones



There is a general trend for both the median and average performance to increase as the Development Zone moves further towards the edge of London. It is suggested that this is linked to the typical non-residential typologies in the outer Boroughs compared with the inner Boroughs For example the tendency towards retail spaces rather than office spaces in outer Boroughs may have an impact as offices would tend to have greater space heating/cooling loads where as retail areas emissions are often lead by lighting requirements. The exception to this is Zone A, which is very central and performs better than all the other zones.

There is not a significant contribution to the overall savings being made by Clean measures in any of the Development Zones. This suggests that energy efficiency is being targeted as good performance will be required to meet the GLA 35% reductions target. This is corroborated by the high average savings observed - only zone B does not have an average over 10%.

Although there is significant variation in the average and median savings across the zones, the worst performing zones (B and C) show a wide spread in the data indicating that increased savings are feasible in these areas. This suggests that no one zone would be particularly harshly impacted by and energy efficiency target.

The results and analysis undertaken for this study suggests that there is a wide range of specifications across varying building types can be utilised to meet the varying target levels of performance. A more detailed study to understand how different building types achieve the final target level should be undertaken. This should test architectural typologies across differing development zones.

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Average of saving from energy efficiency (%)	Average of saving from CHP/DH (%)	Average of saving from renewable (%)	Average of Overall savings (%)
A	15	18.03 %	16.59 %	8.80 %	4.81 %	30.20 %
C	6	17.11 %	16.15 %	5.08 %	10.07 %	31.31 %
B	20	4.13 %	8.53 %	8.85 %	14.89 %	32.20 %
D	14	13.20 %	13.58 %	7.84 %	16.80 %	38.23 %
E	7	19.30 %	16.68 %	0.09 %	24.69 %	40.78 %
Total	**62**	**15.11 %**	**13.28 %**	**7.26 %**	**13.53 %**	**33.96 %**

See Appendix 2. for a breakdown of project performance by scale

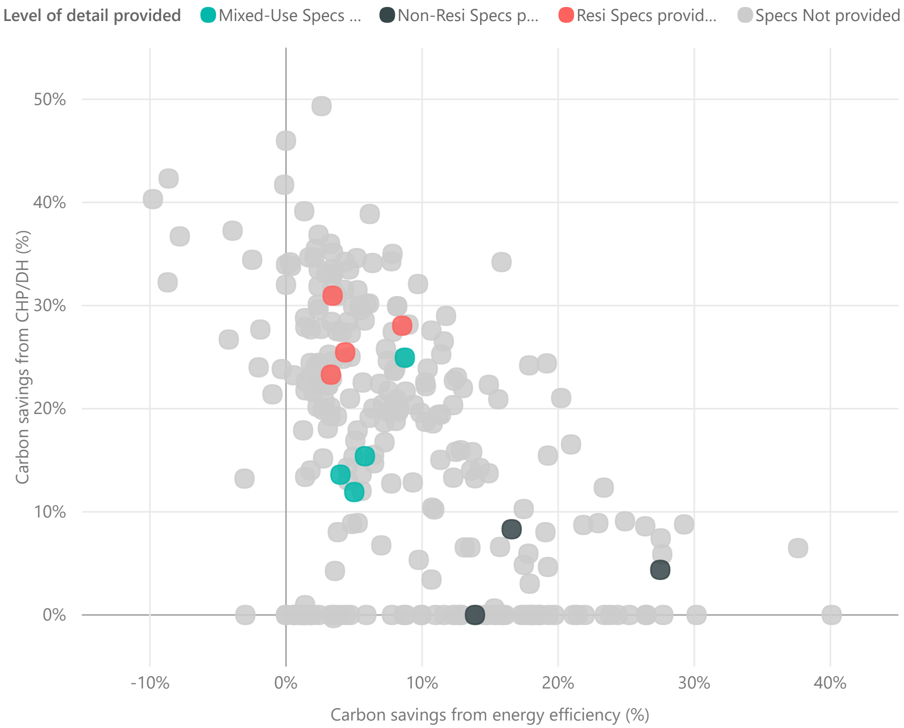
17. What are the fabric and services specifications in applications submitted to the GLA?

The graph shows the % lean carbon reduction and % carbon reductions from CHP in the GLA database. For a few cases (shown in red, green or black), the fabric and services specifications have been provided. These cases represent examples and not typical cases. They have been outlined to understand the specification present across the dataset. Among the detailed GLA cases outlined, the residential buildings achieve Lean carbon reductions around 3-5%, with one development achieving up to 8%. Mixed-use cases achieve Lean savings between 4% and 9% carbon reductions. From the examples outlined only one residential or non-residential case has triple glazing specified. This case achieved a 5.69% Lean reduction in Residential and 10.09% in Non-residential elements. The examples show a wide range of Lean reductions, 3%-27%, without the use of triple glazing, in all but one case.

Non-residential projects provided achieve carbon reductions between 14% and 27%. Although the results are strongly dependent on the specific space type, it can be observed that the highest performing project has a higher chiller efficiency (SEER of 6), which reduces the building's electricity consumption and is considered high. Larger carbon reductions in the residential buildings analysed could be achieved by improving the buildings' fabric. Most developments show high U-values (1.2-1.4 for windows, 0.16-0.35 for walls). Further improvements can be obtained through reduced air tightness (3-5 in the example projects). In a few cases natural ventilation could be replaced with MVHR for better performance.

In the non-residential cases, fabric performance could be greatly improved by reducing glazing U-values (in most cases between 1.3 and 1.9), wall U-values (mostly exceeding 0.18) and air tightness (ranging between 3 and 5). Almost all the examples present manual lighting controls; thus, lighting consumption could be greatly reduced by using automatic daylight dimming and occupancy controls, as applicable in the specific projects. Furthermore, chiller efficiency could be pushed above 4 for higher carbon savings.

Carbon savings from energy efficiency (%) and Carbon savings from CHP/DH (%) and Level of detail provided



Mean Residential specifications provided for example cases

7	5.06 %	3.64	0.45	1.30	0.22	0.91	MVHR	Manual	4.00
Count of Cases	Lean % reduction	Air Tightness	Glazing G-Value	Glazing U-value	Wall U-value	Boiler Eff. (%)	Ventilation type	Lighting Controls	Chiller SEER

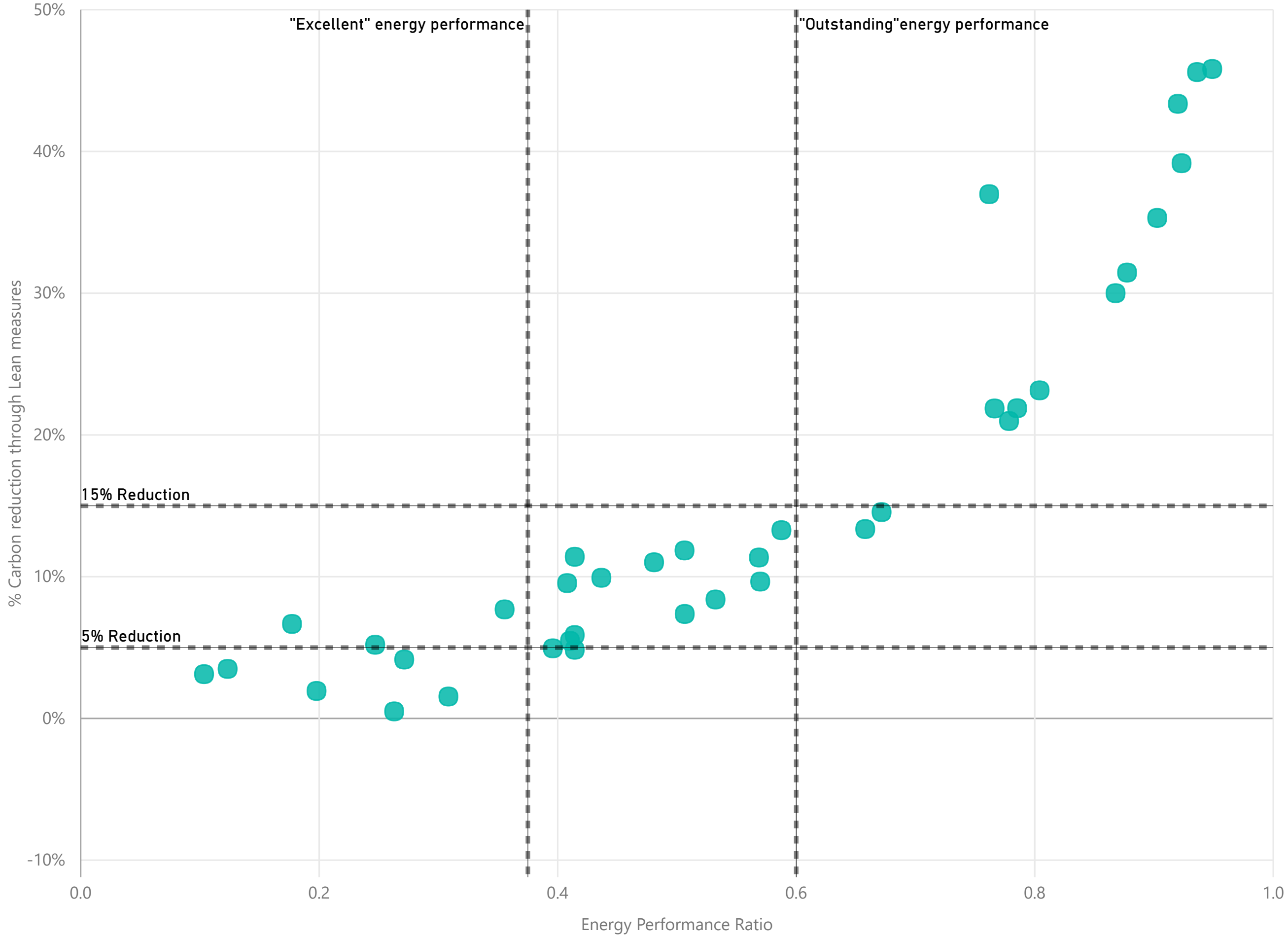
Mean Non-Residential specifications provided for example cases

2	5.92 %	MVHR	3.50	0.30	1.80	0.24	0.95	Auto	4.10
Count of Cases	Lean % reduction	Ventilation type	Air Tightness	Glazing G-Value	Glazing U-value	Wall U-value	Average of Lean b...	Lighting Controls	Chiller SEER
6	14.21 %	AHU	4.00	0.40	1.44	0.22	0.92	Manual	4.81
Count of Cases	Lean % reduction	Ventilation type	Air Tightness	Glazing G-Value	Glazing U-value	Wall U-value	Average of Lean b...	Lighting Controls	Chiller SEER

18. Understanding the Interaction between the BREEAM EPR and Lean Carbon Reductions?

BuroHappold data suggests that BREEAM planning targets could support an energy efficiency target in non-domestic buildings.

EPR and % Carbon reduction through Lean measures by % carbon saving



BREEAM (BRE Environmental Assessment Method) is a sustainability certification system for Non-residential buildings. The Energy Performance Ratio (EPR) is used to determine the number of BREEAM points a scheme can be awarded for energy use reduction for the ENE 01 credit. The separate calculation uses Part L results, identifying reductions from the actual building compared to the notional.

The calculation takes into account the heating/cooling demand, primary energy consumption and carbon dioxide emissions of the actual building compared with the notional. As a result of the inclusion of the heating and cooling demand directly into the calculation the EPR is heavily influenced by "lean" measures, such as improved building fabric.

This plot shows a very clear correlation between the EPR of a project and the % reduction in carbon it is achieving. It is shown that projects achieving a BREEAM excellent rating are meeting at least a 5% carbon reduction target through energy efficiency, and a BREEAM outstanding rating correlates to a 15% carbon reduction through lean measures. As shown on slide 15, this suggests that energy efficiency targets in the range of 5-15% fit well with current and future BREEAM requirements around London.

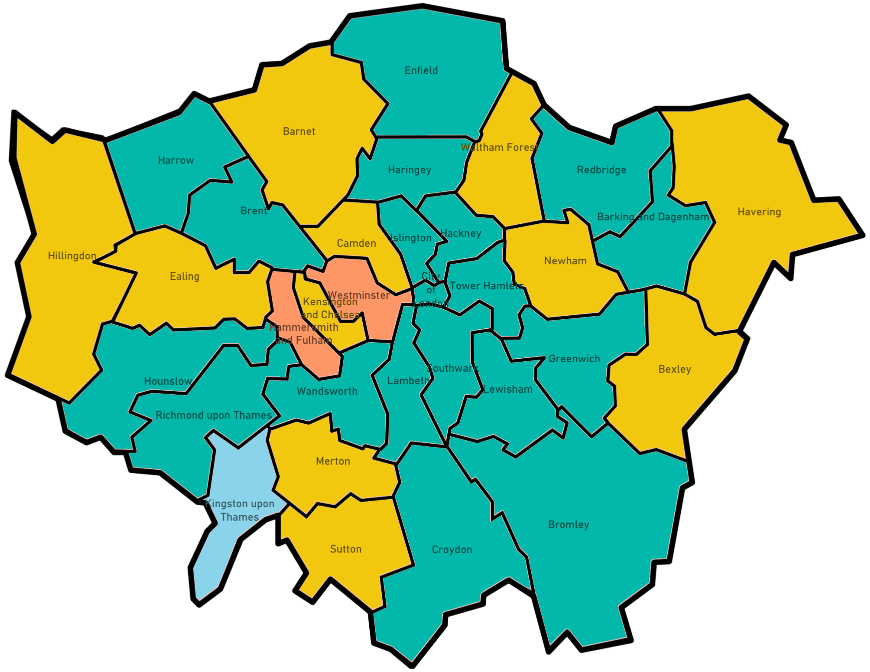
It is worth noting that although the BREEAM score is calculated based on the final carbon emissions and energy use of a project (including lean and green measures) the BRE are very strict in that it must be the as built model at the time of occupation - it is not permitted to include future district heat connections. The result of this is that it is not uncommon for schemes to meet their BREEAM target through lean measures alone.

18. How does BREEAM rating requirements vary by London Borough and by Development Zone, now and in 2019?

This slide provides a visualisation of how BREEAM targets are integrating into local planning across the different viability development zones

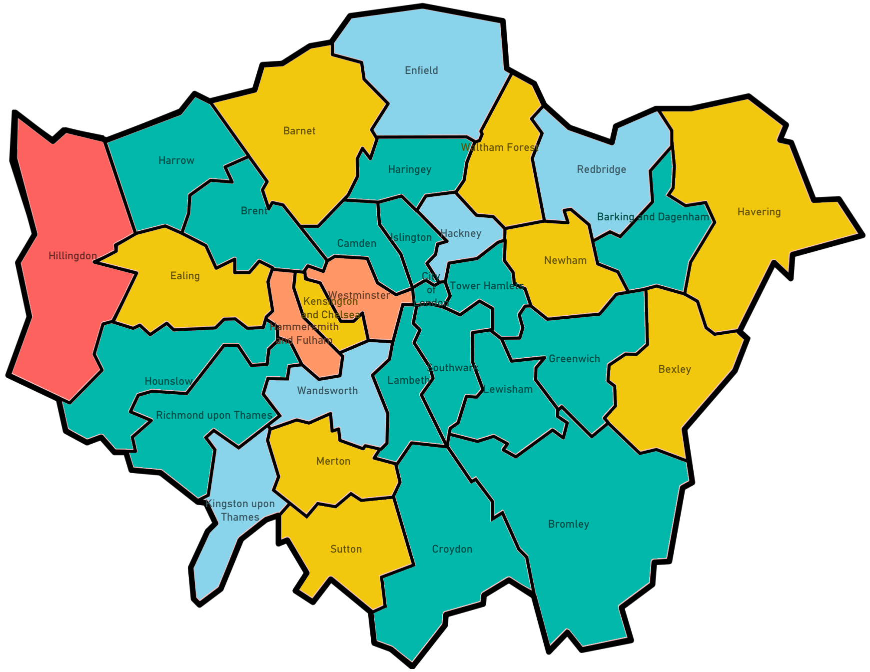
Current BREEAM requirement by London Borough from Local Authority Planning policy

Excellent · No Minimum · Outstanding · Very Good



Future BREEAM requirement by London Borough (2019) from Local Authority Planning policy

Excellent · No Minimum · Outstanding · Removed · Very Good



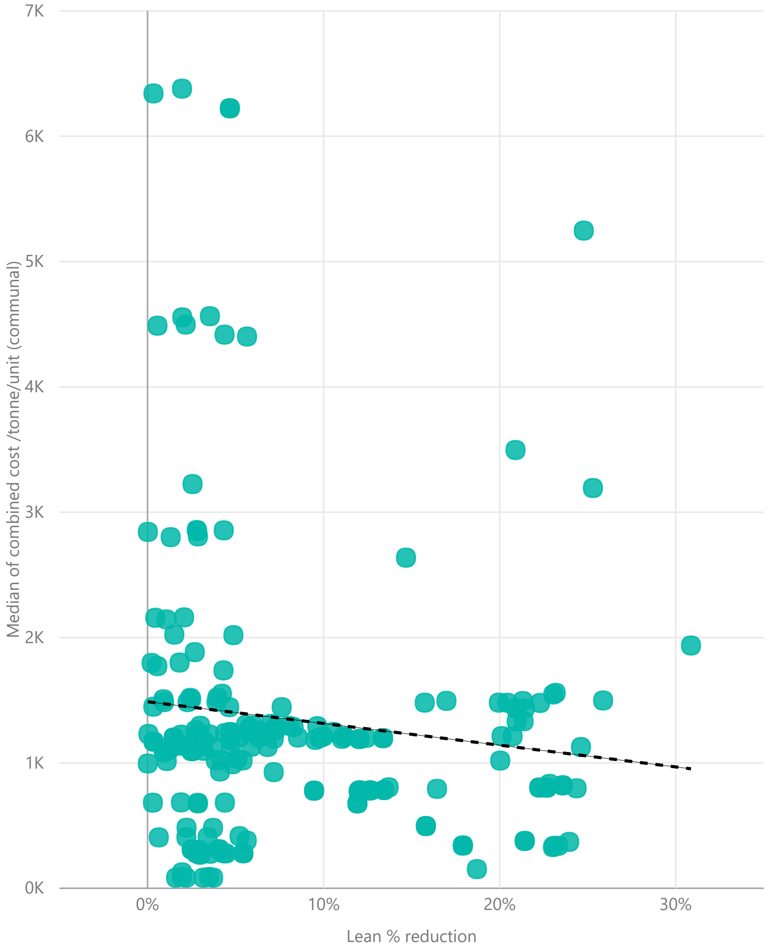
These maps show that the majority of London Boroughs already have a BREEAM target embedded in their local planning policy. The most common requirement is for developments to achieve an "Excellent" rating, with more areas moving towards "Outstanding" in future policy. Both "Excellent" and "Outstanding" ratings have an associated minimum requirement for energy performance. In the EPR calculation methodology energy efficiency has a significant impact on the score awarded (CO2 reduction and primary energy are also incorporated). This suggests that energy efficiency targets are already embedding in local planning policy.

There is a connection between location/viability development zone and local BREEAM requirements. Several of the central boroughs have no requirement or only require "Very Good". It is thought that this is likely linked to historical buildings/heritage areas. Viability zones B and C typically have the highest requirement, this is the result of freedom from heritage constraints in tandem with a relatively high land value. There is great variation in the policy in development zones D and E. In these zones building typology may allow for significant energy and carbon savings, however the land value is comparatively low.

20. Is the Cost of meeting Zero Carbon impacted by the level of Lean Savings achieved for residential developments?

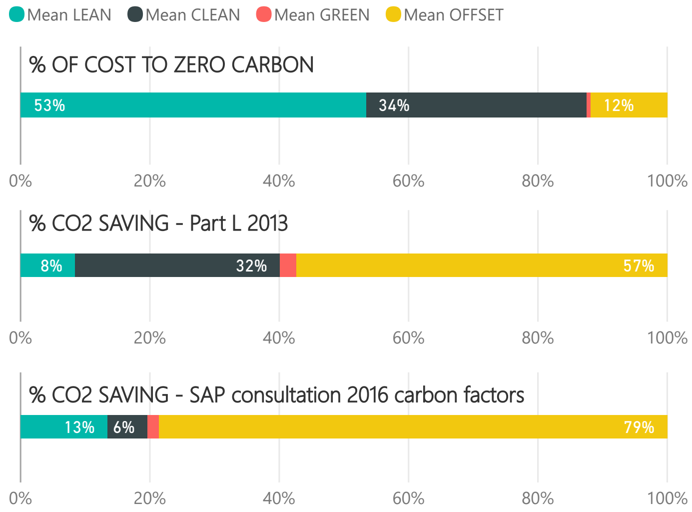
An investigation of the total capex associated with carbon emissions reduction as the % reduction from Lean measures varies

Lean % reduction and Median of combined cost /tonne/unit (communal heating system)



The scatter graph explores the relationship between the % carbon reduction through lean measures and the overall cost per tonne (normalised for development size) to meet net zero carbon.
The cost per tonne incorporates the uplift costs (over notional) for each level of the energy hierarchy plus offsetting. The graph shows a slight trend (a 0.003 probability that the gradient of the line is zero but the correlation of the data is low, R2=0.14.) The plot shows that increasing energy efficiency will not significantly increase the cost per tonne of CO2 of zero carbon for residential developments.See Appendix 6 for more information.

Proportion of CO2 saving and cost for each level of the hierarchy



The bar chart above show the proportion of costs for each level of the hierarchy as well as the mean % savings expected under Part L 2013 and the potential reduction in 2016. It shows that on average Lean cost account for 53% of overall cost of zero carbon and provides a mean 8% reduction on Part L 2013 and an equivalent mean 13% with a change to the carbon factors. Analysis shows that the savings from Clean in Part L 2013 show a 32% reduction and could drop to 6% with SAP consultation 2016 carbon factors. Communal heating is assumed for the Clean carbon reductions. Carbon factors of a low carbon heat source, either CHP or Haet Pump has been assumed as taken from the previous BuroHappold District Heating study. It also suggest that Lean will become more effective and cost effective at reducing carbon emissions in the short term.

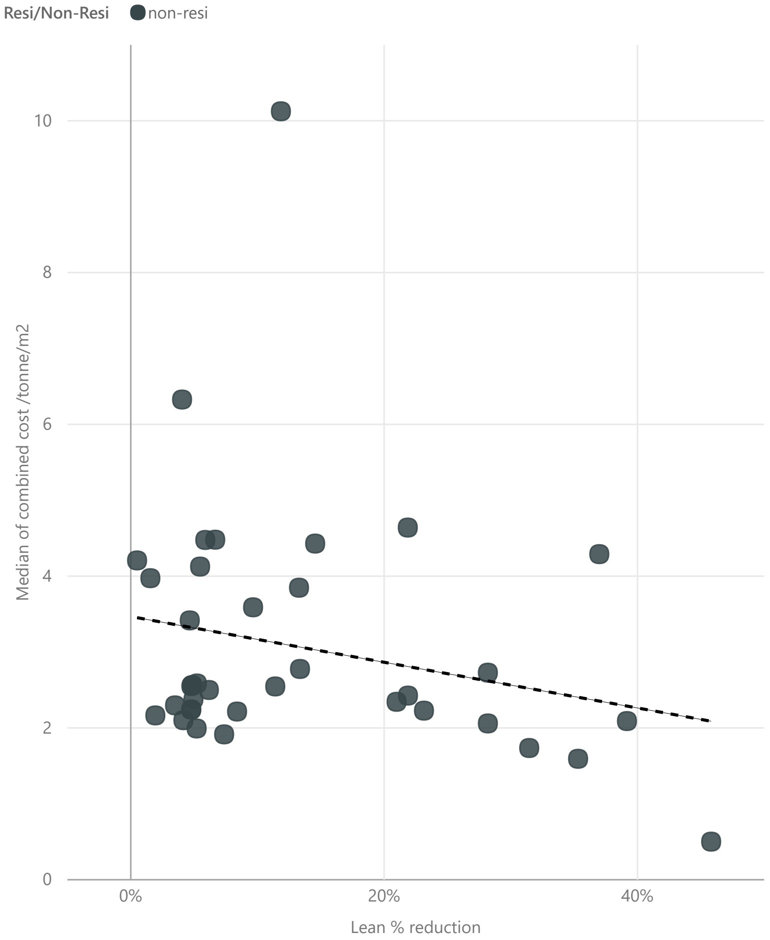
Additionally the significant cost uplift over notional, 53%, is associated with meeting Building Regulations with typical, London building typologies and architecture (i.e. that a significant proportion of the cost apparently associated with energy efficiency is actually required just to meet regulations and is therefore not associated with any saving over notional carbon emissions).

An assumed 7% flat reduction over baseline from Part L 2013 to 2016 baseline, 2016 baseline emits 93% of the carbon emissions of the 2013 Baseline. This is based on the previous BuroHappold study for the GLA and used a typical residential block. It is appreciated that the % reduction by development may vary by development, however this is considered a suitable proxy to provide an indicative impact with future regulations.

21. Is the Cost of meeting Zero Carbon impacted by the level of Lean Savings achieved in Non-residential developments?

An investigation of the total capex associated with carbon emissions reduction as the % reduction from Lean measures varies

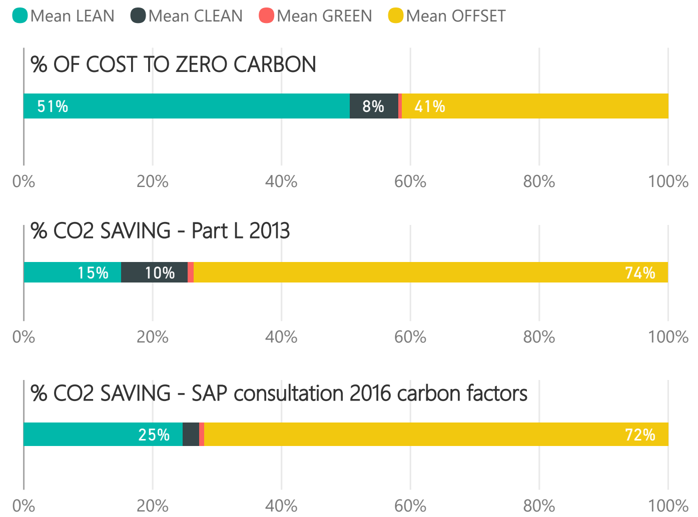
Lean % reduction and Median of combined cost /tonne/unit (communal heating system)



The scatter graph for non-residential costs and carbon savings shows less of a trend than the residential data. (There is a 0.13 probability that the gradient of the line is zero and there is very little correlation R2=0.01.) The plot suggests that other factors have a great effect on the cost of carbon savings.

This would suggest that increasing Lean reduction will not significantly increase the cost per tonne of CO_2 of zero carbon for residential developments. See Appendix 6 for more information.

Proportion of CO2 saving and cost for each level of the hierarchy



The bar chart above show the proportion of costs for each level of the hierarchy as well as the mean % savings expected under Part L 2013 and the potential reduction in 2016. It shows that on average Lean cost account for 51% of overall cost of zero carbon and provides a mean 15% reduction on Part L 2013 and an equivalent mean 25% with a change to the carbon factors.

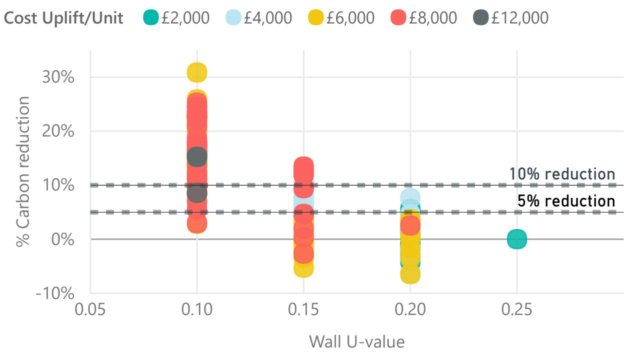
This is because total electricity emissions reducing due to lower carbon factor of the grid. Heat emissions generated by fossil fuels are increasing due to distribution losses. However the total % reduction is increasing because the reduction in electricity out weights the increase from heat emissions. This would suggest that Lean reduction are would be come easier to achieve and more cost effective compared to other measures in the hierarchy.

An assumed 20% flat reduction over baseline from Part L 2013 to 2016 baseline, 2016 baseline emits 80% of the carbon emissions of the 2013 Baseline. This is based on the previous BuroHappold study for the GLA and used a mixed use development with office, retail, leisure and community uses. It is appreciated that the % reduction by development may vary by development, however this is considered a suitable proxy to provide an indicative impact with future regulations.

22. How does the performance of building elements affect Lean % carbon reduction in Residential buildings in the BuroHappold models?

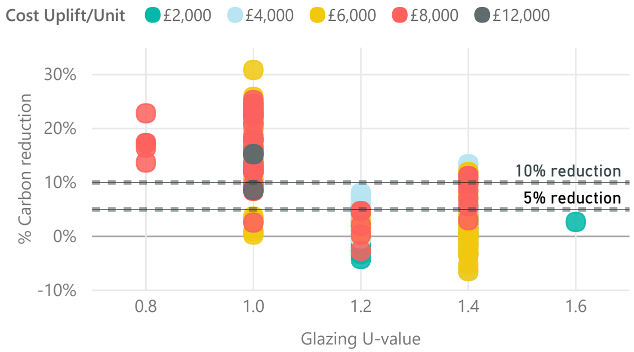
The graphs below show how total Lean carbon reductions correlate with the different buildings' fabric and services specifications and how these affect the cost uplift. The database includes both actual buildings submitted for planning and push modelling cases. Each point represents a modelling run, which can represent the same building with differing specifications. Savings are shown over Notional/GLA baseline.

Lean % reduction against Wall U-value shown by Cost uplift bands



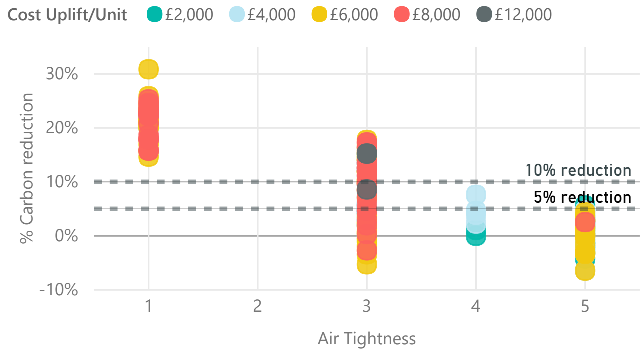
U-values of 0.2 and above are generally not sufficient to achieve a 5% reduction in carbon. 10% reductions are achieved with U-values of 0.1 and below.

Lean % reduction against Glazing U-value shown by Cost uplift bands



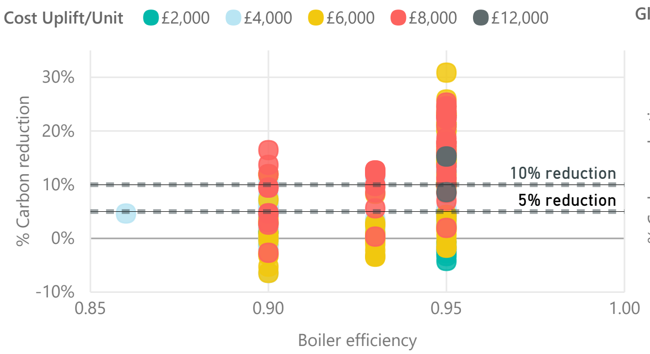
A 5% carbon target does not necessarily require triple glazing on all buildings and can be achieved with higher windows U-values. In order to achieve 10%, however, triple glazing was needed in the majority of models.

Lean % reduction against Air Tightness shown by Cost uplift bands



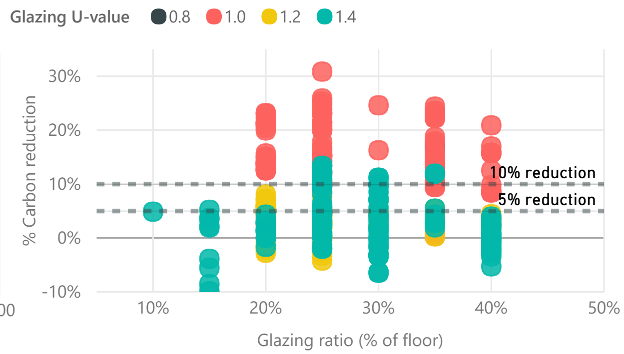
Air permeability of 3 m3/m2 and below will generally be needed to achieve a target of 5% or 10% carbon reduction. MVHR is used in most units, regardless of the air tightness. It does not conclude that MVHR is 'needed' to meet the target however it is expected that MEV or MVHR will be required in most London apartments due to density, moving away from natural ventilation.

Lean % reduction against Boiler efficiency shown by Cost uplift bands



5% and 10% carbon reduction is achieved with a range of boiler efficiency above 90%.

Glazing ratio and % Carbon reduction by Glazing U-value



For glazing ratio >30% triple glazing is needed in the majority of developments to achieve 10% carbon reduction.

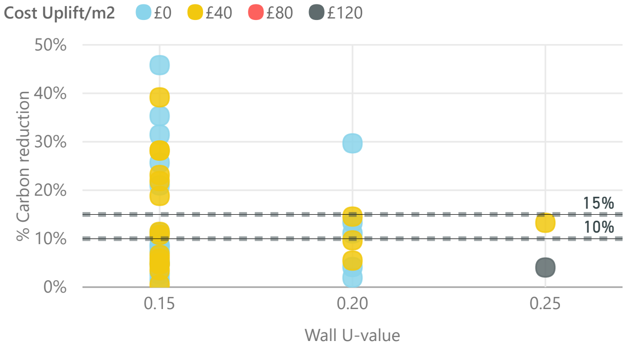
Residential buildings are heating-led. For this reason, in general, a correlation can be observed between carbon reduction and the specified fabric and services. In particular, a strong correlation is observed with wall and window U-values, air tightness and boiler efficiency. Conversely, little to no correlation is found, with glazing ratios. Thermal bridging coefficient was reviewed and the targets can be met by using Y=0.15, Default and improved detailing.

From BuroHappold modelling it can be seen that a range and combination of measures, including wall U-values of 0.1-0.15, high performance glazing (U-values of 0.8 -1.4), air tightness of 3 and below and 90-95% boiler efficiency, can achieve a Lean carbon saving of 10% and above. This modelling sample is not exhaustive and a further detailed study will be required to evidence how standard building types can achieve a 5% and 10% or higher reductions.

23. How does the performance of building elements affect Lean % carbon reduction in Non-Residential buildings in the BuroHappold database?

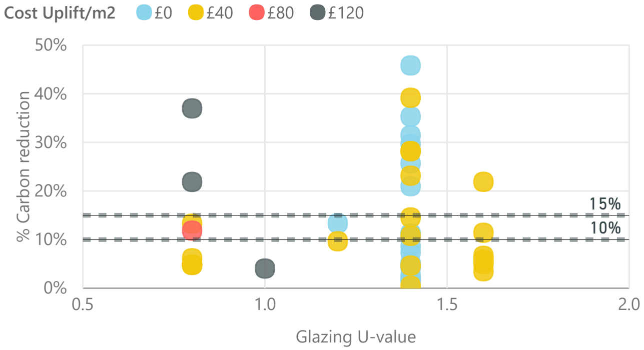
The graphs below show how total Lean carbon reductions correlate with the different fabric and services specifications and how these affect the cost uplift. Each point represents a modelling run from the BuroHappold dataset and shows savings over Notional/GLA baseline.

Lean % reduction against Wall U-value shown by Cost uplift bands



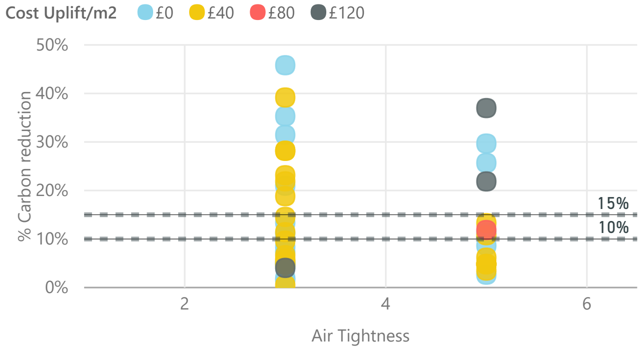
A 10% or 15% reduction can be achievable with a range of Wall U-values

Lean % reduction against Glazing U-value shown by Cost uplift bands



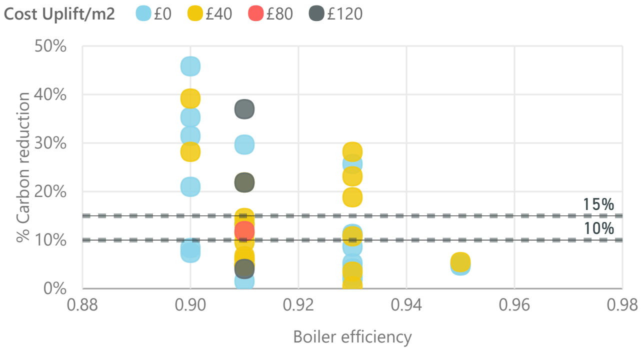
10% or 15% reductions can be achieved with a range of windows U-values and specifying triple glazing is not required

Lean% reduction against Air Tightness shown by Cost uplift bands



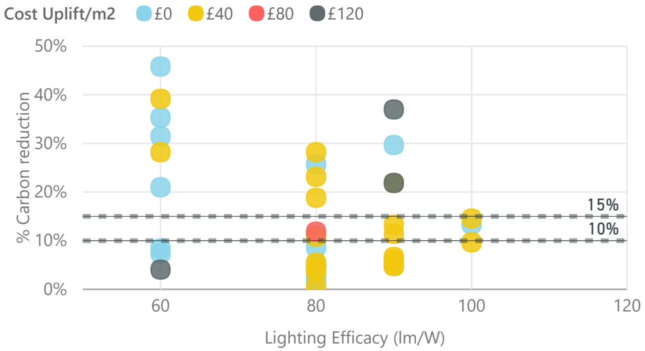
A 10% pr 15% reduction is achievable with a range of air tightness values

Lean % reduction against Boiler Efficiency shown by Cost uplift bands



A 10% or 15% reduction is achievable with a range of boiler efficiencies

Lean % reduction against Lighting efficacy shown by Cost uplift bands



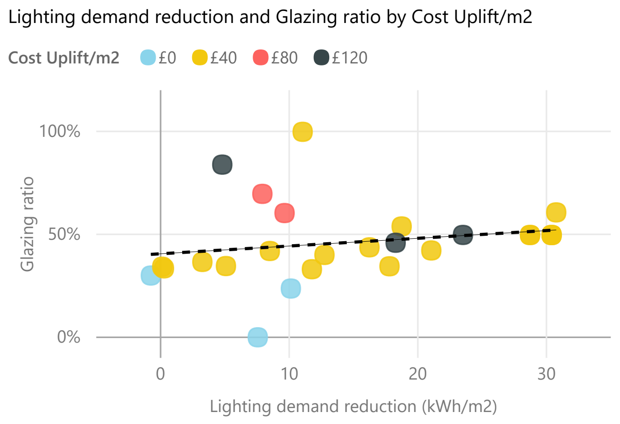
A 10% or 15% reduction is achievable with a range of lighting efficacy

Carbon reduction does not show a strong correlation with any of the fabric and services improvement measures taken individually. In addition to the charts shown, carbon reductions were not found to correlate with either chiller efficiency or the use of lighting controls. Different HVAC systems; Natural Ventilation, MVHR and Air Handling Units, have been tested rather than different system efficiencies as variation in HVAC efficiencies is not enough to show a correlation.

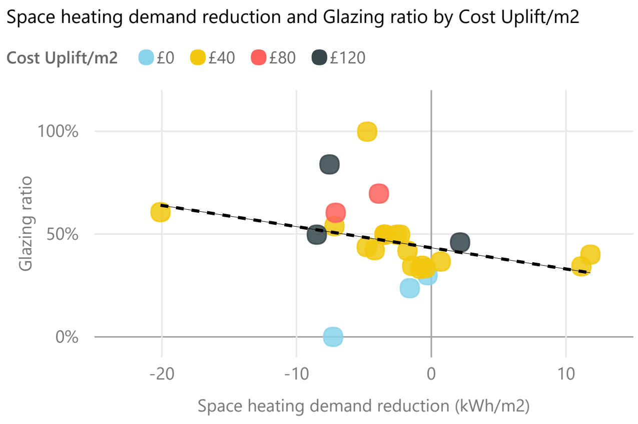
It can be inferred that none of the parameters analysed alone precludes achieving a 10% or 15% carbon reduction. However, given the small sample there is a risk that some untested combinations of space type and architectural design may not be able to achieve these savings due to site specific constraints.. A further detailed study will be required to evidence how standard building types can achieve a 10%, 15% or higher reductions.

24. How does the building's glazing ratio affect energy demand and Lean % carbon reduction in Non-Residential developments in the BuroHappold database?

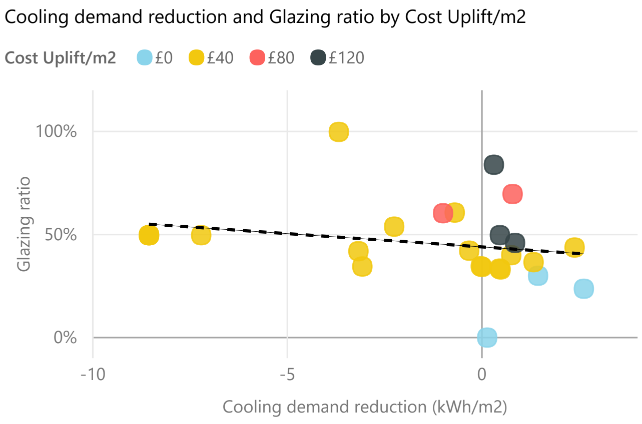
No strong correlation is found between carbon and fabric and services specifications, suggesting that the building shape and design may have a bigger impact on its performance. The graphs below show how energy demand and carbon savings correlate with the buildings' glazing ratio. Each point represents a modelling run from the BuroHappold dataset and shows savings over Notional/GLA baseline.



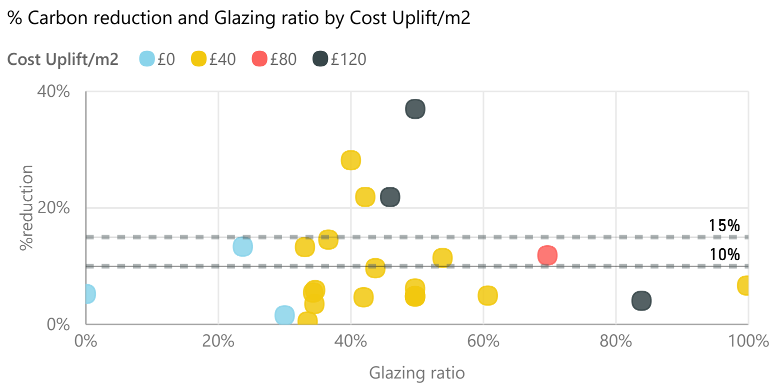
Lighting reductions increase with glazing ratio.



Space heating demand increases as glazing ratio increases.



Cooling demand increases as the glazing ratio increases.



Extremes of glazing ratio fail to achieve maximum carbon savings.

High glazing ratios entail low lighting consumption but high space heating and cooling, while the opposite is true for low glazing ratios. As these effect are counterbalancing, little correlation can be seen between glazing ratios are necessary to achieve the highest lean % carbon savings

25. What are the energy demand savings corresponding to the buildings' carbon reductions in BuroHappold projects?

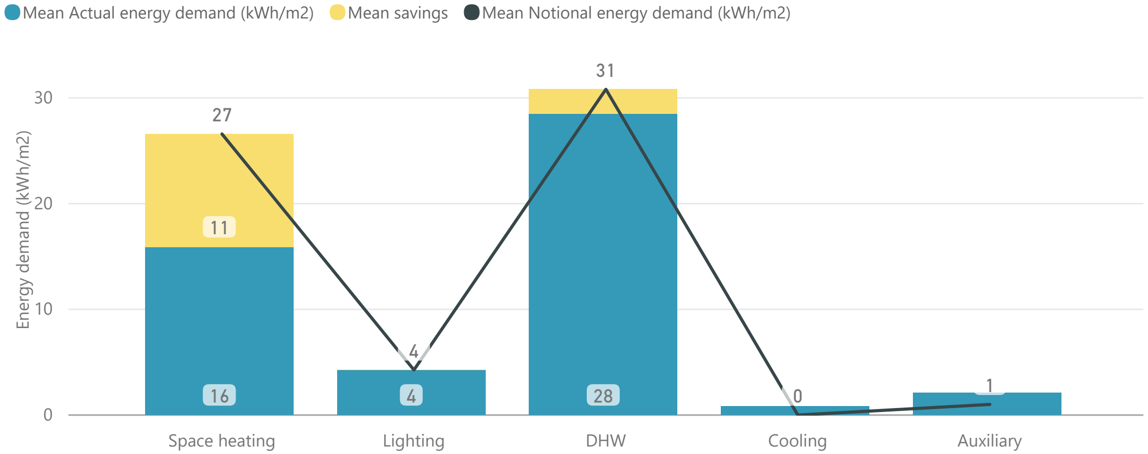
The graph shows the energy demand breakdown for the actual and notional buildings in the selected projects, as well as the corresponding energy savings.

It can be observed that the key energy demand reductions in residential buildings occur in space heating and domestic hot water end-use consumption. In non-residential buildings, space heating and lighting are the main drivers for energy demand reduction.

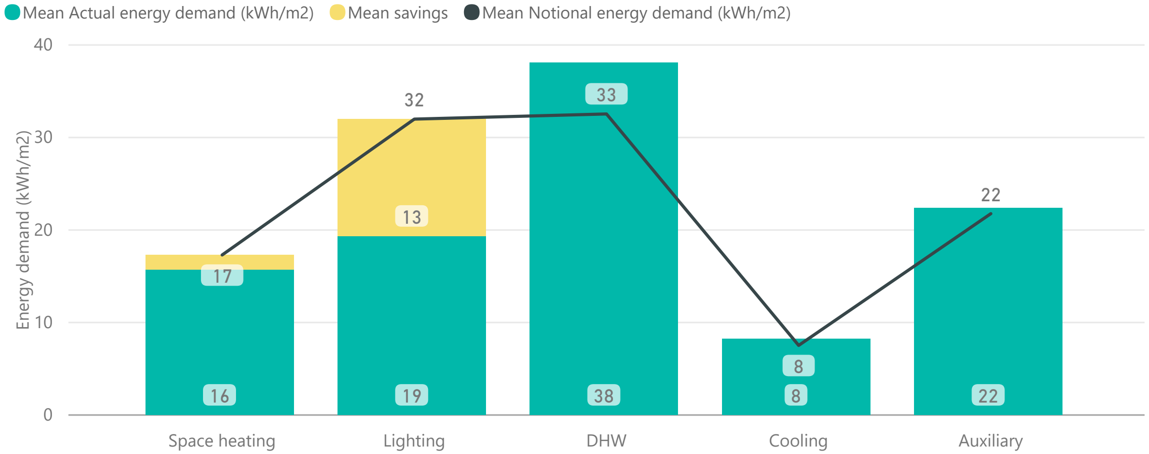
% Carbon reduction 7.82%
Total energy demand (kWh/m2) 10.31
Total heat demand (kWh/m2) 44.39
Heating and Cooling demand (kWh/m2) 16.74
Electricity demand (kWh/m2) 6.34

% Carbon reduction 12.90%
Total energy demand (kWh/m2) 20.76
Total heat demand (kWh/m2) 53.84
Heating and Cooling demand (kWh/m2) 23.95
Electricity demand (kWh/m2) 41.73

Energy demand breakdown in actual and notional Residential models



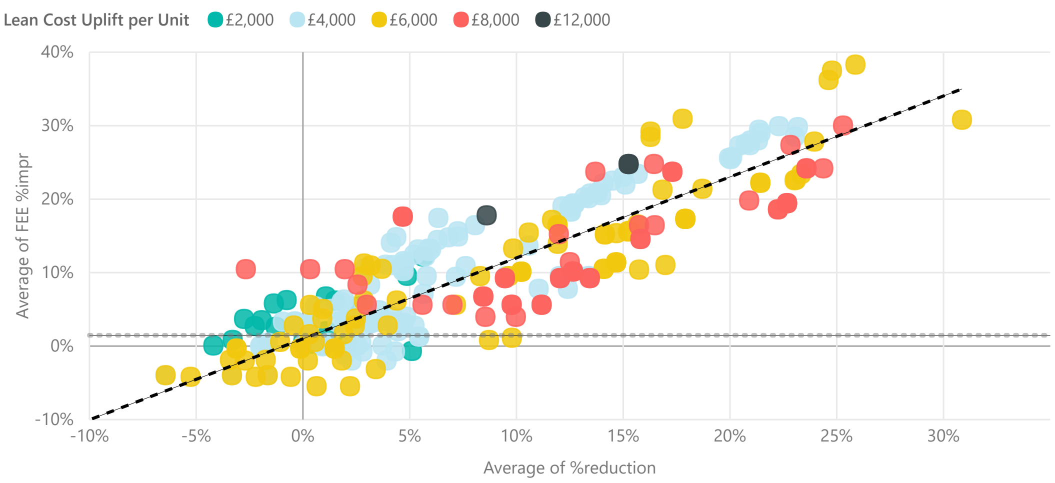
Energy demand breakdown in actual and notional Non-residential models



26. How does the Dwelling Fabric Energy Efficiency (FEE) rating vary by the Lean % reduction?

The Fabric Energy Efficiency (FEE) is another requirement for Residential dwellings to achieve in line with Building Regulations Part L1A. The FEE is another metric, other than % carbon reduction that can be used judge the performance. The BuroHappold Residential model results show which of these is the driver for compliance and the trends of FEE with glazing ratio.

Lean % reduction against FEE %improvement shown by Cost uplift bands



Little correlation is shown with cost uplift and FEE improvement. This is due to cost uplift being driven by three, main parameters, boiler efficiency, Ventilation type and glazing performance, of which glazing is the only factor that impacts FEE performance.

The Glazing ratio against FEE % improvement graph, that as glazing ratio increases lower FEE % improvements are generally achieved. It also shows that as the glazing ratio increases typically the window specification will also need to improve to meet the FEE target.

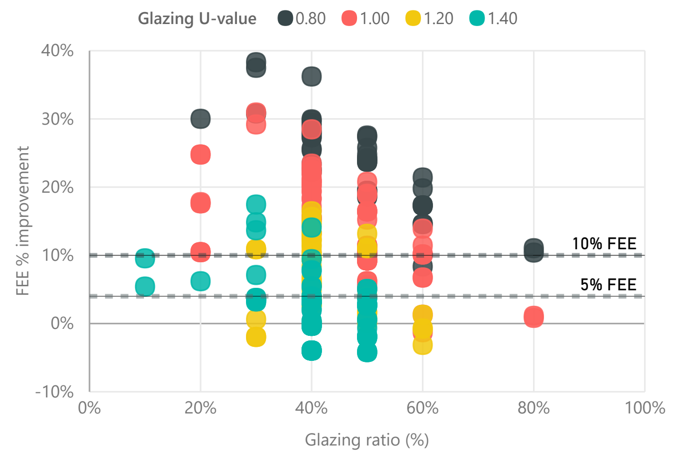
A 10% FEE reduction shows that a push towards triple glazing will be required with glazing ratios over 50%. This suggests that a 10% reduction can be achieved with double if lower reduced glazing ratios are implemented, 30-50%.

The graphs above shows a positive trend and strong correlation in both data sets. As the % reduction is increased as is the FEE performance. The table shows that when the LEAN % reduction is 0.0% the average FEE improvement is 1.62%. This suggests that the carbon reduction metric is on average driving residential developments to meet Building Regulations Part L Criterion 1.

This graph additionally is shown against the cost uplift in bands of £2000. The correlation is not strong with the costing bands, which spanning all performance levels. This is because the FEE calculation does not take into consideration active systems; only considering heating cooling demands with impact from passive fabric only. Boiler, ventilation and lighting efficiencies do not impact this metric. Therefore for these two reasons it is proposed that % Lean carbon reduction is used as the appropriate metric for any policy.

LEAN % reduction	Median FEE % reduction
-2.00 %	0.47 %
-1.00 %	3.06 %
0.00 %	1.62 %
1.00 %	3.25 %
2.00 %	3.36 %
3.00 %	3.32 %
4.00 %	6.20 %
5.00 %	10.85 %
6.00 %	14.63 %
7.00 %	10.17 %
8.00 %	6.75 %
9.00 %	9.26 %
10.00 %	10.13 %

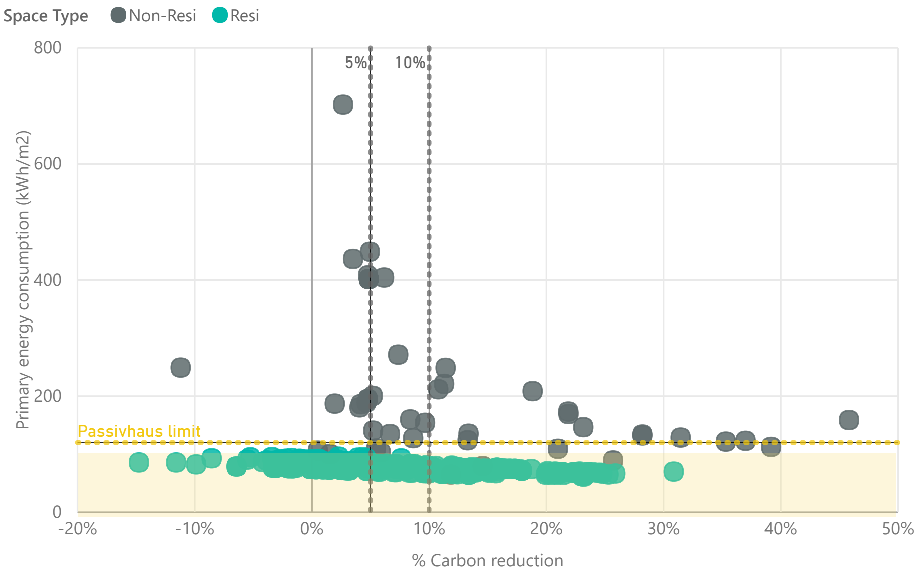
Glazing ratio against FEE % reduction



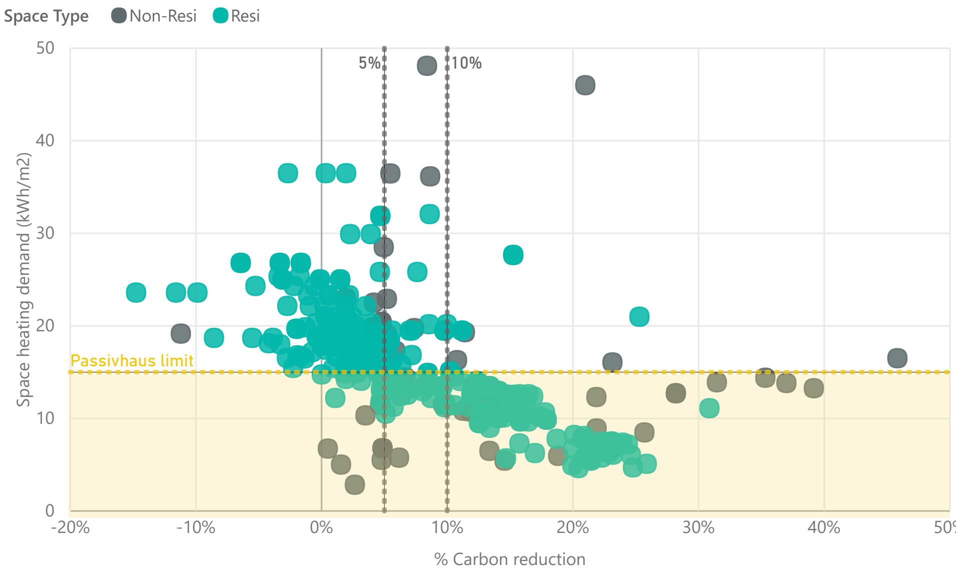
27. How do carbon reduction targets correlate with Passivhaus requirements?

Two key requirements for Passivhaus certification are a maximum primary energy consumption of 120 kWh/m2/year and a maximum space heating demand of 15 kWh/m2/year (for both residential and non-residential buildings). The BuroHappold models show that as Lean % reduction reduces developments will expect to be close to Passivhaus house levels.

% Carbon reduction and Primary energy consumption (kWh/m2) by Resi and Non-Resi



% Carbon reduction and Space heating demand (kWh/m2) by Resi and Non-Resi



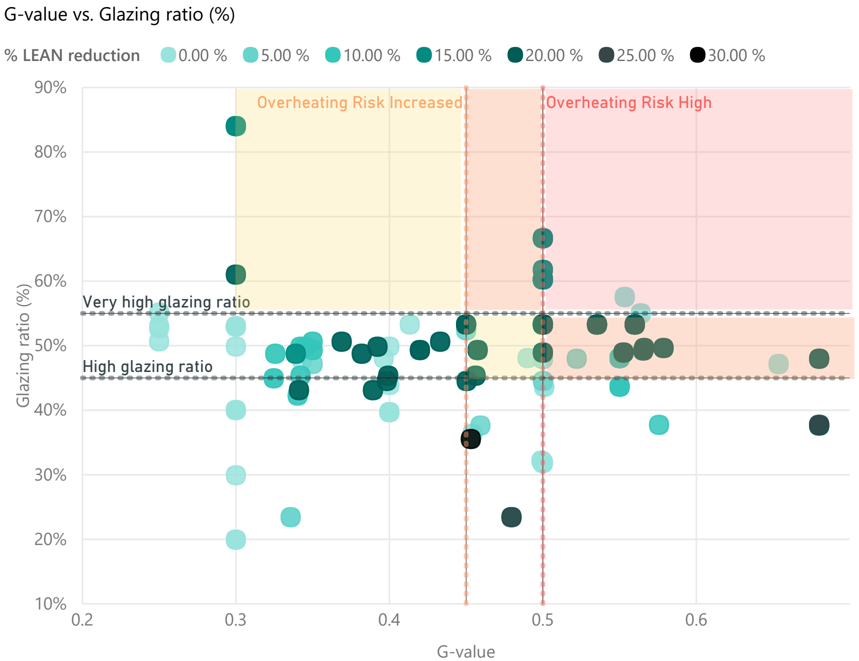
The BuroHappold analysis shows that all residential models are achieving levels of primary energy consumption below the required 120 kWh/m2 required by Passivhaus. This suggests that apartments are of an inherently lower energy density than Passivhaus would normally assess as standard. In general, for both residential and non-residential buildings, the Passivhaus primary energy requirement can be achievable with a wide range of % Lean carbon reductions.

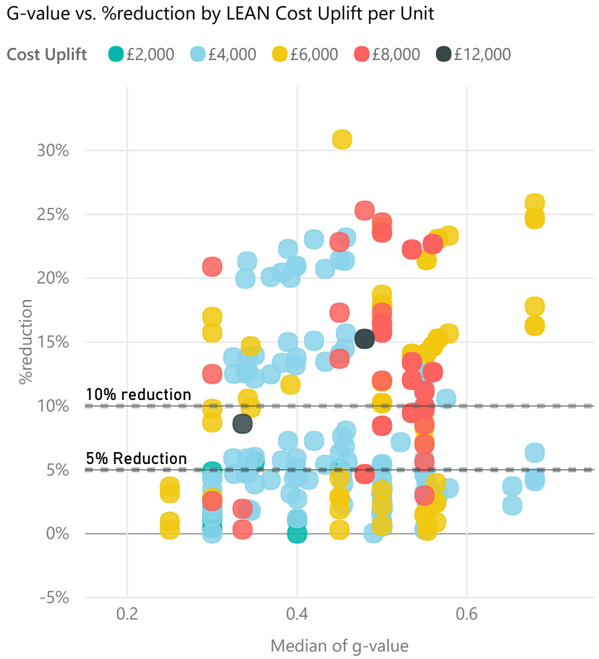
A negative strong correlation is observed between space heating demand and carbon reduction, in residential buildings. At a 5% and below, few models achieve the requirement, and beyond 10% the majority of models achieve the heating threshold. This infers that to achieve the Passivhaus standard, carbon savings of the order of 10% or above are required. However this is shown using the outputs from Standard Assessment Procedure (SAP) assessments, which is not a Passivhaus certified tool and is not representative of actual certification.

Passivehaus is considered a well-rounded design approach to building performance, focusing on in operation performance. However it can be challenging to apply all the design principles in multi dwelling building or varying orientations. Additionally different software, from Part L compliance, is required to design for Passivhaus Certification. This would therefore change the modelling approach away from Part L or add an additional modelling for planning application referred to the GLA.

28. Could a Lean policy have a knock on impact in increasing residential overheating risk?

Increasing the G-value of windows can help meet Part L compliance, increasing winter solar gains and reducing winter heating demands. However this can have a secondary knock-on impact to summer overheating. The graphs shows the impact of G-value on Lean performance on BuroHappold models and indicative overheating risk zones, based on BuroHappold experience.





The graphs show a Positive correlation between increased G-value of glass and the % Lean reduction, which may lead to projects increasing G-value as a low cost measure to improve winter and SAP energy performance.

Analysis shows that a wide range G-value can achieve a Lean 5% or 10% reduction target, therefore it is deemed that this target can be achieved without compromising occupant thermal comfort.

However, at a 10% lean reduction G-value may be raised to increase winter solar gains. External shading or exposed thermal mass could be implemented to limit solar gains and manage internal temperatures. This would be expected to have limited negative impact on SAP energy performance, however has not been fully tested.

Overheating is strongly linked to solar gain, influenced by the G-value and glazing ratio. From BuroHappold experience it has been found that a G-value of 0.4 and above will increase risk and over 0.5 a high risk is likely unless solar shading or high thermal mass to manage solar gains are used.

A glazing ratio of 40% is generally considered typical by architects and a glazing ratio higher than this could be considered high or atypical. It would be expected that at these glazing ratios overheating risk would also be increased. BuroHappold projects have looked to manage high solar gains with reduced G-values with low G-values (0.3-0.4).

Matrix showing % Lean reduction by glazing ratio and G-vlaue

Glazing ratio	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.65	Total
10.00 %		3.78 %							**3.78 %**
20.00 %		1.74 %			15.25 %				**4.68 %**
30.00 %				1.20 %	4.28 %	2.84 %	10.56 %	17.03 %	**4.14 %**
40.00 %		5.89 %	13.19 %	7.27 %	14.29 %	2.54 %	9.53 %	4.12 %	**7.27 %**
50.00 %	2.06 %	2.82 %	12.15 %	9.43 %	4.39 %	14.09 %	12.65 %		**12.04 %**
60.00 %		12.50 %				9.34 %			**10.23 %**
80.00 %		6.56 %							**6.56 %**
Total	**2.06 %**	**4.73 %**	**12.32 %**	**4.92 %**	**6.56 %**	**10.23 %**	**9.71 %**	**16.28 %**	**8.18 %**

29. How does cost uplift correlate with % Lean carbon reduction?

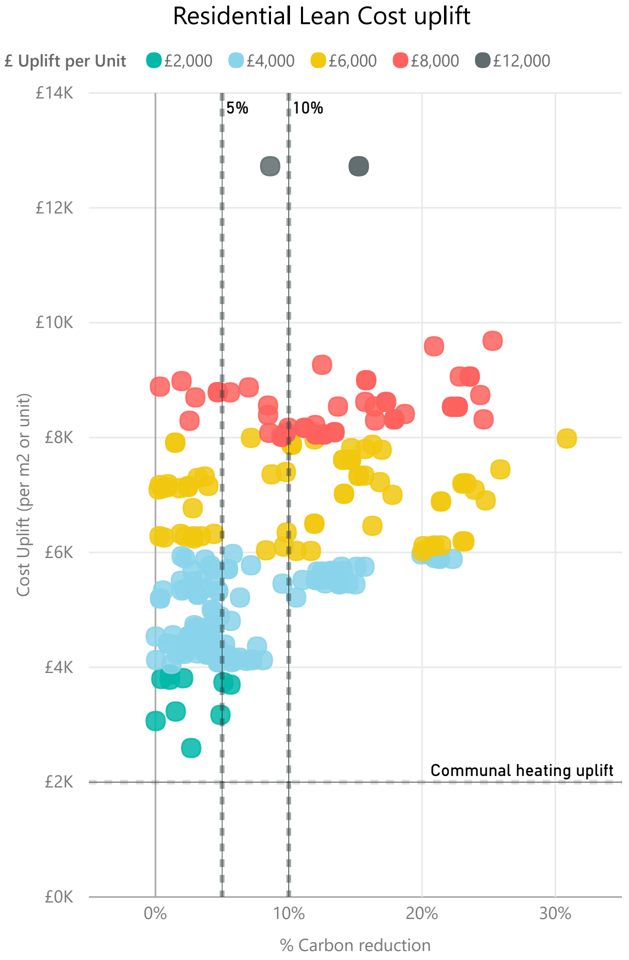
The cost uplift of Lean measures, over Building Regulations Part L 2013, is shown for BuroHappold Residential and Non-residential models. Its shows that there is a weak positive correlation for the residential cost uplift however shows little to no correlation for non-residential models. Costs are shown by unit for residential and by m2 of Gross Internal Area for Non-residential.

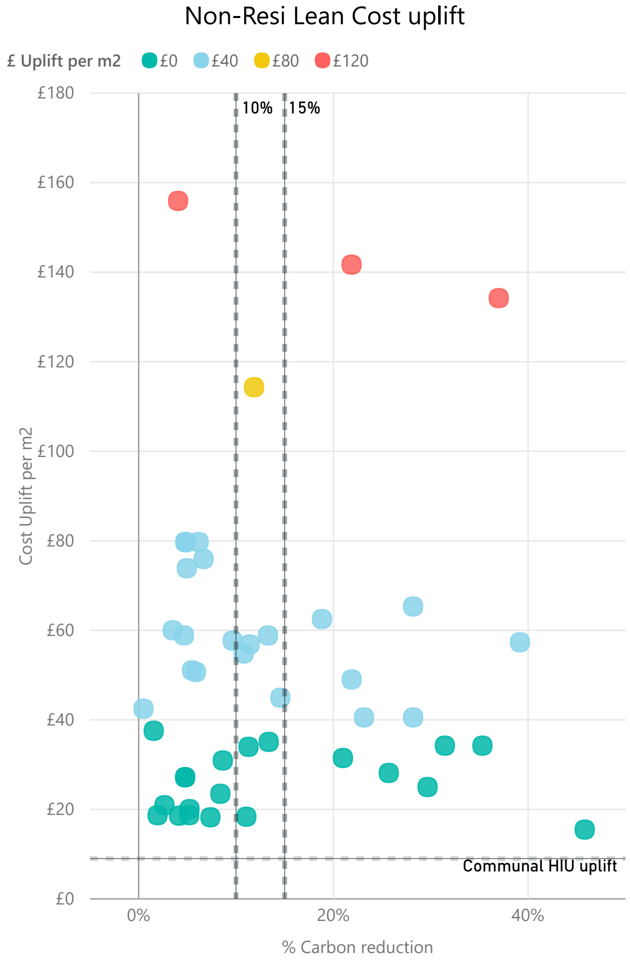
The graphs show how the achieved % lean carbon reduction affects cost uplift (compared to the notional building).

In residential buildings, there is a small correlation between carbon reduction and cost (R2=0.25 and the probability that the gradient is equal to zero is 0.001). Carbon reductions greater than 5% are only achieved for cost uplift greater than £4000 per unit. Increasing this to 6000-£9000 per unit, achieves reductions up to 25%.

The BuroHappold Lean residential models all include communal heating within the cost analysis. The cost uplift associated with dwelling distribution, HIU, communal pipework distribution and central plant over the notional individual boiler is on average £2,000. The nominal uplift of all units is shown to be no less than £2,500 per unit and the communal heating system could be assumed to make up the majority of this. A jump in minimum cost uplift is observed at 5% and 10% reduction. At 5% the minimum specification cost uplift of £4,100 is observed and this again to jumps to £5,200 at 10% reduction and above.

The BuroHappold non-residential modelling, however, shows no correlation (R2=0) between carbon reduction and cost uplift is observed. This suggests that, carbon savings in non-residential buildings are driven by a combination of services specification as well as space type and architectural design. The non-residential modelling assumes a communal heating system in both notional and actual building however, the additon of a HIU in each unit has been considered to allow for connection to a site wide heat network. This contributes on average a £9 per m2 uplift in cost.





30. What are the key elements driving cost uplift?

Cost uplifts by element have been calculated from BuroHappold models. Elements have been costed for the notional buildings and the actual buildings in each model based on the area, number, and performance. Uplifts have been produced based upon the difference between the actual and notional cost by element. Capital cost information for the developer has been provided by Currie & Brown for each element. Operational or maintenance costing has not been considered within these uplifts.

The biggest contributors to cost uplift in the analysed residential developments (compared to notional) are boilers (communal heating systems), ventilation and windows. In fact, higher efficiency boilers are specified in most units (compared to notional) and most units are provided with MVHR systems. All buildings will have either the same or higher glazing ratios compared to notional, as the notional dwelling will match actual up to 25% of floor area. The increased glazing ratio also determines the negative wall cost uplift; however, due to the improved U-values, this results in a net positive facade cost uplift.

Regarding non-residential developments, the analysis shows that the main driver of cost uplift compared to notional are boiler, lighting and windows costs. The cost of lighting takes into account the improvement on lighting efficacy compared to the notional building and the provision of lighting controls.

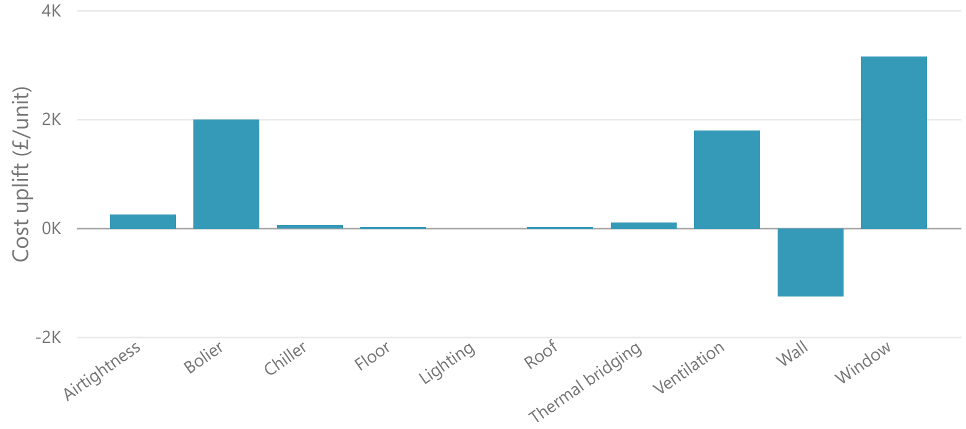
Averaged Residential cost uplift breakdwon per Unit (£/unit)

£259 Airtightness	£2,002 Bolier	£63 Chiller	£11 Floor	£0 Lighting
£5 Roof	£112 Thermal bridging	£1,800.00 Ventilation	-£1,243 Net Wall	£3,162 Window

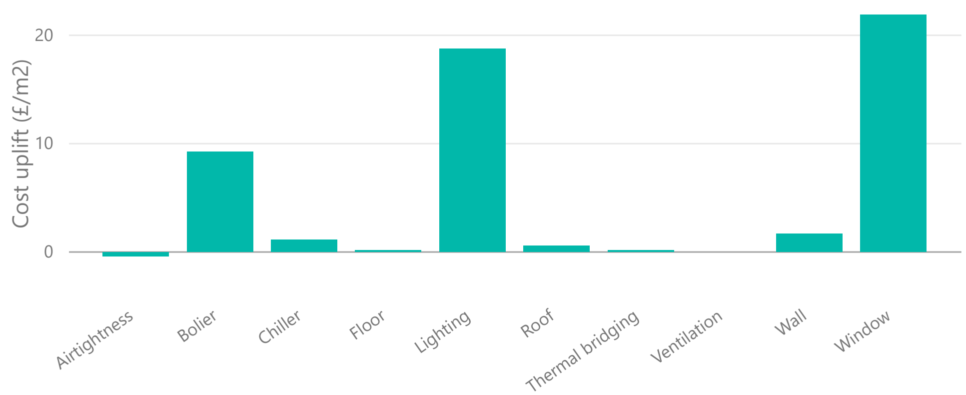
Averaged Non-Residential cost uplift breakdwon per Unit (£/sqm of GIA)

-£0 Airtightness	£9 Bolier	£1 Chiller	£0 Floor	£19 Lighting
£1 Roof	£0 Thermal bridging	£0.00 Ventilation	£2 Net Wall	£22 Window

Residential cost uplift by cost element



Non-Residential cost uplift by cost element



31. What is the expected Cost uplift for a new Lean target policy?·

The Cost uplift expected for varying levels of energy efficiency reduction based on the BuroHappold models and Currie & Brown cost data, are outlined in this slide. These costs will be used for the viability assessment of a new Energy efficiency policy, depending upon the level chosen to be taken forward.

The cost uplifts have been outlined compared to the Building Regulations Part L Notional building, however this may not be considered typical or appropriate as a London Counterfactual case. The London Counterfactual could be considered current London new build performance, received by the GLA under the current London Plan.

Current London median shows is shown on the cost uplift tables. This indicates which performance region the median Resi or Non-Resi development sits within. This is the point where 50% of the current applications currently meet. A hard or soft policy of this region would expect to influence the majority (over 50%) of developments in the future. London median Resi 0%-4.9% region and 10%-19.9% region Non-resi. This is without an energy efficiency policy, under the current London Plan. Therefore the viability consultant should choose whether to use the full cost uplift or difference between this figure and the cost of a chosen policy. Ranges have been provided based on upper, lower quartile of data sets as well as median cost, this outlines spread of datasets and a cost figures that can be chosen by the viability consultant.

Analysis suggests, a cost uplift is always present over notional for residential, min. £2,594, and a lower quartile of £15 per sqm for non-residential. This is due to mechanical ventilation and communal heating systems. The notional dwelling is based on a 'typical' UK home with individual boiler and is naturally ventilated.

Range of residential cost uplifts over notional (£/unit) for varying Lean % carbon reduction targets

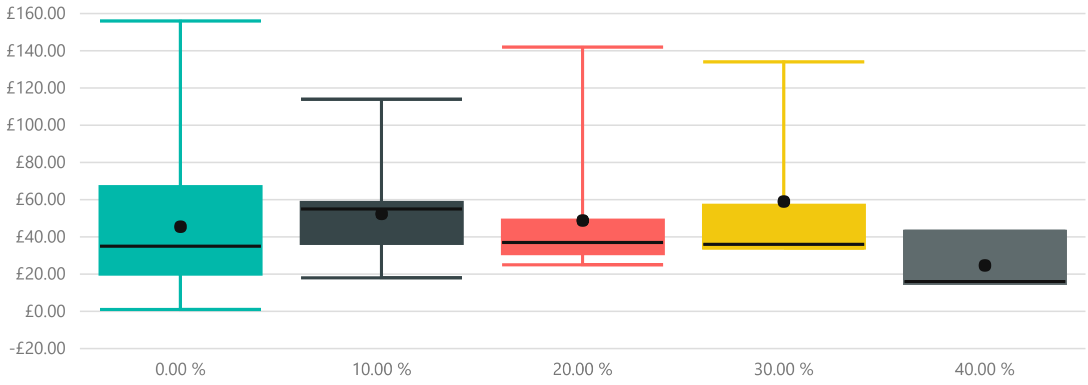
LEAN % reduction Target	Notional	0%-4.9% (Current London Median in this region 3.7%)	5%-9.9%	10%-14.9%	15%-19.9%
Upper Quartile	£0	£6,300	£8,010	£7,920	£8,560
Median		£5,000	£5,710	£6500	£7,870
Lower Quartile		£4,350	£4,130	£5,550	£7,330

Range of non-residential cost uplifts over notional (£/m²) for varying Lean % carbon reduction targets

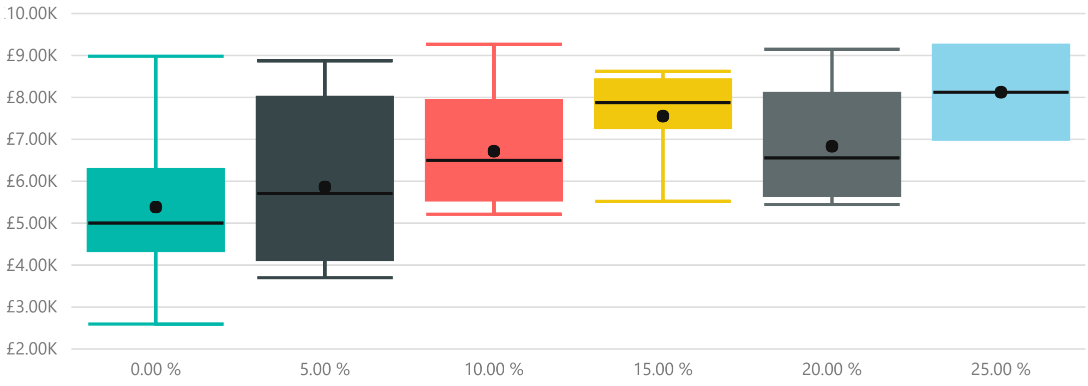
LEAN % reduction Target	Notional	0%-9.9%	10%-19.9% (Current London Median in this region, 15.1%)	20%-29.9%	30%-39.9%
Upper Quartile	£0	£64	£59	£47	£57
Median		£35	£55	£37	£36
Lower Quartile		£20	£37	£32	£34

Box = Upper and lower quartile
Line = Median
Dot = Mean
Top and bottom line = Min/Max

£ Uplift for % Lean Improvement by Non-Residential (£/sqm)



£ Uplift for % Lean Improvement by Residential (£/Unit) (with outliers removed)



32. What is the typical Residential and Non-Residential Specification to meet the varying performance levels?

The following Median and Mean specifications for Residential and Non-Residential developments have been outlined from the BuroHappold models as indicative ways to achieve varying levels of % reduction improvement. Not all routes to the level of reduction are outlined. The Median and Mean of the models has been shown to outline the pattern of specification. Median is shown to outline specific example developments. Mean has been used to show the nuisance of the variation of models within a region of performance. Improvement could be gained by balancing areas of performance against each other.

Median Residential specification by models in each % reduction range

% LEAN reduction ▲	Wall U-value (W/m2.K)	Glazing U-value (W/m2.K)	Air Tightness (m3/m2)	Boiler efficiency (%)	Glazing g-value	Glazing ratio (% of external)	Lighting Efficacy (lm/Watt)	% of development with cooling
-5.00 %	0.15	1.40	5	0.93	0.50	44.89 %	80	6 %
0.00 %	0.15	1.40	4	0.93	0.48	48.75 %	80	28 %
5.00 %	0.15	1.20	3	0.90	0.48	47.57 %	80	28 %
10.00 %	0.10	1.00	3	0.95	0.50	49.84 %	80	18 %
15.00 %	0.10	1.00	3	0.95	0.50	53.28 %	80	56 %

Mean Residential specification by models in each % reduction range

% LEAN reduction ▲	Wall U-value (W/m2.K)	Glazing U-value (W/m2.K)	Air Tightness (m3/m2)	Boiler efficiency (%)	Glazing g-value	Glazing ratio (% of external)	Lighting Efficacy (lm/Watt)	% of developments with cooling
-5.00 %	0.16	1.34	4.39	0.93	0.45	46.57 %	80.00	6 %
0.00 %	0.15	1.29	4.03	0.93	0.45	48.02 %	80.00	28 %
5.00 %	0.13	1.24	3.08	0.90	0.47	49.02 %	80.00	28 %
10.00 %	0.11	1.08	2.96	0.95	0.47	50.26 %	80.00	18 %
15.00 %	0.10	0.98	2.28	0.95	0.50	53.02 %	80.00	56 %

Mean Non-Residential specification by models in each % reduction range

% LEAN reduction ▲	Wall U-value (W/m2.K)	Glazing U-value (W/m2.K)	Air Tightness (m3/m2)	Bolier Efficiency (%)	Glazing ratio (% of external)	Lighting Efficacy (lm/Watt)	% of development with cooling
-20.00 %	0.15	1.60	3.00	0.91	60.34 %	90.00	100 %
0.00 %	0.13	1.18	3.64	0.92	46.57 %	82.00	92 %
10.00 %	0.16	1.11	3.89	0.92	43.37 %	86.67	89 %
20.00 %	0.14	1.35	3.75	0.91	42.70 %	78.75	75 %
30.00 %	0.11	1.25	3.50	0.90	44.85 %	67.50	100 %

The matrices show the varying specifications taken from the BuroHappold Models to indicate the expected typical requirements to meet a varying Lean % reduction policy. They indicate that the residential specification can utilise double glazing in many instances to achieve 5% reduction.

However to achieve 10%, the specification will be required to become more stringent. With Triple glazing and an air tightness of 3 m3/m2 @ 50pa required for the majority of developments.

This specification will most likely cause a significant additional uplift to construction time compared to current London Plan policies. This is due to the air tightness testing which will likely be required across all dwellings in a development to achieve 3 m3/m2 @ 50pa. The cost implications of this addition have not been considered within the cost uplift calculations in this study.

Whereas this may not be the case for the Non-residential specification. Little to no trend in strictness of specification can be observed as the the % reduction increases.

This analysis only shows how BuroHappold models could achieve the targets and a further detailed study will be needed to test how typical building types could achieve the policy level required.

33. What is the impact on occupant annual energy bills in residential dwellings?

BuroHappold modelling show that residential heating bills reduce as energy efficiency increases, however electricity bills for fixed services will increase. Overall occupants would expect to save between, depending upon heating system, £40 to £73/year for a 5% reduction and £50 to £81/year for a 10% reduction compared to the notional equivalent. It also shows that occupants could save between £15 to £25/year for a 5% reduction and £24 to £33/year for a 10% reduction compared to the equivalent 0% lean reduction, considered current policy, depending upon heating system.

Median Notional annual energy bills for occupants by heating system for varying for the equivalent % Lean reductions (£/unit/yr)

% LEAN reduction ▲	NOTIONAL Individual Gas boiler Heat cost (£/yr/unit)	NOTIONAL Communal gas Heat cost (£/yr/unit)	NOTIONAL Communal Low carbon Heat cost (£/yr/unit)	NOTIONAL Electricity cost (£/yr/unit)
0.00 %	239.33	342.49	355.02	47.02
5.00 %	249.55	357.13	370.19	48.19
10.00 %	226.58	324.25	336.12	44.53
15.00 %	238.31	341.04	353.52	45.65
20.00 %	230.73	330.18	342.26	44.53
25.00 %	423.49	606.04	628.21	60.11

Median annual energy bills for occupants by heating system for varying % Lean reductions (£/unit/yr)

% LEAN reduction ▲	LEAN Individual Gas boiler Heat cost (£/yr/unit)	LEAN Communal gas Heat cost (£/yr/unit)	CLEAN Communal Low carbon Heat cost (£/yr/unit)	LEAN/ CLEAN Electricity cost (£/yr/unit)
0.00 %	199.37	285.31	295.74	61.64
5.00 %	195.01	279.07	289.28	67.77
10.00 %	169.08	241.96	250.81	56.76
15.00 %	167.54	239.76	248.53	64.06
20.00 %	146.93	210.26	217.96	59.39
25.00 %	242.91	347.62	360.34	91.77

Mean annual energy bills savings between Notional and Lean by heating system for varying % Lean reductions (£/unit/yr)

% LEAN reduction	CLEAN Individual Gas boiler Heat cost saving (£/yr/unit)	CLEAN Communal gas Heat cost saving (£/yr/unit)	CLEAN Communal Low carbon Heat cost saving (£/yr/unit) ▲	CLEAN Electricity cost saving (£/yr/unit)
0.00 %	44.87	64.22	66.57	-18.40
10.00 %	64.01	91.60	94.95	-13.80
5.00 %	65.53	93.77	97.20	-24.41
15.00 %	82.25	117.70	122.00	-26.90
20.00 %	85.79	122.77	127.26	-12.83
25.00 %	180.58	258.42	267.88	-31.66

SAP 2012 modelling has been used to generate energy demands per unit. This is compliance modelling rather than in-use modelling therefore the figures stated may not be wholly representative of post occupancy bills. However these figures have been used for analysis in line with Building Regulations Part L and current GLA planning guidance. The Lean models have been compared to the energy demands from the equivalent notional dwellings. Analysis does not take into account unregulated electrical services.

Three heat provisions options tested:
- Individual gas boilers in dwellings
- Communal gas boiler system
- Low Carbon District Heat network

The annually averaged cost per kWh of heat consumed have been based upon previous BuroHappold District Heat Network study undertaken for the GLA. This cost of heat includes consumption, metering and billing and standing charge. Individual gas boilers have the lowest annual heat bills, however occupants on communal heating system or heat network have the largest decrease in bill due to the higher rate per kWh. This assumes that heat network providers do not raise the cost per kWh to compensate for the reduced demand. Therefore it is key for ESCOs or DHN designers to consider these reduced demands in designs and business plans.

Assumed annually averaged cost per kWh of heat consumed

Individual gas boiler - 5.7 p/kWh

Source: Turning up the heat: getting a fair deal for district heating users, Which report, March 2015

Communal gas boiler - 8.2 p/kWh

Low carbon communal systems (CHP or Heat Pump) - 8.5 p/kWh

Cost of Electricity - 11.96 p/kWh

Source: BuroHappold Report for GLA, The future role of the London Plan in the delivery of area-wide district heating, June 2017

34. What is the impact on occupant annual energy bills in Non-residential developments?

BuroHappold modelling show that Non-residential electricity bills will out weight heating bills. Electricity bills will be higher due to lighting and ventilation demands driving energy performance ranging from £3.8/m2 to £7.8/m2 in total from the modelling undertaken. Savings compared to the notional building of up to £0.3/m2 can be achieved on heating bills and up to £3.1/m2 on electricity bills dependent upon building demands and demand reduction. It also shows that occupants could save between £0.5/m2 for a 10% reduction and £1.4/m2 for a 20% reduction compared to the equivalent 0% lean reduction, considered current policy, depending upon heating system.

Median Notional annual energy bills for occupants by heating system for varying for the equivalent % Lean reductions (£/m2/yr)

% Lean reduction in Actual development	NOTIONAL Individual Gas boiler Heat cost (£/yr/m2)	NOTIONAL Communal gas Heat cost (£/yr/m2)	NOTIONAL Communal Low carbon Heat cost (£/yr/m2)	NOTIONAL Electricity cost (£/yr/m2)
0.00 %	3.93	5.63	5.83	4.22
10.00 %	0.72	1.03	1.07	3.84
20.00 %	1.30	1.87	1.93	4.60
30.00 %	1.67	2.39	2.48	4.60
40.00 %	1.04	1.49	1.54	7.78

Median annual energy bills for occupants by heating system for varying % Lean reductions (£/m2/yr)

% Lean reduction in Actual development	LEAN Individual Gas boiler Heat cost (£/yr/m2)	LEAN Communal gas Heat cost (£/yr/m2)	CLEAN Communal Low carbon Heat cost (£/yr/m2)	LEAN/ CLEAN Electricity cost (£/yr/m2)
0.00 %	3.60	5.15	5.34	5.32
10.00 %	0.60	0.86	0.89	4.56
20.00 %	1.16	1.66	1.72	4.01
30.00 %	1.58	2.26	2.35	3.39
40.00 %	1.57	2.25	2.33	4.70

Mean annual energy bills savings between Notional and Lean by heating system for varying % Lean reductions (£/m2/yr)

% Lean reduction in Actual development	CLEAN Individual Gas boiler Heat cost saving (£/yr/m2)	CLEAN Communal gas Heat cost saving (£/yr/m2)	CLEAN Communal Low carbon Heat cost saving (£/yr/m2)	CLEAN Electricity cost saving (£/yr/m2)
0.00 %	0.21	0.31	0.32	-1.35
10.00 %	0.20	0.29	0.30	-0.77
20.00 %	0.23	0.33	0.34	0.09
30.00 %	-0.05	-0.07	-0.07	1.30
40.00 %	-0.53	-0.76	-0.79	3.08

Apache Sim modelling has been used to generate energy demands per development. This is compliance modelling rather than in-use modelling therefore the figures stated may not be wholly representative of post occupancy bills. However these figures have been used for analysis in line with Building Regulations Part L and current GLA planning guidance. The Lean models have been compared to the energy demands from the equivalent notional dwellings.

For consistency the same three options of heat provision and cost, as for residential, have been tested for Non-residential. This has been done for consistency however it is understood that combined heating and cooling heat pumps may be more appropriate in may instances over a separate heating and cooling system as modeled.

Modelling shows that the driver for energy bills for fixed services is electricity over heat in Non-residential developments. This can be over double the heat bill in many cases. This also suggests that focusing on improving the fabric performance to minimise heating demand will provide marginal benefit over priority of electrical systems demand reduction.

Assumed annually averaged cost per kWh of heat consumed

Individual gas boiler - 5.7 p/kWh

Source: Turning up the heat: getting a fair deal for district heating users, Which report, March 2015

Communal gas boiler - 8.2 p/kWh

Low carbon communal systems (CHP or Heat Pump) - 8.5 p/kWh

Cost of Electricity - 11.96 p/kWh

Source: BuroHappold Report for GLA, The future role of the London Plan in the delivery of area-wide district heating, June 2017

35. How might the change in grid carbon factors affect the % reduction and the hierarchy overall?

By using Carbon intensity of heat factors, investigated from the previous BuroHappold DHN study, future emissions have been projected for the Hierarchy. The analysis based upon the demand figures from the BuroHappold Part L 2013 models, shows that % lean reduction can be passed on to Clean reduction in if carbon factors are updated in line with the 2016 SAP consultation.

The baseline reduction from Part L 2013 to the 2016 SAP consultation carbon factors, have been assumed based on previous study models. This results in a 7% reduction in baseline emission for Residential and a 20% Non-residential. The analysis below shows communal boilers may not meet Baseline unless a 15-20% Lean reduction is present to compensate communal heat losses. Individual boiler will highlight the improvement made through other elan measures. It is recommended that the planning guidance is updated at the time to allow for Lean to not be punished by communal heating losses; to understand the value of the measures implemented. Analysis suggests the average clean performance, with 0% Lean reduction, shows 28% improvement over baseline. If a Business As Usual London Plan is enacted, this clean reduction may drop on average to 14%. With a 5% or 10% Lean reduction Policy in place a Clean reduction of 18% to 23% could be observed. A 5% lean reduction will have a 4.8% positive impact on Clean and a 10% Lean target will have a 9% positive impact on Clean.

% Lean reduction over 2013 Part L	Mean BASELINE Emissions (kg CO2)	Mean LEAN % reduction	Mean CLEAN % reduction	Mean GREEN % reduction	Mean TOTAL % reduction	Mean OFFSET % required
-15.00 %	16,122.56	-13.17 %	18.95 %	3.82 %	22.77 %	77.2 %
-10.00 %	78,300.40	-7.01 %	24.49 %	1.87 %	26.36 %	73.6 %
-5.00 %	16,447.19	-1.94 %	27.25 %	1.74 %	28.99 %	71.0 %
0.00 %	18,818.23	2.66 %	28.20 %	2.86 %	31.06 %	68.9 %
5.00 %	12,323.12	7.33 %	30.52 %	2.72 %	33.25 %	66.8 %
10.00 %	15,315.86	12.79 %	34.63 %	2.07 %	36.70 %	63.3 %
15.00 %	22,487.59	16.58 %	33.04 %	4.15 %	37.19 %	62.8 %
20.00 %	15,796.35	22.31 %	40.60 %	2.62 %	43.22 %	56.8 %
25.00 %	6,694.18	25.58 %	44.29 %	10.23 %	54.52 %	45.5 %

% Lean reduction over 2013 Part L	Mean 2016 Baseline Emissions (kg CO2)	Mean 2016 LEAN (Indiv. Gas bolier) % reduction2	Mean 2016 LEAN (Comm. Gas bolier) % reduction2	Mean 2016 CLEAN % reduction	Mean 2016 GREEN % reduction	Mean TOTAL 2016 % reduction	Mean 2016 OFFSET % required
-15.00 %	14,993.98	-4.29 %	-30.58 %	3.21 %	2.39 %	5.6 %	94.4 %
-10.00 %	72,819.38	0.57 %	-25.02 %	7.89 %	1.17 %	9.1 %	90.9 %
-5.00 %	15,295.89	3.60 %	-21.35 %	10.73 %	1.09 %	11.8 %	88.2 %
0.00 %	17,500.96	6.82 %	-16.84 %	13.59 %	1.79 %	15.4 %	84.6 %
5.00 %	11,460.50	12.18 %	-9.57 %	18.40 %	1.70 %	20.1 %	79.9 %
10.00 %	14,243.75	16.58 %	-4.28 %	22.54 %	1.30 %	23.8 %	76.2 %
15.00 %	20,913.45	17.88 %	-1.85 %	23.52 %	2.60 %	26.1 %	73.9 %
20.00 %	14,690.61	26.14 %	8.15 %	31.29 %	1.64 %	32.9 %	67.1 %
25.00 %	6,225.59	30.37 %	13.31 %	35.24 %	6.40 %	41.6 %	58.4 %

<u>Assumed carbon intensity of used heat for current and SAP 2016</u>

Part L 2013

Individual gas boilers
= 0.24 kgCO2/kWh

Communal gas boilers
= 0.25 kgCO2/kWh

CHP district heat network
= 0.15 kgCO2/kWh

Grid electricity
= 0.519 kgCO2/kWh

SAP 2016

Individual gas boilers
= 0.23 kgCO2/kWh

Communal gas boilers
= 0.3 kgCO2/kWh

Communal Heat pump = 0.21 kgCO2/kWh

Grid electricity
= 0.302 kgCO2/kWh

APPENDICES

APPENDIX 1. DEVELOPMENT ZONE PERFORMANCE - RESIDENTIAL

Very Large and Large

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	2	2.38 %	35.05 %	1.20 %	38.64 %
C	2	10.88 %	29.89 %	8.86 %	49.63 %
Total	**4**	**4.79 %**	**34.92 %**	**4.41 %**	**41.71 %**

Medium

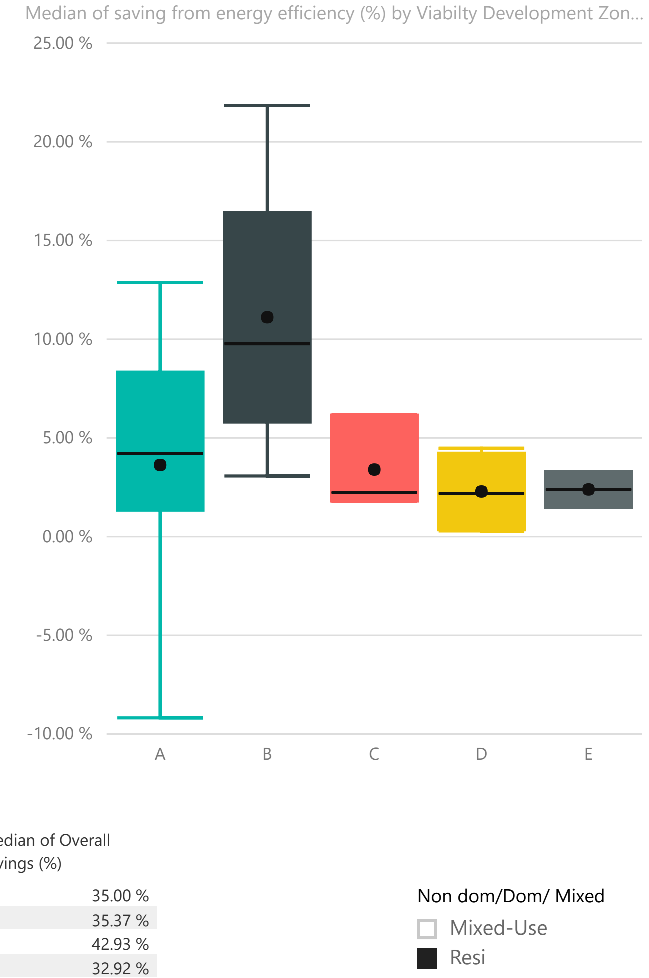
Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	4	8.29 %	19.86 %	9.67 %	35.06 %
B	5	11.00 %	8.72 %	12.63 %	35.17 %
C	3	2.23 %	22.35 %	14.29 %	34.93 %
D	2	2.96 %	28.36 %	2.36 %	33.68 %
E	2	2.39 %	22.98 %	7.43 %	32.80 %
Total	**16**	**3.82 %**	**21.17 %**	**11.85 %**	**35.06 %**

Small

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	3	1.41 %	6.75 %	7.25 %	21.00 %
B	3	8.54 %	27.44 %	3.43 %	35.82 %
D	4	2.57 %	10.70 %	16.04 %	32.00 %
Total	**10**	**3.65 %**	**20.40 %**	**7.70 %**	**32.00 %**

All

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Average of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	9	3.42 %	1.85 %	20.00 %	7.17 %	35.00 %
B	8	9.77 %	9.56 %	18.75 %	8.38 %	35.37 %
C	5	4.35 %	6.03 %	22.35 %	11.30 %	42.93 %
D	6	2.57 %	2.34 %	21.96 %	11.29 %	32.92 %
E	2	2.39 %	2.39 %	22.98 %	7.43 %	32.80 %
Total	**30**	**3.70 %**	**4.74 %**	**21.87 %**	**7.70 %**	**35.02 %**



APPENDIX 2. DEVELOPMENT ZONE PERFORMANCE - NON-RESIDENTIAL

Very Large and Large

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	8	21.47 %	6.68 %	1.29 %	30.04 %
B	2	11.07 %	20.49 %	0.31 %	31.86 %
C	2	32.05 %	3.24 %	0.78 %	36.08 %
D	2	18.85 %	0.00 %	16.35 %	35.20 %
E	1	25.22 %	0.00 %	15.20 %	40.42 %
Total	**15**	**23.82 %**	**5.94 %**	**1.15 %**	**33.99 %**

Medium

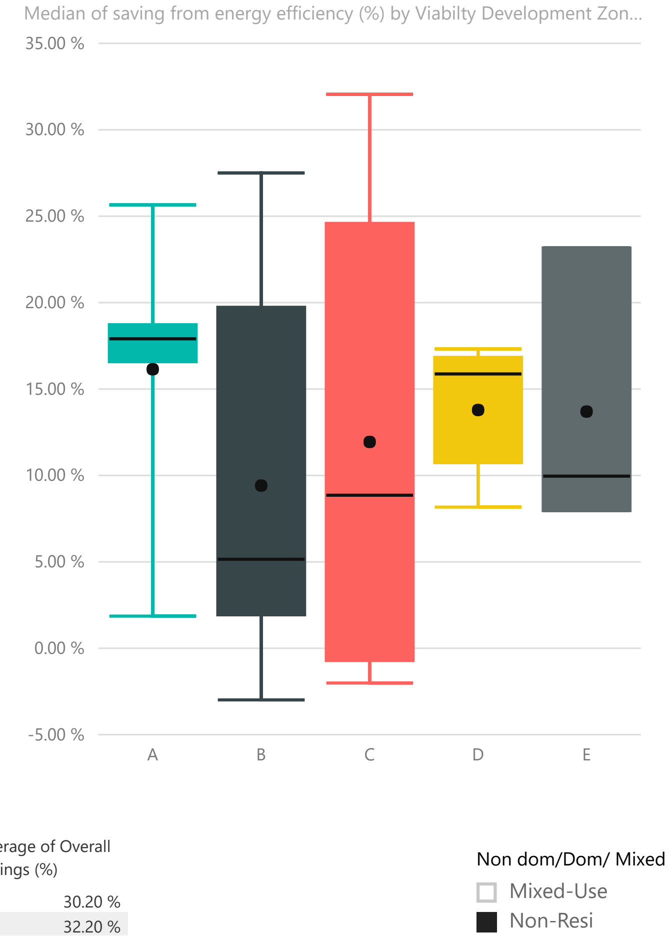
Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	6	17.21 %	1.52 %	3.20 %	25.32 %
B	13	3.24 %	0.95 %	7.11 %	35.00 %
C	3	0.60 %	0.00 %	12.66 %	20.00 %
D	11	12.52 %	0.00 %	14.86 %	38.34 %
E	3	15.31 %	0.00 %	15.54 %	25.50 %
Total	**36**	**12.07 %**	**0.00 %**	**8.56 %**	**34.14 %**

Small

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Median of saving from CHP/DH (%)	Median of saving from renewable (%)	Median of Overall savings (%)
A	1	18.72 %	0.00 %	16.84 %	35.56 %
B	5	3.55 %	0.00 %	32.23 %	37.29 %
C	1	21.43 %	0.00 %	25.00 %	46.43 %
D	1	10.74 %	10.40 %	13.76 %	34.90 %
E	3	19.30 %	0.00 %	13.41 %	35.36 %
Total	**11**	**5.91 %**	**0.00 %**	**25.00 %**	**35.56 %**

All

Viabilty Development Zone	Count of Case No.	Median of saving from energy efficiency (%)	Average of saving from energy efficiency (%)	Average of saving from CHP/DH (%)	Average of saving from renewable (%)	Average of Overall savings (%)
A	15	18.03 %	16.59 %	8.80 %	4.81 %	30.20 %
B	20	4.13 %	8.53 %	8.85 %	14.89 %	32.20 %
C	6	17.11 %	16.15 %	5.08 %	10.07 %	31.31 %
D	14	13.20 %	13.58 %	7.84 %	16.80 %	38.23 %
E	7	19.30 %	16.68 %	0.09 %	24.69 %	40.78 %
Total	**62**	**15.11 %**	**13.28 %**	**7.26 %**	**13.53 %**	**33.96 %**



APPENDIX 3. UNDERSTANDING THE STATISTICAL APPROACH FOR THIS STUDY

There are several key points to note about the statistical analysis carried out for this study

- The data set provided by the GLA represents the full population of projects that have been referred to them over the last three years, it is not a sample taken from a larger population. This means that all averages, medians and other statistical measures taken for this data set are the true population measure, not a measure corresponding to a sample. As a result there is no associated confidence interval or range.

- The BuroHapppold data is independent from the GLA data set. It is not a sample of the GLA data and it includes iterative modelling for some projects. It has not been used at any stage to infer properties of the GLA data set, it has been used to perform detailed costing analysis where the level of detail required was not available in the GLA data. This is approach is validated through the comparison of the two data sets carried out in slides 5 and 6 which show that the BuroHappold data covers the full range of performances seen by the GLA.

- Throughout the study statistical analysis has been undertaken on key graphs and data to understand if a trend is present and if so, the confidence level of this trend. This has been undertaken using regression analysis or R squared analysis, and is stated next to the corresponding graphs.

APPENDIX 4. COSTING INFORMATION AND METHODOLOGY

The following tables outline the actual and notional elements that have been assumed for the energy modelling and therefore have been costed in the analysis. The uplifts stated are the difference between the cost of the actual dwelling/building vs the equivalent cost of the notional building. In most instances the performance of the elements varies slighting. However the glazing areas and subsequent external wall areas will vary, as the notional building will fix the area or not allow over a certain % of floor area.

Residential model element	Simplified actual dwelling performance for costing	Simplified Part L Notional performance for costing
External Walls	0.1 - 0.3 W/m²K	0.18 W/m²K
Roof	0.1 – 0.25 W/m²K	0.13 W/m²K
Floors	0.1 – 0.25 W/m²K	0.13 W/m²K
External Windows	0.8 – 2.0 W/m²K	1.4 W/m²K
Glazing ratio	20% - 80% of external area	Up to max. 25% of floor area
Thermal Bridging	Default/Improved/Accredited	Reference details
Air Permeability	1 - 5m³/m²/hour	5m³/m²/hour
G value (not included in costing)	0.25 – 0.75	0.63
Boiler type	Communal, sized based on development scale	Individual combi per dwelling
Gross annual boiler Efficiency	89.5 - 95%	89.5% (SEDBUK)
Heat losses from pipe work	Default (5%)	Default (5%)
Heat Emitter	Underfloor heating	Underfloor heating
Ventilation type	MVHR/MEV/AHU/Natural Vent.	Natural ventilation with intermittent extract fans
Lighting Efficacy	80 lumens/Watt	60 lumens/Watt
Lighting Controls	Manual	Manual
Chiller Efficiency (SEER)	2.6 – 5.5	N/A

Non-residential model element	Simplified actual dwelling performance for costing	Simplified Part L Notional performance for costing
External Walls	0.1 - 0.3 W/m²K	0.25 W/m²K
Roof	0.1 – 0.25 W/m²K	0.18 W/m²K
Floors	0.1 – 0.25 W/m²K	0.2 W/m²K
External Windows	0.8 – 2.0 W/m²K	1.6 W/m²K
Glazing ratio	0% - 100% of external area	~40% of external area
Thermal Bridging	Default/Improved/Accredited	10%
Air Permeability	1 - 5m³/m²/hour	3 or 5 m³/m²/hour
G value (not included in costing)	0.25 – 0.75	0.4
Boiler type	Communal, sized based on development scale	Communal, sized based on development scale
Gross annual boiler Efficiency	89.5 - 95%	91%
Heat losses from pipe work	Variable	Variable
Heat Emitter	FCUs	FCUs
Ventilation type	MVHR/MEV/AHU/Natural Vent.	Matching
Lighting Efficacy	60 -100 lumens/Watt	60 lumens/Watt
Lighting Controls	Manual/Daylighting/Occupancy sensors	Manual/Daylighting/Occupancy sensors
Chiller Efficiency (SEER)	2.6 – 5.5	3.5

The following tables outline the which building elements have been included within the costs energy efficiency uplifts, as provide by Currie & Brown.

Soruce of data

Cost data were drawn together from a range of sources including, information from the market, analysis of tender returns and published cost studies and datasets (eg Spons and DECC/BEIS research). Costs exclude preliminaries, overheads, profits and contingency. The scope and inclusions of all data were reviewed for consistency before use. All the data were brought into Q2 2017 prices using appropriate indexation / adjustments. Because of the limited time available for the analysis limited new engagement with market was possible.

Time Period

All costs are adjusted for 2017

Scope of coverage

The following building elements are included in the costs datasets, for each included / or partially included item the scope of the costed items are described.

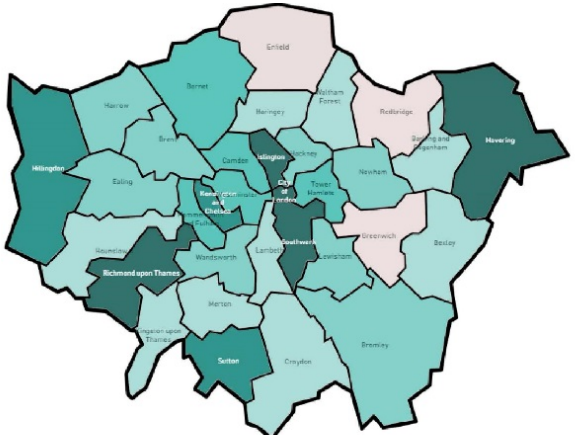
Element	Capital costs	Operating costs	Replacement costs	Notes
1 Substructure	**No**	**No**	**No**	
2A Frame	No	No	No	
2B Upper Floors	No	No	No	
2C Roof	Yes	No	No	Includes roof structure (trusses + joists or deck) + insulation, covering (membrane or slates), ceiling finish and vapour control membranes
2D Stairs	No	No	No	
2E&F External Walls, Windows and Doors	Yes	No	No	Includes inner leaf, insulation, outer leaf, ties/fixings as appropriate, wallboard, cavity tray's and closers and lintols. Windows and doors include all necessary furniture.
2G Internal Walls and Partitions	No	No	No	
2H Internal Doors	No	No	No	
2 Superstructure	Partial	**No**	**No**	**Includes items above**
3A Wall Finishes	No	No	No	
3B Floor Finishes	No	No	No	
3C Ceiling Finishes	No	No	No	
3 Finishes	**No**	**No**	**No**	
4 Fittings and Furnishings	**No**	**No**	**No**	
5A Sanitary Appliances	No	No	No	
5B Services Equipment	No	No	No	
5C Disposal Installations	No	No	No	
5D Water Installations	No	No	No	
5E Heat Source	Yes	No	No	For non-domestic buildings costs only include for generator plant, for homes costs include generator, pipes (supply and distribution), wiring and radiators
5F Space Heating and Air Conditioning	Yes	No	No	Includes chiller plant and FCU units, excludes distribution pipes and ducts
5G Ventilating Systems	Yes	No	No	Includes AHU or MVHR, excludes distribution pipes and ducts.
5H Electrical Installations	Yes	No	No	Includes for light fittings, wiring and controls. Excludes other wiring for power distribution.
5I Fuel Installations	No	No	No	
5J Lift and Conveyor Installations	No	No	No	
5K Fire and Lightning Protection	No	No	No	
5L Communications and Security Installations	No	No	No	
5M Special Installations	No	No	No	
5N Builder's Work in Connection	Partial	No	No	Included where appropriate in figures for each element.
5O Management of the Commissioning of Services	No	No	No	
5 Services	Partial	**No**	**No**	**Includes items above**
Building Sub-total	Partial	**No**	**No**	**Includes items above**
6A Site Works	No	No	No	
6B Drainage	No	No	No	
6C External Services	No	No	No	
6D Minor Building Works	No	No	No	
6E Demolition and Work Outside the Site	No	No	No	
6 External Works	**No**	**No**	**No**	
7 Preliminaries	**No**	**No**	**No**	
8 Contingencies	**No**	**No**	**No**	
Total (less Design Fees)	Partial	**No**	**No**	**Includes items above**
9 Design Fees	No	No	No	
Total Contract sum	Partial	**No**	**No**	**Includes items above**

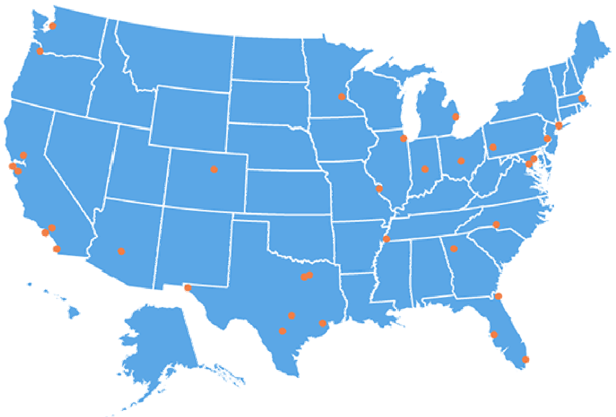
Other unassessed costs	Capital costs	Operating costs	Replacement costs
Assessed percentage of construction costs (approx)	34%	0%	0%
Unassessed percentage of construction costs (approx)	66%	0%	0%

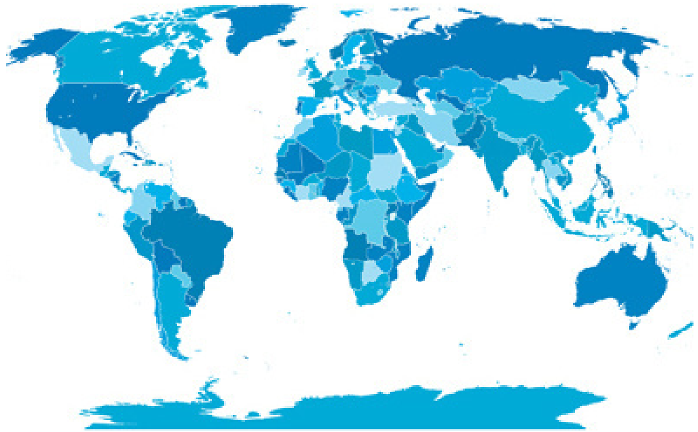
Other unassessed costs	Capital costs	Operating costs	Replacement costs
Land aqusition	No	No	No
Consultants fees	No	No	No
Legal fees	No	No	No
Marketing / Agency fees	No	No	No
SIL / 106 etc.	No	No	No

APPENDIX 5: POLICY REVIEW - SUMMARY

This section outlines Energy efficiency policy findings from City, country and Global or continent level.







City-level policy

- C40 Cities: Global Survey of Building Energy Efficiency Policies
- Amsterdam

Country-level policy

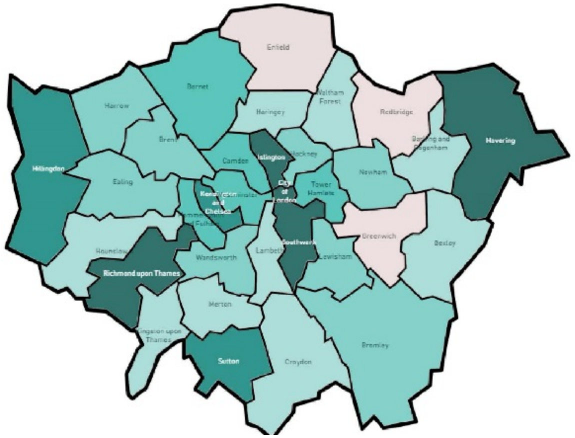
- Zero Carbon Hub
- American Council for an Energy Efficient Economy
- Denmark

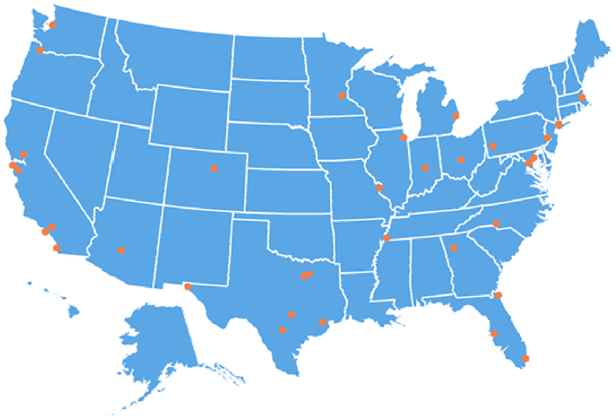
Global policy

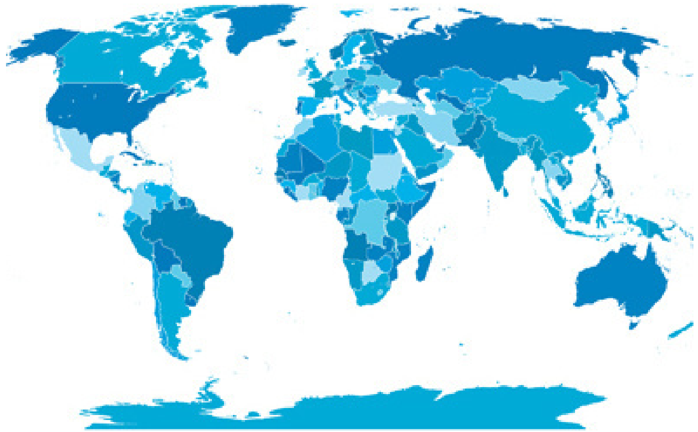
- EU Energy Efficiency Directive
- The CCC: Best Practice in Residential Energy Efficiency Policy
- Odyssee-MURE (EU member states)
- GBPN: A Comparative Analysis of Building Energy Efficiency Policies for New Buildings

KEY FACTORS TO SUCCESS

Key factors for success have been taken from the policies outlined or the case studies from, Amsterdam and Denmark.







City-level policy review

- Public communication
- Targeting small to medium sized buildings
- Establishing ambitious future targets
- Partnership between government, private sector, and the local residents

Country-level policy review

- Economic incentives
- Minimum standards for all local authorities to adhere to and develop on, raised over time
- Simple public communication with a clear message and a single resource/database of information

Global policy review

- EU Member States must set national policies to adhere to Energy Efficiency Directive
- Policy stability and sustained funding
- Improve energy efficiency policy in several phases over time
- Minimise complexity of communication

City Level Policy

URBAN EFFICIENCY: A GLOBAL SURVEY OF BUILDING ENERGY EFFICIENCY POLICIES- *C40 CITIES*

"The Urban Efficiency report's specific objectives are:

- *to begin to capture the range of different policies being implemented in cities around the world;*
- *to obtain detailed information on the necessary conditions, opportunities and potential challenges when introducing and implementing such initiatives; and*
- *to analyse what approaches have been successful in which context and why."*

What they looked at-

- Policy map of both new and existing buildings, comparing which policy elements exist, or are city-led or regional/national/state government-led or partner-led programmes for a variety of international cities
- Explores the policy map global trends further, and discusses the policy elements in more detail in terms of the trends with the different types of programmes
- Detailed case studies for Hong Kong, Houston, Melbourne, New York City, Philadelphia, San Francisco, Singapore, Seattle, Sydney and Tokyo
- Summary of policies, how these have been enforced, the targets of the programme, and the results and lessons to be learned
- It also states clearly for each city the citywide reduction target and building-specific reduction target, if specified

  Most of the programmes studied target commercial buildings, and the majority are regulatory as opposed to voluntary

- These case studies are built upon to discuss future directions of building energy efficiency regulations in cities, and identify possible challenges
- Table in the appendices establishes priority benefits (e.g. health + well-being, job creation, economic competitiveness), their associate indicators, and global examples of how they are put in place through building energy efficiency policy

Targets-

- The report should provide a resource for city officials developing new or reviewing existing policies, enabling them to learn from successes and challenges, and anticipate future obstacles in terms of building energy efficiency

How was it received?

- Feedback from city officials suggested it would *"fill a gap in the literature on city-level building efficiency programmes"*
- The report was created in collaboration with Tokyo Metropolitan Government, who plan to continue in future research endeavours to provide additional city appropriate resources in terms of energy efficiency

Report (pdf)

URBAN EFFICIENCY: A GLOBAL SURVEY OF BUILDING ENERGY EFFICIENCY POLICIES- *C40 CITIES*

Key Findings

Success Factors-

- **Stakeholder engagement** was a crucial factor for almost all cities. Stakeholder participation at early stages allows for the needs/interests of certain communities to be incorporated into design of legislation (Tokyo, Philadelphia and Houston). In Philadelphia, stakeholders also assisted with outreach and gaining wider public/industry support. It can also help to attain higher compliancy levels with regulatory measures e.g. benchmarking/ auditing requirements (Hong Kong, Singapore, Seattle and San Francisco).
- **Partner support**, i.e. the potential for certain organisations or enterprises to become official programme partners and assume roles beyond those expected during the public consultation process. Examples of partner support can be: academic partners for technical support (NYC); non-profit organisations (Houston) and professional associations (Singapore, Sydney) to assist with marketing/communication; corporate partners to provide sponsored funds to the city and free energy audits to participants (Houston).
- **Top-level political support**, which San Fran and Seattle reported as crucial for new benchmarking programmes, and is even more important for voluntary programmes e.g. in Houston a non-regulatory initiative received official support from the Mayor and the prospect of receiving formal recognition for outstanding practice.
- The majority of programmes allowed for a significant amount of **flexibility** when enforcing compliance- in many cases non-compliance can instead by lack of ability to comply. As a result of flexibility and a commitment to capacity building rather than legal enforcement through issuing of fines, many cities have found that compliance rates have improved (e.g. San Fran, Hong Kong, Singapore).
- **Different strategies for different segments**- e.g. Melbourne and San Fran have used different communication strategies for different audiences
- **Commitment to driving action via incentives and capacity building**- many examples of success when linking regulatory and voluntary programmes to financial incentives and capacity building efforts to help building owners act on the results of energy audits and data reporting schemes, e.g. voluntary leadership programme in Sydney and Melbourne.

Key Challenges-

- **Data accuracy**, for example for benchmarking and emissions trading schemes ensuring accuracy of data submitted has been highlighted as a challenge for the majority of case studies. Accuracy errors largely occur as human error due to self-reporting and manual entry of data from energy invoices.
- Programmes implementing benchmarking systems (or collecting building performance data) will inevitably experience **difficulties in obtaining aggregated data** (whole building) for energy consumption.
- **Outreach and marketing** challenges, particularly for the small to medium building owners in terms of efforts to market programmes, drive compliance and educate building owners on the importance of building efficiency and retrofitting.
- **Moving from benchmarking compliance to understanding**, i.e. the need to move beyond achieving mere compliance to triggering actions to improve energy efficiency.
- **Tenant engagement**- potentially reflects the fact that building owners are the primary target audience of the various programmes surveyed in this report, particularly for regulatory programmes.
- **Staffing limitations** for the time-intensive activities required to be undertaken- coordination across multiple city agencies has been seen to be a success in Hong Kong and Philadelphia.

Future perspectives and London case study continued on following page.

Key Findings (continued)

Future Perspectives-

- **Public disclosure and communicating the value of environmental performance data**
  By introducing measures to convey to the public and to individual building owners and key industry groups the importance of programme outputs, such as benchmarking data and auditing results, and make clear that this energy efficiency data can guide future performance and generate financial benefits in the local building markets.
- **Targeting small to medium sized buildings**
  All case study cities have measures targeting larger buildings, and, in parallel to this, some are developing programmes for small and medium-sized buildings. These programmes would require different strategies and increased staff, however it has been very successful in Houston with their Green Office Challenge.
- **Engaging tenants**
  One of the key challenges identified was the difficulty engaging tenants, so this will require a future effort. In Singapore, since Sept 2014, tenant awareness has been the main focus of the third stage of the Green Building Masterplan, and in Tokyo large tenants have consistently been involved,

AMSTERDAM ENERGY EFFICIENCY POLICY

What does the policy entail?

- Focus on existing building stock
- Implementation of Chapter 5 of National Building Code "Bouwbesluit"
  - Mandates an energy frame calculation to obtain EPC
  - Energy Performance Certificates
  - Positive labelling for building beyond the minimum BC (Building Code) level
  - Inspection of boilers, done every year or two, depending on the type, size and age of the boiler
  - Inspection of HVAC (heating, ventilation and air conditioning) systems. Introduced in the EPBD
  - revision of 2010 in order to maintain the correct adjustment in accordance with the product specification and in that way to ensure optimal performance from an environmental, safety and energy point of view.
  - Energy offsets/Green certificates
- Additional city-level targets established
  - Mandate a minimum of Energy Certificate B for buildings
  - Climate neutral new buildings (implemented since 2015)

How is it enforced?

- The Amsterdam Smart City partnership – between government, private sector and local residents
- An energy helpdesk has been set up to help Small and Medium size Enterprises (SMEs) realise energy savings

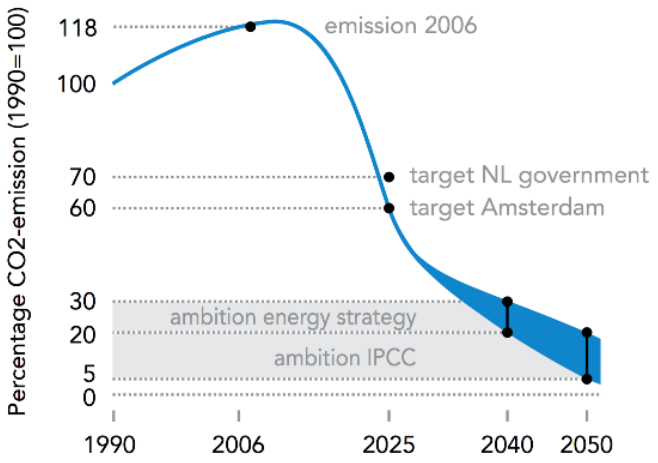
Future Vision-

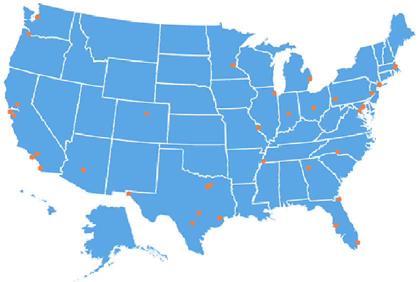
The Netherlands:

- Energy neutral buildings by 2020 (VROM 2007)

Amsterdam:

- Reduction of 40% in CO_2 emissions by 2025 (compared to 1990)
- 30% of the city's energy will be sustainable and locally produced
- Progressive improvement of existing buildings via insulation, double glazing and the use of solar energy





Country Level Policy

ZERO CARBON HUB

- Active between 2008-2016
- Collaborate with government and industry to ensure minimal risk is associated with implementing the 2016 Zero Carbon Homes Policy (reports progress to government)
- Organisation core focus areas:
  - Developing the zero carbon definition
  - Undertaking associated research
  - Disseminating information to the wider industry

What they looked at-

- Areas of research:
  - Analysing the gap between the designed and as-built energy performance of new homes
  - Understanding and tackling overheating in buildings
  - Trialling various aspects of the Zero Carbon definition in practice
  - Assessing indoor air quality and occupant comfort in new homes
  - Finding and publicising best practice and exemplar projects
  - Understanding and addressing future skills and knowledge requirements
  - Exploring approaches which raise awareness and interest in zero carbon homes among consumers.
- Several guidebooks released to cover topics such as thermal bridging, SAP calculations, overheating, ventilation, and cost efficiency
- Studies into UK Policy and European Policy, and global case studies of zero carbon homes
  - *Who's Doing What In Housing Worldwide, 2011*

Targets-

Fabric energy efficacy of For the majority of homes, levels of 39 and 46 kWh/m2/year are proposed:

- 39 kWh/m2/year for apartment blocks and mid-terrace homes.
- 46 kWh/m2/year for end terrace, semi-detached and detached homes.

Also additional specific and detailed guidance to achieve zero carbon homes.

How was it received?

- During its active period, the Zero Carbon Energy Hub reported its findings back to the government, and worked with industry to create a wide portfolio of zero carbon homes
- Since 2015 and the removal of the Zero Carbon Homes Policy, the hub mainly focused on researching overheating in homes and closing the performance gap, and has since disbanded

http://www.zerocarbonhub.org/

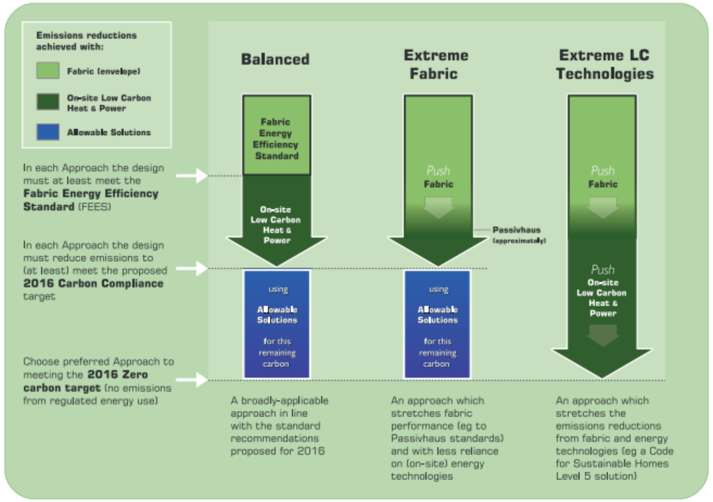
Key Findings

Carbon Compliance:

- Establishes the three steps to design and build zero carbon homes, which are carbon compliance (ensuring an energy efficient approach to design, and reducing CO2 emissions on-site) and allowable solutions (mitigating remaining carbon emissions).
- They recommend that further modelling is done on different housing types, based on the following results they achieved:
  - the previous proposal for 2016 of a 70% reduction in carbon emissions (equivalent to a Carbon Compliance limit of 6 kg CO2(eq) /m2 /year) is not feasible in all cases;
  - the performance of detached houses, attached houses, low-rise and high-rise apartments are different, so they should be subject to different limits
- The Zero Carbon Hub found that the following had negligible impacts on where the Carbon Compliance limit should be set:
  - Householder health and well-being
  - The need for desirable homes on a mass scale
  - Deliverability of new homes
  - Energy efficiency and energy security
  - Monitoring and enforcement
  - Consumer behaviour and perceptions
  - The impact of UK targets for renewable energy and CO2 emissions
- Wider considerations need to be incorporated into the strategy, these include:
  - Design v built performance (i.e. there is an energy performance gap which needs to be closed)
  - Averaging across a development (not necessary for each building to achieve carbon compliance limit)
  - National v local weather
  - Localisation (there should be no local power to set local Carbon Compliance limits, but currently local authorities allowed flexibility in this area)

Zero Carbon Strategies:

- Sets out key ways of achieving zero carbon targets
- Looks at successful case studies of zero carbon projects in the UK



AMERICAN COUNCIL FOR AN ENERGY EFFICIENT ECONOMY (ACEEE)

The ACEEE is a non-profit organisation which aims to serve as a catalyst to advance energy efficiency policies, amongst other things. Their main focus areas are US energy policy (federal, state, and local), research, and outreach.

The scope of their work includes:

- Conducting in-depth technical and policy analyses
- Advising policymakers and program managers
- Working collaboratively with businesses, government officials, public interest groups, and other organizations
- Convening conferences and workshops, primarily for energy efficiency professionals
- Assisting and encouraging traditional and new media to cover energy efficiency policy and technology issues
- Educating consumers and businesses through our reports, books, conference proceedings, press activities, and websites

What they looked at-

- State policy database:
  - A detailed description of state government policies, background and incentives, and the policies on buildings, CHP, utilities, transportation, and appliance standards
  - Focusing on buildings: summary of requirements; residential codes; commercial codes; compliance; and important links
- Local policy database:
  - A detailed description of local government background, energy efficiency goals and recent procurement and construction, also the community-wide initiatives and the policies on buildings, energy + water utilities, and transportation
  - Building policies: summary of requirements; stringency of energy codes; enforcement and compliance; requirements and incentives for energy efficient buildings; and benchmarking, rating + transparency.
- Energy data is available to download, as well as both the entire city and entire state database (in excel format)
- Several additional publications with further research into this area

Targets-

ACEEE have established their "local policy priorities" as areas to focus the bulk of their policy, which are:

- Government lead by example initiatives
- Local and community initiatives
- Transportation system efficiency
- Vehicle fleets
- Building codes
- Building rating and disclosure
- Retrofits
- Multifamily homes
- Distributed generation
- Public buildings
- Waste and wastewater

ACEEE also aim to encourage alignment with the 2015 Energy Savings Targets,

How was it received?

- The ACEEE has helped to develop building codes for new homes and commercial buildings, which have been adopted in the majority of US states
- They assist many states with adopting and implementing energy efficiency policies and programs (e.g. a leading role in passing a 2008 legislation in Maryland)

These results have been considered to discuss Los Angeles energy policy and New York policy.

http://database.aceee.org/city/new-york-city-ny

DENMARK ENERGY EFFICIENCY POLICY

What does the policy entail?

- Mandatory minimum energy performance standards for new buildings are in place (it has one of the most ambitious and strictest MEPS for new buildings among comparable countries). See Figure 1 below.

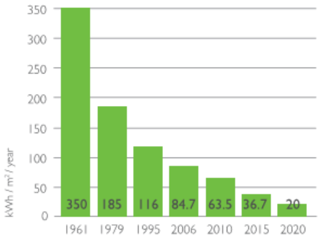


Figure 1. Danish building codes from 1961 to present: Maximum allowed energy demand per year and m2 heated floor space in a new 150 m² residential building. The limit is on the total amount of supplied energy for heating, ventilation, cooling and domestic hot water.

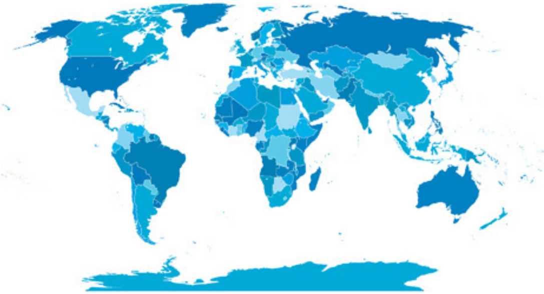
  - For a residential building the maximum limit on energy demand per year is 1650 kWh/HFS plus 52.5 kWh/m2, where HFS is the building's total heated floor space measured in square meters.
  - For a non-residential building the equivalent figures are 1650 kWh/HFS plus 71.3 kWh/m^2.
- Component requirements in building regulations to ensure use of high quality materials
- Third-party financing is available
- Energy performance certificates required in the BPIE 2010 (not in the NEEAPs)
- Has requirements on the renovation of existing buildings, which is important as approximately 75% of the buildings in Denmark were built before 1979, when the requirements were tightened for the first time

How is it enforced?

- Since 2006 all Danish energy distribution network companies (electricity, gas, district heating) are obliged to promote a more efficient use of energy
- Each year the obligations are increased and will be tightened further by 50% from 2013 and by 75% in 2015-2020
- Economic incentives- grants and subsidy programmes implemented by the government and the energy companies
- Tools, information, education and training are provided by the Knowledge Centre on Energy Savings and others.
- Information and motivation activities are commonly performed measures.
- Electricity is taxed and (in cold climates) space heating, therefore energy efficiency measures have increased value.

Future Vision-

- Aim of strategy is to reach target of being fossil fuel free by 2050
- Prioritising long-term rather than short-term cost efficiency



Global Policy

ENERGY EFFICIENCY DIRECTIVE – *EUROPEAN UNION*

- *"This report, published by the Global Buildings Performance Network (GBPN), analyses the content of building energy efficiency codes and surveys how countries are developing and implementing them.*
- *Twenty-five best practice building energy efficiency codes from around the world were scored based on criteria developed by experts from different regions and large international organisations."*
- The results are also presented online in an interactive comparative tool

What does this ask for?

Under the 2010 Energy Performance of Buildings Directive:

- energy performance certificates are to be included in all advertisements for the sale or rental of buildings
- EU countries must establish inspection schemes for heating and air conditioning systems or put in place measures with equivalent effect
- all new buildings must be nearly zero energy buildings by 31 December 2020 (public buildings by 31 December 2018)
- EU countries must set minimum energy performance requirements for new buildings, for the major renovation of buildings, and for the replacement or retrofit of building elements (heating and cooling systems, roofs, walls and so on)
- EU countries have to draw up lists of national financial measures to improve the energy efficiency of buildings.

Under the 2012 Energy Efficiency Directive:

- EU countries make energy efficient renovations to at least 3% of buildings owned and occupied by central government
- EU governments should only purchase buildings which are highly energy efficient
- EU countries must draw-up long-term national building renovation strategies which can be included in their National Energy Efficiency Action Plans.

Major revisions:

- Legislation involving building renovation in Energy Efficiency Directive to be moved to Energy Performance of Buildings Directive
- Introduced strict regulations on car parking compatibility with electric cars and number of chargers per 10 parking spaces for non-residential developments

How is it enforced?

Following up on the Commission's implementation report on the Energy Efficiency Directive from November 2015, the European Parliament adopted a resolution on 23 June 2016 in which it took the following position:

- Parliament deplored the insufficient implementation of the Energy Efficiency and Buildings Directives, and called on Member States to improve it and on the Commission to oversee it.

Implementation:

- Setting national targets
- Policy adoption by member states
- Energy Efficiency Obligation Schemes used to deliver savings in a cost-effective way and to create a market for energy efficiency
  - Most measures focus on implementation of "low-hanging fruits" in the residential sector e.g. efficient light bulbs and roof insulation
- Measures jointly addressing financial incentives and information/education campaigns
- Best practices can be useful to highlight replicable approaches
- Simple implementation rules complemented by a transparent process as well as an effective and periodic evaluation of the scheme can result in higher effectiveness of measures.

BEST PRACTICE IN RESIDENTIAL ENERGY EFFICIENCY POLICY: A REVIEW OF INTERNATIONAL EXPERIENCE – *THE COMMITTEE ON CLIMATE CHANGE*

A document produced by the CCC as part of their "*Next Steps for UK Heat Policy*" report, which sets out guidelines for what UK energy efficiency policy should cover in the built environment, using evidence from various countries across the globe. It primarily focuses on residential heat and individual energy consumption, but also discusses policy for new builds

What they looked at-

- Policy across other countries
- Economic impact of strict energy efficient policy

Case studies:

- Better Energy Homes, Ireland
  - Grant scheme run by the Sustainable Energy Authority of Ireland as an incentive to encourage people to improve the energy performance of their homes
  - Grants covering part of the cost of energy efficiency improvement are available for a range of insulation measures, heating controls and solar heating
- Warm Up New Zealand
  - Warm Up New Zealand: Heat Smart ran from 2009 to 2013 as a soft loan and grants scheme to promote insulation and clean heating to homeowners and landlords
  - Warm Up New Zealand: Healthy Homes is the current grant programme which subsidises landlords in delivering underfloor and ceiling insulation to low-income rental households
- KfW loans and grants, Germany
  - Long-term fixed-rate low-interest loans and grants to support energy efficiency work during the general refurbishment of existing buildings
  - Encourage energy efficiency standards in new buildings that are higher than the legally required minimum standards
- Flat 35 Mortgages, Japan
  - Japan's mandatory building codes do not specify a minimum energy performance standard
  - voluntary standards exist and the Flat 35 mortgage scheme is offered to incentivise homebuyers to buy properties that exceed the voluntary standards

Targets-

- Breakdown of recommended policy:
  - Information and advice
  - Energy and admission taxes
  - Financial incentives
  - Access to capital
  - Minimum standards (raised over time to drive performance)
- Set out essential factors for the success of policy design and implementation

How was it received?

- Since the report's release in October 2016, little has been done to reform heat policy[1]
- The Government committed to publishing an 'emissions reduction plan' by December 2016 and then revised the timetable to early 2017. As of June 2017, that plan has not been published
- Many of the current policies responsible for delivering long-term climate action come to an end around 2020

[Report (pdf)](#)

BEST PRACTICE IN RESIDENTIAL ENERGY EFFICIENCY POLICY: A REVIEW OF INTERNATIONAL EXPERIENCE – *THE COMMITTEE ON CLIMATE CHANGE*

Key Findings

The following success factors were defined in the report as essential for effective policy design and implementation:

1. **Policy stability and sustained funding**

   A stable government policy framework is necessary to allow consumers to make cost-effective investment decisions, thereby reducing the energy efficiency gap, and to avoid counter-productivity. Denmark demonstrates an incredibly stable energy policy, through targets and standards developed well in advance and which progress over time.

2. **Targeting trigger points**

   By targeting the time when households are considering renovation and reviewing their options, policies can become more effective. Denmark and Sweden require simultaneously high levels of efficiency for home extensions and certain upgrades to be made to the existing structure.

3. **Minimising hassle and complexity**

   Simple and transparent programmes from a household's perspective will be most effective, however schemes need to be aware to target their specific consumer, to avoid over-simplification. For example, comparing between Warm Up New Zealand and the UK Green Deal, the NZ website is designed so that customers can see what they are eligible for and find local registered providers, whereas the UK website required separate searches for providers, assessors and installers. Contractors should have a formal on-site project management process, and loans may be required for costs extending beyond the direct cost of measures.

4. **Consumer trust**

   Many countries have a designated energy agency to ensure programmes are well-aligned and consumer protection is a priority. Minimum training requirements and rigorous accreditation allow for a stable delivery method which ensures consumer trust, the use of organisations with which consumers are already familiar can add to this too (e.g. KfW bank loans in Germany or local council repayments in New Zealand).

5. **Effective communication and marketing**

   Communicating the message to the public is essential, and is most effective when communication one simple message, backed up by a source on information taking a streamlined approach across multiple schemes.

ODYSSEE-MURE

"MURE (Mesures d'Utilisation Rationnelle de l'Energie) provides information on energy efficiency policies and measures that have been carried out in the Member States of the European Union. The information is accessible by query in the database. The distribution of measure by type can be visualized through radar graph."

What they looked at-

Data Tools:

Allows comparison between EU member states of policies defined, and effectiveness/ success of these policies.

- Policies by Topic
  - Number of measures on energy efficiency and renewable energy in buildings by each EU member state
  - Summary of these measures
  - Further breakdown of building policies and number of measures of each sub-topic
- Successful Policies
  - Ranks success of policies for each country according to defined criteria
- Policy Interaction
  - Select the country, the targeted end-use class (e.g. for "tertiary use"- new buildings, VAC, appliances, lighting, etc.) , then click on the button Submit to calculate the energy saving of the measures package
- Policy Mapper
  - Maps MURE measures onto Odyssee impact indicators
- Policy Scoreboard
  - Either output based scoring (based on energy savings or related to energy efficiency potentials or related to 2020 efficiency targets) or input-based scoring

Report: *Energy Efficiency Trends and Policies in Buildings*

- Evaluates energy efficiency progress achieved in buildings since 2000 at EU level, and discusses the successes and failures of the implementation of EU Directives and national energy efficiency policy and measures

Targets-

Report: *Energy Efficiency Trends and Policies in Buildings*

- Examples of areas needing further attention in EU legislation:
  - Improve the existing building renovation strategies, and encourage all countries to adopt them
  - Need for better visibility of energy certificates, databases need to be developed and consumer trust must be increased
  - Energy efficiency should be systematically integrated into public procurement processes
- Sectorial policies do not suffice in the transformation towards low carbon economy. Increased focus needs to be given to system level improvements.
- Smart meters and informative billing need to be backed up by other energy services such as tailored advice as well as financing opportunities to actually induce change.

etc.

How was it received?

- Co-funded by the Horizon 2020 programme of the European Union

http://www.measures-odyssee-mure.eu/

A COMPARATIVE ANALYSIS OF BUILDING ENERGY EFFICIENCY POLICIES FOR NEW BUILDINGS – *GLOBAL BUILDINGS PERFORMANCE NETWORK (GBPN)*

- *"This report, published by the Global Buildings Performance Network (GBPN), analyses the content of building energy efficiency codes and surveys how countries are developing and implementing them.*
- *Twenty-five best practice building energy efficiency codes from around the world were scored based on criteria developed by experts from different regions and large international organisations."*
- The results are also presented online in an interactive comparative tool.

What they looked at-

- Comparison of different building energy efficiency codes using defined criteria to score them (e.g. levels beyond minimum, zero energy target, certification, overall performance, etc.)
- Countries looked at: Austria; Denmark; England & Wales; Finland; France; Germany; Ireland; Lithuania; Netherlands; Spain; Sweden; India (Energy Conservation Building Code); China – (Hot Summer/ Warm Winter Zones); China – Public Buildings, All Zones; China - Severe Cold and Cold Zones; New South Wales; Singapore; US (California, Ontario, Maryland, City of Austin, Massachusetts, NYC, Oregon, Seattle)
- On the online database, further information can be found about each of the 25 codes. This information includes: summary +general info; remit of code; coverage; type of building code; energy covered; enforcement; values for new buildings; code history and future targets; supporting measures
- The graphical comparative tool plots the country according to its overall rating, and for each country breaks this down into its score for each of the established criteria

Targets-

- There is a need to develop overall performance values for most codes in order to accurately compare the actual level of energy efficiency achieved by the codes
- To promote examples of dynamic and ambitious building energy efficiency regimes for new buildings with a particular focus on building energy efficiency codes
- Codes need to be better enforced- need for more onsite construction inspections, post-occupancy energy verification, inspector training and compliance statistics was highlighted

How was it received?

- "*One of the main outcomes of this project has been the development of criteria for comparing best approaches to energy efficiency building codes and identifying best practice elements of dynamic building codes and policy packages for new buildings. The criteria were developed by experts from different regions and large international organisations."*

Report (pdf)

A COMPARATIVE ANALYSIS OF BUILDING ENERGY EFFICIENCY POLICIES FOR NEW BUILDINGS – *GLOBAL BUILDINGS PERFORMANCE NETWORK (GBPN)*

Interactive Tool: Key Findings

Comparison of dynamic energy efficiency in new buildings, comparing 25 best practice building energy efficiency codes using the 15 criteria set out in the following slides. The criteria allow the codes to score marks (10 total for each criteria) based on their contents, and to rank and compare codes according to their marks, they can be viewed in further detail in the PDF file. Particularly strong performances come from France, Ireland, Denmark, Sweden and the Netherlands. Case studies for Denmark (country-level), and Amsterdam (city-level) have been investigated in further detail in previous slides. England & Wales rank just behind these countries, so have scored highly, but also have room for improvement.

Looking specifically at England & Wales, they perform well in terms of "Holistic Approach", scoring 8 marks in "Performance Based Approach", 9 in "Includes All Energy" and 9 in "Energy Efficiency and Renewable Energy". This high score indicates the codes take a systematic approach to the design and construction processes, and set standards for the total energy consumption of the building.

In terms of "Dynamic Process", England & Wales score 6 in each criteria, so there is a lot to be improved. Denmark excels comparative to all other codes in this category. **This demonstrates a need for multiple phases of improving energy efficiency requirements** to be incorporated into the Best Practice Code.

When implementing the codes, this is an area where most of the countries studied fell back, and all scored similar ratings of around 6/10. England & Wales scored 7 for Certification, 6 for Policy Packages, and a 3 for Enforcement Standards. This ranking suggests **there is an issue with ensured enforcement of the code and compliance of individual buildings**, and the detailed results show a lack of penalties for non-compliance, surveys are not clearly conducted on compliance rates to show a high level of compliance, and assessing compliance is not sufficiently defined.

England & Wales fall significantly behind when it comes to technical requirements, where Ireland scores full marks in almost every criteria, and France, Germany, Seattle and Sweden also perform very well. England & Wales scored 6 in Energy Demands on Building Shell, 8 in Technical Systems and 4 in Renewable Energy Systems. **There is a need for additional requirements on the use of active renewable energy for all types of buildings, and with stringent demands.**

APPENDIX 6. EXPECTED COST OF ZERO CARBON

These tables provide a detailed breakdown of the cost of zero carbon for the residential and non-residential models used. The table show little to no correlation with total offset cost and % Lean reduction. Therefore it can be inferred that an increase in Lean performance will not significantly increase the total cost of zero carbon. Mean has been shown as results were being skewed by single develops due to the number of units in a model or the size of a development.

Mean cost of GLA energy Hierarchy for Residential developments with offsetting by % lean Improvement

% Lean reduction ▲	Average of LEAN uplift cost (total for units modelled)	Average of CLEAN (DHN) heating cost (total for units modelled)	Average of GREEN cost (total for units modelled)	Average of OFFSET cost (total for units modelled)	Average of combined onsite and offset cost
0.00 %	£81,880	£41,039.82	£1,082	£24,061	170,223.80
5.00 %	£64,816	£23,173.08	£483	£13,464	114,450.07
10.00 %	£108,609	£36,935.48	£883	£18,933	185,306.45
15.00 %	£190,046	£58,214.29	£1,834	£30,525	312,055.86
20.00 %	£104,984	£35,156.25	£859	£15,633	175,616.64
30.00 %	£39,919	£12,500.00	£1,382	£4,892	65,442.79

Mean Tonnes saving of GLA energy Hierarchy for Residential developments with offsetting by % lean Improvement

% Lean reduction ▲	BASELINE Emissions (kg CO2) (total for units modelled	LEAN tonnes saved (for al units modelled)	CLEAN tonnes saved (for all units modelled)	GREEN tonnes saved	TONNES CO2 to offset (total for units modelled)
0.00 %	2,069,284.85	62.44	495.39	63.43	1,510.47
5.00 %	286,644.84	24.10	85.65	6.52	194.48
10.00 %	993,696.54	130.66	313.13	28.41	652.15
15.00 %	349,602.10	62.10	98.86	13.32	237.42
20.00 %	487,278.85	110.31	195.11	14.26	277.91
30.00 %	6,757.71	2.09	3.32	0.72	2.72

Mean cost of GLA energy Hierarchy for Non-Residential developments with offsetting by % lean Improvement

% Lean reduction	Average of LEAN uplift cost (total)	Average of CLEAN heating cost (total)	Average of GREEN cost (total)	Average of OFFSET cost (total) (current tariff)	Combined onsite and offset cost
0.00 %	£412,405	£72,060	£5,978	£548,325	£1,038,768
10.00 %	£251,752	£37,798	£6,434	£163,628	£459,612
20.00 %	£86,140	£14,089	£0	£42,588	£142,816
30.00 %	£58,337	£9,105	£4,324	£14,726	£86,492
40.00 %	£26,312	£7,822	£4,313	£813	£39,260

Mean Tonnes saving of GLA energy Hierarchy for Non-Residential developments with offsetting by % lean Improvement

% Lean reduction ▲	Average of BASELINE Emissions (kg CO2) (total)	Average of LEAN tonnes saved	Average of CLEAN tonnes saved	Average of GREEN tonnes saved	Average of TONNES CO2 to offset
0.00 %	393,940.00	16.76	69.46	2.07	304.63
10.00 %	130,508.41	14.62	21.65	1.69	90.90
20.00 %	48,264.15	11.38	13.23	0.00	23.66
30.00 %	38,304.39	12.17	15.71	2.66	8.18
40.00 %	43,399.15	19.54	22.11	3.67	0.45

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