C40 Cities and Greater London Authority

CAP Technical Assistance for London Work Package 2 – Zero Carbon Building Policies

Key Findings Report

REP/02

Issue 4.2 | 17 August 2018

This report takes into account the particular instructions and requirements of our client.

It is not intended for and should not be relied upon by any third party and no responsibility is undertaken to any third party.

Job number 258285-01

Ove Arup & Partners Ltd
13 Fitzroy Street
London
W1T 4BQ
www.arup.com

ARUP

Document Verification

ARUP

Job title	CAP Technical Assistance for London Work Package 2 – Zero Carbon Building Policies			Job number 258285-01
Document title	Key Findings Report			File reference
Document ref	REP/02			

Revision	Date	Filename	WP2_Building_Carbon_Policy_Key_Findings_Report_DRAFT_1_2018-02-05.pdf		
Issue	5th February 2018	Description	For C40, GLA and stakeholder review		
			Prepared by	Checked by	Approved by
		Name	Christina Lumsden / Ethan Monaghan Pisano	Stephen Cook	Stephen Cook
		Signature			
Issue 2	9th Apr 2018	Filename	WP2_Building_Carbon_Policy_Key_Findings_Report_ISSUE_2018-04-09.docx		
		Description	Final copy		
			Prepared by	Checked by	Approved by
		Name	Christina Lumsden	Stephen Cook	Stephen Cook
		Signature			
Issue 3	16 May 2018	Filename	WP2_Building_Carbon_Policy_Key_Findings_Report_ISSUE-3_2018-05-16.docx		
		Description	Minor edits		
			Prepared by	Checked by	Approved by
		Name	Christina Lumsden	Stephen Cook	Stephen Cook
		Signature			
Issue 4	5 Jul 2018	Filename	WP2_Building_Carbon_Policy_Key_Findings_Report_ISSUE-4_2018-07-05.docx		
		Description	Updates following client comments		
			Prepared by	Checked by	Approved by
		Name	Stephanie Robson	Christina Lumsden	Stephen Cook
		Signature			

Issue Document Verification with Document ✓

Document Verification

Job title	CAP Technical Assistance for London Work Package 2 – Zero Carbon Building Policies	**Job number** 258285-01	
Document title	Key Findings Report	**File reference**	
Document ref	REP/02		

Revision	**Date**	**Filename**	WP2_Building_Carbon_Policy_Key_Findings_Report_ISSUE-4.1_2018-07-12.docx		
Issue 4.1	12 Jul 2018	**Description**	Snagging		
			Prepared by	Checked by	Approved by
		Name			
		Signature	CL		
Issue 4.2	17 Aug 2018	**Filename**	WP2_Building_Carbon_Policy_Key_Findings_Report_ISSUE-4.2_2018-07-17.docx		
		Description	Further snagging		
			Prepared by	Checked by	Approved by
		Name	CL	BS	BS
		Signature	CL		
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			

Issue Document Verification with Document ✓

Contents

Tables

Figures

Terms and Acronyms

Defined terms

Able to pay sector	Households with higher incomes or greater access to finance than associated with the social housing or households living in fuel poor conditions.[1] The improved financial situation of this sub-group is assumed to reflect a greater ability to self-finance (including via loans etc.) energy efficiency measures.
Deep retrofit	Describes retrofit which takes a whole-building approach, addressing many opportunities for improved energy efficiency at once.
Fuel poor sector	Households defined as suffering from fuel poverty based on the UK government definition. Households are fuel poor if their required fuel costs are above average and spending this amount would result in a residual income below the official poverty line.[2] Note this sub-group includes any households living in social housing where they meet the fuel poor criteria.
Intervention	A physical measure or behavioural action aimed at reducing carbon emissions from a building.
London Environment Strategy (LES) buildings pathway	The London Environment Strategy pathway refers to a proposed annual emissions trajectory to deliver on London's Zero Carbon by 2050 ambition. This draft pathway was published in London's Zero Carbon Pathway Tool[3]. For the purposes of this report, the pathway was that of the building sector only, covering emissions from energy consumed in London's buildings including residential, commercial and public buildings. As such, we refer to the draft LES buildings pathway.
Large enterprises	Defined as any business with greater than 250 employees.
Lever	An investment, programme, policy, regulation or law which is intended to result in one or more interventions being undertaken.
Minimum energy efficiency standard (MEES)	A requirement to meet a specified minimum level of energy efficiency performance. MEES could be applied to building fabric, household appliances, lighting products or other building plant or equipment. MEES are typically introduced through regulations. Except where noted, the term does not refer specifically to the Energy Efficiency (Private Rented Property) (England and Wales) Regulations 2015.
Public sector	The public sector buildings consist government offices, schools and healthcare centres.
Social housing	Social housing consists of properties provided for social tenants either by a local authority or other social housing provider. Social housing tenants in fuel poor conditions are included as part of fuel poor and therefore excluded from this sub-group (in order to avoid double-counting in the model).
Small and medium enterprises (SMEs)	Any business with fewer than 250 employees.

[1] It is acknowledged that many "able to pay" households are capital constrained or may be at the margin of the fuel poor indicator / social housing eligibility and therefore in practice have limited ability to self-finance energy efficiency retrofit.
[2] https://www.gov.uk/government/collections/fuel-poverty-statistics
[3] https://data.london.gov.uk/dataset/london-s-zero-carbon-pathways-tool

Executive Summary

Arup was appointed by the C40 Cities Climate Leadership Group under its Climate Action Planning Technical Assistance Programme (CAPTAP) to create a tool for London's buildings which could enable an informed assessment of the delivery potential of selected policies, regulations and programmes (referred to as "levers") to achieve greater energy efficiency in buildings. The analysis built on previous scoping of the technical potential for carbon emissions reduction from energy efficiency measures and focused on translating feasibility into deliverability via a portfolio of London and national government-initiated levers.

This report has been written by Arup and does not necessarily reflect the views of the GLA. No endorsement by the GLA of specific policies, regulations or programmes discussed in the report is claimed or implied.

This study forms a part of a suite of studies undertaken for the GLA to provide an overall evidence base for action on energy and carbon in London. This study included the following:

- Thermal and electrical energy efficiency measures in buildings (e.g. fabric improvements, new appliances and low energy lighting)
- Installation of building-scale solar thermal and heat pumps
- Adoption of energy efficient cooling systems was included as an exogenous phenomenon (i.e. not driven by the levers)

On-site renewable electricity and assessment of different options for decarbonisation of heat supply such as hydrogen supply were excluded.

A separate zero carbon energy systems study (covering low carbon infrastructure and energy supply technologies) was undertaken in parallel with this buildings-focused study. That study included deployment and decarbonisation scenarios for electricity, heat networks, heat pumps, hydrogen and local solar PV generation.

The two studies fit together. The building energy performance model created for this study formed a key input to the separate zero carbon energy systems study.

Core to this study was the identification of "lever packages" targeting groupings of the building stock – with a primary lever providing the overarching characteristics of each lever package. These packages seek to represent a wide range of available policy mechanisms which respond to the breadth of barriers to carbon reduction within the built environment (e.g. cost and complexity of measures, poor financial payback, regulatory drivers, lack of incentives, access to finance etc.).

Our application of the modelling tool identified lever package scenarios under which London delivers different rates of deployment of energy efficiency measures and related carbon emissions reduction. The rates of deployment were shaped by judgements by the project team on the timing and effectiveness of each lever package in each scenario. The judgements were based on evidence where available (e.g. the Government's Clean Growth Strategy); where evidence was lacking, the judgements were applied with consideration of current and potential future political limitations and the potential power of each lever package to influence the behaviour of building owners and investors.

However, even with an extensive portfolio of lever packages, no scenario pathway was found to achieve the extent of decarbonisation reflected in the buildings element of the ‘zero carbon by 2050’ pathway presented in the draft London Environment Strategy. Note that this is just the buildings sector. London’s overall emissions pathway under different infrastructure decarbonisation scenarios, and considering offsetting to reduce residual emissions, is presented in the Element Energy Zero Carbon Energy Systems study.

Arup defined a Central scenario which set out the possible deployment of energy efficiency if a concerted policy effort begins. This was then sensitivity tested for increased/decreased effectiveness and earlier/later deployment. This central scenario enables annual energy savings through building retrofit of 380 TWh against a No Action Business as Usual (BAU) projection. The Central scenario also enables annual savings from appliance energy efficiency of 140 TWh.

The Central scenario results in an energy efficiency savings gap, against the draft LES buildings pathway, of 15 TWh in 2050. From a carbon perspective, the Central scenario results in cumulative emissions of 448 $MtCO_2e$ over the period 2015-2050. Further cumulative savings from buildings of 90 $MtCO_2e$ are required to align fully with the draft LES buildings pathway.

The Central scenario, nonetheless, requires a considerable increase on past rates of interventions. For instance, at its peak, the Central scenario requires four times more installations of cavity and solid wall insulation annually than has been achieved since 2008 by national and London-initiated levers combined.

Carbon savings were modelled from a combination of London and national government-initiated levers. It should be recognised that government initiatives may not be the only means to enable transformation. Given the emissions gap highlighted by the Central scenario, further analysis is required to investigate possible ways to develop a market in which energy efficiency is valued and undertaken outside specific Government/GLA programmes, e.g. tied to life events, such as home purchase.

Barriers to energy efficiency are wide ranging and persistent; therefore, government intervention, particularly through national regulation, forms part of the lever packages modelled for this study. Assuming no change in powers between national government and city government, national government action will greatly determine London’s success due to its powers to introduce minimum energy performance standards and fiscal incentives for energy efficiency retrofit. According to our analysis, London-initiated levers can achieve 39 $MtCO_2e$ of savings of the Central scenario against the No action BAU, representing 31% of the total savings. The largest contribution stems from national government-initiated levers with 77 $MtCO_2e$ carbon savings, representing 61% of total emission savings. The savings from the Minimum Energy Efficiency Standard (MEES) on appliances and lighting products are assumed to continue to be driven by European Union (EU) product policy standards and contribute 11 $MtCO_2e$ or 9% of cumulative savings.

The split power relationship over interventions is reflected in the total capital expenditure (CAPEX) of interventions attributed to each, estimated to total £39 billion, of which the London government-initiated levers and national government-initiated levers represent £14 billion (38%) and £25 billion (62%) respectively. Further analysis is required to understand who will pay for these interventions and build a cost effective funding strategy combining local and national government grants and loans, private finance and consumer investment.

The key recommendations resulting from this analysis are the following:

- Further analysis is required to improve understanding of the potential effectiveness of levers both directly and in triggering self-initiated retrofit (associated with a change in perception towards energy efficiency).
- The GLA can lead pilot projects and scale up city-led action to help develop the market and supply chain. Technical assistance and whole house retrofit programmes present an important opportunity to support key sectors of the market such as the fuel poor, social housing tenants, SMEs and the public sector. Additionally, updates to the London Plan will now require zero carbon new non-domestic builds and will encourage further low carbon heat, including heat pumps and energy efficiency measures, as well as smart controls.
- London cannot deliver on its ambitions of achieving near zero carbon emissions from its building sector by 2050 without the support of national government and London boroughs. The introduction of ambitious MEES relating to building performance (stipulated against EPC ratings), appliance and lighting products is imperative to achieving higher levels of retrofit.
- Maintaining high levels of retrofit is critical to developing a mature and sustainable supply chain which ultimately will bring quality and cost benefits. However, this development is not guaranteed, with careful attention needed through training and monitoring to close the performance gap.
- It will take time to build a consensus for some of the more politically challenging levers; through continuing to engage with the national government to build a coalition for action.
- Delaying action is likely to result in higher carbon emissions and therefore action on readily deliverable levers should be ramped up immediately. The Late scenario indicated a five-year delay could lead to 33 $MtCO_2e$ of additional carbon emissions compared to the Central scenario, representing a 7% increase in total emissions over the modelled period.

1 Introduction

1.1 Context

Arup was appointed by the C40 Climate Leadership Group under its Climate Action Planning Technical Assistance Programme (CAPTAP) to create a tool for London's buildings which could enable an informed assessment of the delivery potential of selected policies, regulations and programmes (referred to as "levers") to achieve greater energy efficiency in buildings.

Core to the tool and the study was the identification of "lever packages" targeting sub-sectors of the building stock – with a primary lever providing the overarching characteristics of each lever package. These packages seek to represent a wide range of available policy mechanisms which respond to the breadth of barriers to carbon reduction within the built environment (e.g. cost and complexity of measures, poor financial payback, regulatory drivers, lack of incentives, access to finance etc.).

Since the GLA has already undertaken technical modelling of emissions from London's buildings, this work focused on how levers can shape the timing and scale of interventions in the sector which will lead to the desired energy efficiency and carbon reduction outcomes. The analysis built on previous scoping of the technical potential for emission reduction and focused on translating feasibility into deliverability via a portfolio of government-initiated levers. Thus, although review of technical feasibility was not within the scope of this study, key areas of uncertainty from the previous assessment of technical potential are outlined below given their implication on policy priorities:

- It was assumed in the modelling that a significant proportion of properties will not be retrofitted beyond Energy Performance Certificate (EPC) rating C. This decision reflects the understanding that the feasibility of retrofitting most existing domestic stock in the UK is limited by technical and economic factors. The choice of EPC C as a target was based on the fact that to model an increased level of retrofit above EPC C depends much more heavily on individual building characteristics and limitations, rather than the generic improvements that can be assumed in reaching up to EPC C. There is also research showing that the target of EPC C represents a cost-effective level of ambition, both for property owners and in terms of delivering net economic benefits to society as a whole[4]. Finally, using EPC C as a target rating is consistent with government policy; the government's Clean Growth Strategy features the use of EPC C as a target for the domestic sector[5].
- Cross-checking of estimates of the modelled energy saving potential from retrofit interventions within the domestic sector against figures from the Energy Saving Trust and RE:NEW indicate these may be conservative and energy saving potential therefore could be higher.

[4] http://www.energybillrevolution.org/wp-content/uploads/2014/10/Building-the-Future-The-Economic-and-Fiscal-impacts-of-making-homes-energy-efficient.pdf
[5] https://www.gov.uk/government/publications/clean-growth-strategy

- Cross-checking of the modelled energy saving potential from energy efficiency improvements in domestic and non-domestic appliances against Household Energy Use Survey results indicates these may be ambitious and total energy saved could be lower, by 20-30%. This has significant implications on energy saving potential across the building stock as a whole (see Section 5.1.1 which discusses the total energy savings from appliance efficiency).
- Characterisation of the non-domestic sector was poor due to low data availability in particular with regard to reflecting the variety of building envelopes and Heating, Ventilation and Air Conditioning (HVAC) systems. HVAC improvements affecting cooling and fan operation were not affected by lever packages. Additionally, the impact of lighting energy efficiency is arguably underestimated. Previous modelling proposed that lighting demand per m^2 would remain unchanged despite an increase in units (i.e. higher demand and efficiency offset each other).

Our application of the modelling tool identified lever package scenarios under which London delivers different rates of deployment of measures and related carbon emissions reduction. The rates of deployment were shaped by judgements by the project team on the timing and effectiveness of each lever package in each scenario. The judgements were based on evidence where available (e.g. the Government's Clean Growth Strategy); where evidence was lacking, the judgements were applied with consideration of political limitations and the potential power of each lever package to influence the behaviour of building owners and investors.

1.2 Purpose of report

This report presents a summary of the key findings of Arup's Building Energy Efficiency Lever Deployment Tool (BEELDT) completed in February 2018.

A separate technical report has been prepared to provide technical background to the production of Arup's lever deployment model, including methodology and key references. Detailed assumptions and information on how the model works are contained within the model itself.

This report has been written by Arup and does not necessarily reflect the views of the GLA. No endorsement by the GLA of specific policies, regulations and programmes discussed in the report is claimed or implied.

1.3 Structure of report

Following this introductory chapter, this report is structured into the following topics:

- Chapter 2: Scope of Arup's commission
- Chapter 3: Summary of London's building stock and energy demand according to the sub-groups used for policy analysis
- Chapter 4: Review of past performance of levers to deliver building retrofit

- Chapter 5: Presentation of key findings from analysis of future levers
- Chapter 6: Recommendations to the GLA based on the findings from the analysis

2 Scope

2.1 Scope

Arup's work is referred to as "Work Package 2" (WP2) and is focused on delivery of emissions reduction interventions within buildings. The scope of this analysis was to model carbon emission pathways of London's buildings in annual increments based on an informed assessment of the delivery potential of selected levers. Based on previous GLA modelling, the key opportunities for decarbonisation were identified as energy efficiency measures and replacement of gas boilers with heat pumps.

This study forms a part of a suite of studies undertaken for the GLA to provide an overall evidence base for action on energy and carbon in London. This study included the following:

- Thermal and electrical energy efficiency measures in buildings (e.g. fabric improvements, new appliances and low energy lighting)
- Installation of building-scale solar thermal and heat pumps
- Adoption of energy efficient cooling systems was included as an exogenous phenomenon (i.e. not driven by the levers)

On-site renewable electricity and assessment of different options for decarbonisation of heat supply such as hydrogen supply were excluded.

A separate zero carbon energy systems study (covering low carbon infrastructure and energy supply technologies) was undertaken in parallel with this buildings-focused study, called Work Package 3 (WP3). That study included deployment and decarbonisation scenarios for electricity, heat networks, heat pumps, hydrogen and local solar PV generation.

The two studies fit together. The building energy performance model created for this study formed a key input to the separate zero carbon energy systems study.

The following table clarifies the scope of WP2 and WP3 in relation to reducing emissions in the built environment. Within the WP3 remit, the heat pump deployment rates were reviewed and revised and as such, these are treated by both studies.

Table 1 Scope of each work package with regard to defining the deployment of a decarbonisation solution in building emissions

Decarbonisation solution	WP 2	WP 3
Energy efficiency	✓	
Solar thermal	✓	

Decarbonisation solution	WP 2	WP 3
Heat pumps	✓	✓
District heat networks including heat supply systems		✓
Bio-methane supply		✓
Conversion to hydrogen supply		✓
Hybrid heat pumps		✓
Options for full electrification of heat		✓
On-site renewable electricity		✓
Energy storage and demand side response		✓

3 London's building stock

3.1 London's building stock and energy demand

When considering London's building stock from a public policy perspective, sub-groups emerge within the domestic and non-domestic sector. These sub-groups broadly reflect differentiated capacity to finance building retrofit and alignment with the GLA and London boroughs powers. The table below presents a definition of the resulting sub-groups:

Domestic / non-domestic	Sub-group	Definition
Domestic	Fuel Poor	Households defined as suffering from fuel poverty based on the UK government definition. Households are fuel poor if their required fuel costs are above average and spending this amount would result in a residual income below the official poverty line.[6] Note this sub-group includes any households living in social housing where they meet the fuel poor criteria.
	Social Housing	Social housing consists of properties provided for social tenants either by a local authority or other social housing provider. Social housing tenants in fuel poor conditions are included as part of fuel poor and therefore excluded from this sub-group (in order to avoid double-counting in the model).
	Able to Pay	Able to pay was a term used to represent households with higher incomes or greater access to finance than associated with the social housing or households living in fuel poor conditions.[7] The improved financial situation of this sub-group is assumed to reflect a greater ability to self-finance (including via loans etc.) energy efficiency measures.

[6] https://www.gov.uk/government/collections/fuel-poverty-statistics
[7] It is acknowledged that many households are at the margin of the fuel poor indicator / social housing eligibility and therefore may not be able to self-finance energy efficiency retrofit.

Domestic / non-domestic	Sub-group	Definition
Non-domestic	Small and Medium Enterprises (SMEs)	Defined as any business with fewer than 250 employees.
	Large Enterprises	Defined as any business with greater than 250 employees.
	Public Sector	The public sector buildings consisted in government offices, schools and healthcare centres.

The figures below show the breakdown of the building stock and energy demand in 2015 and 2050 according to the chosen sub-groups. In terms of numbers of buildings, the domestic sector is significantly larger than the non-domestic sector, with each representing 91% and 9% of the total number of buildings in London respectively. The largest of the domestic sector is the Able to pay sub-group representing 68% of the domestic sector, followed by social housing (21%) and the fuel poor (11%). Within the non-domestic sector, the SME and large enterprise[8] sectors are shown to be similar in number of buildings, whilst the number of public buildings represents just 16% of the number of non-domestic buildings.

The share of energy across the domestic and non-domestic sector changes with regard to the stock picture, as the contribution of the non-domestic sector to total heat demand is 35% and total electricity demand is 62%. Public buildings, which represent just 1% of London's buildings are typically large institutions resulting in a contribution of 11% and 14% of London's heat and electricity demand respectively. This concentration of energy demand and ownership is also apparent in the large enterprises and presents an opportunity for energy efficiency levers.

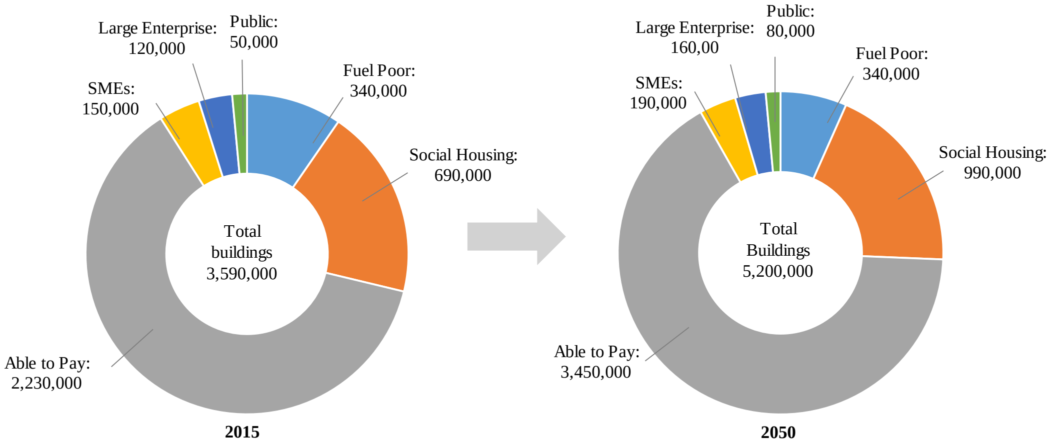

Figure 1 Breakdown of London's building stock in 2015 and 2050 [9]

[8] Note given the lack of data for the non-domestic sector, there is considerable uncertainty regarding the breakdown of the non-domestic sector, in particular within the private sector.
[9] Based on previous GLA modelling, recent Strategic Housing Land Availability Assessment (SHLAA) projections of new housing and Arup analysis to determine split of non-domestic building stock – see supporting technical documentation for more details.

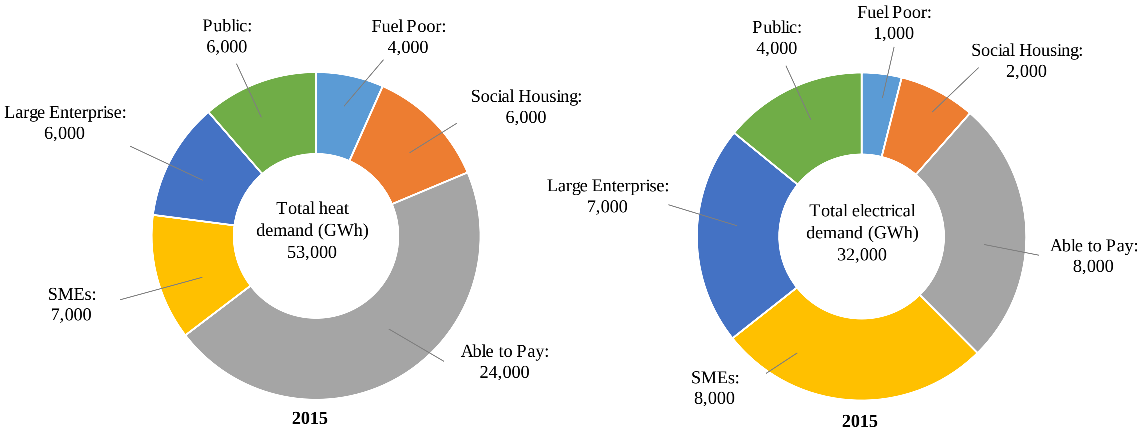

Figure 2 Breakdown of London's electricity and heat demand in 2015

4 Historic and current levers in building retrofit

4.1 Building retrofit from established programmes

Over the last 10 years, there have been several local and national government programmes introduced to drive energy efficiency in existing buildings. A common indicator of effectiveness is the number of buildings retrofitted as a result of the programmes. As such, Figure 3 shows the performance since 2008 in terms of buildings receiving at least one retrofit intervention as a result of national or London specific levers.[10] The corresponding total annual carbon savings enabled by these programmes is estimated to rise to 260,000 tCO_2e by 2021.

Given the difference in eligible interventions of programmes or success in enabling these, the impact in carbon savings differs per programme. For instance, the national government's supplier obligation Carbon Emissions Reduction Target (CERT) was found to have achieved on average carbon savings of 440 tCO_2e per property, nearly double that of RE:NEW with an average 170 tCO_2e saved per property. These is because RE:NEW phase 1 focused on "low hanging fruit" simple measures such as replacing lighting.

Historically, programmes have shown mixed success in achieving deep retrofit, particularly with regard to fabric measures. The number of fabric retrofit measures is much lower than the building engagement figures suggest with just under 40% of interventions undertaking wall insulation[11]. This is particularly notable for early phases of the London programme RE:NEW for which wall insulation has been estimated to account for just 7% of all interventions. Similar results are found for

[10] Based on available data or estimates of historic performance as well as projections based on defined levers. Certain levers were exempted because of poor or no data availability. See supporting Technical Report for more details.
[11] Cavity or solid wall insulation

the RE:FIT programme[12]. However, in the most recent phase of RE:NEW, Phase 3, over 80 % of the measures have been insulation or other fabric improvements, heating improvements or renewable energy installations, with 20% wall insulation. According to conversations with GLA RE:FIT programme manager, lighting replacement was the most popular intervention with wall insulation being introduced in only one case.

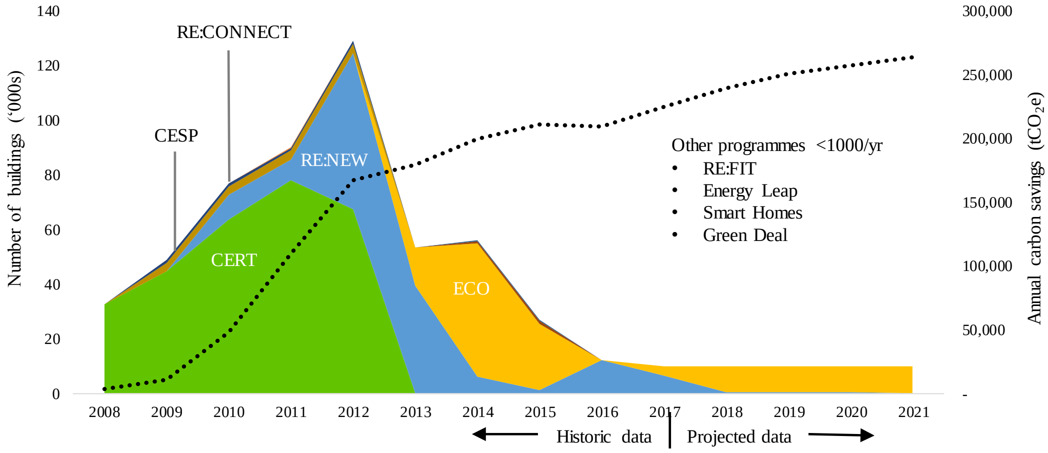

Figure 3 Buildings retrofitted with energy efficiency interventions by programme/policy

Reviewing the profile of deployment of building retrofit, the data indicate that building retrofit peaked in 2012 and has declined significantly since then. The years 2008 to 2012 saw a steep rise of near 300% (from 33,000 to 129,000 buildings) driven primarily by CERT. CERT alone was responsible for undertaking 287,000 retrofit measures over its lifetime, representing 53% of buildings retrofitted from 2008 to 2017. The next most effective programmes in terms of building uptake were RE:NEW and ECO, each of which accounted for 26% and 17% of buildings retrofitted up to 2017.[13] Other programmes had far less impact (numbering in the tens and hundreds of buildings).

CERT's significant historic impact is highlighted by the steep decline in building retrofits since 2012, which coincides with the programme coming to an end. This decline is emphasised by RE:NEW changing its approach from large scale easy-win retrofits in private properties to whole house retrofit targeted at social housing after 2012. Despite the introduction of ECO in 2013, this programme did not replicate the volume of retrofits by CERT and, in fact, there was a significant decline in building retrofits (from 49,000 in 2014 to 3,700 building retrofits per year by 2017). Overall, during the five-year period between 2012 and 2017, the number of annual building retrofits fell by 92% from approximately 129,000 to 10,000 buildings. From 2017 to 2021, projected cumulative retrofits are from RE:NEW and ECO in London, totalling 8,000 and 42,000 buildings respectively.

[12] It is acknowledged that non-domestic buildings vary more significantly in their characteristics and wall insulation may not have been an appropriate measure for those building supported by RE:FIT to date.
[13] The RE:NEW programme also referred buildings for support from ECO. These were assigned to the RE:NEW programme to avoid double counting.

4.2 Need for accelerated action

The need for more effective and increased action is highlighted in the comparison of historic and target carbon savings in Figure 4 (based on the buildings sector achieving its share of the draft LES buildings pathway). Historic savings to date represent just 10% of the target annual savings.[14]

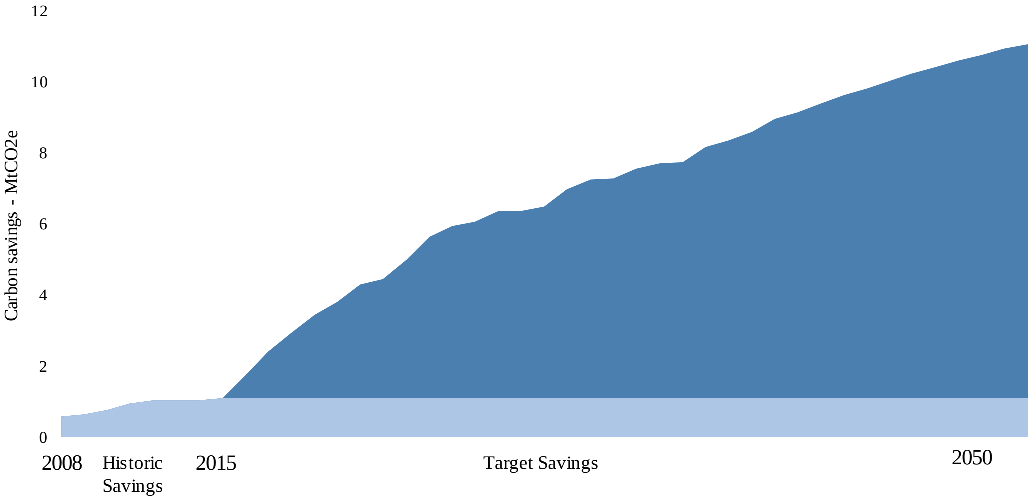

Figure 4 Historic carbon savings in buildings compared to target savings under the draft LES buildings pathway (excluding savings achieved by decarbonisation of the electricity and gas networks).

In order to quantify this, the number of historic interventions and the amount of carbon savings were mapped for levers specific to London, and national levers where London buildings were affected. Table 2 provides a summary of historic and current levers considered in this study.

Table 2 Summary of historic and current levers

Implementation authority	Domestic sector	Non-domestic sector
London	• Smart homes • RE:CONNECT • Fuel poverty support programme • RE:NEW • Fuel poverty support programme • Low Carbon Zones • Zero carbon standard planning policy	• Better Buildings Partnership • Green 500 • Green Homes - Concierge Service • LDA Energy Efficiency Revolving Fund • ERDF • RE:FIT • LEEF • Zero carbon standard planning policy
National government	• RHI	• RHI Non-domestic

[14] The impact of grid and gas decarbonisation has been discounted from the future carbon savings in the graph shown.

Implementation authority	Domestic sector	Non-domestic sector
	• ECO • CESP • CERT • Smart meter rollout domestic • Products policy • Heat networks Investment project • PRS Regulations	• Smart meter rollout • Products policy • Carbon Trust measures • EPBD • SME Loans • CCL Budget 2016 Changes • CRC-ees • ESOS • Heat Networks Investment Project • PRS Regulations

Maintaining London's historic rate of action out to 2050 cannot deliver the required savings according to the London Environment Strategy (LES)[15] buildings pathway, as shown by Figure 5 below.

For context, we have included two BAU scenarios:

1. No action BAU: representative of a scenario in which no efforts are made to improve energy efficiency and deliver on heat decarbonisation however grid decarbonisation is achieved in accordance with the Department of Business Energy and Industrial Strategy (BEIS) projections.
2. Current levers BAU: representative of a scenario in which the national government delivers on its currently defined levers (such as the next phase of ECO running to 2022) and the GLA maintains ongoing[16] programmes up to 2050. Grid decarbonisation aligned with BEIS projections has also been assumed.

Under the Current Levers BAU, London would exceed its carbon budget by 200 $MtCO_2e$, equivalent to 56% higher than its target budget. LES

[15] For the purposes of this report, the draft LES buildings pathway covers emissions from energy consumed in all of London's buildings including residential, commercial and public buildings.
[16] Includes programmes due to commence in the short term provided they are sufficiently defined to estimate carbon savings.

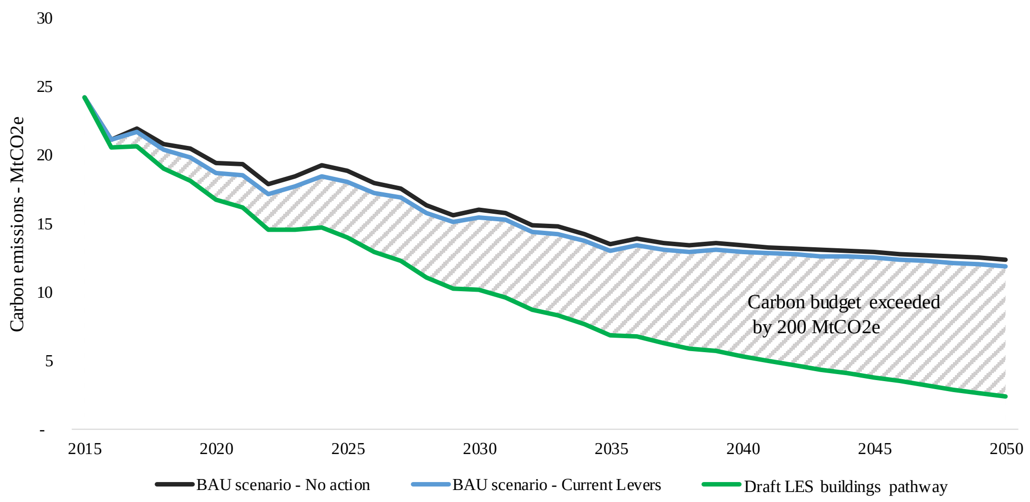

Figure 5 Comparison of draft LES and BAU buildings pathway sector emissions trajectories

The table below summarises the target number of actions considered within this study to achieve the draft LES buildings pathway. These interventions reflect current understanding of the state of the building stock (e.g. number of properties that have empty cavities) as well as an assessment of constraints (e.g. restrictions on external wall insulation in conservation areas). The modelling of lever packages was based on triggering these interventions with an average of five per property.

Table 3 Summary of draft LES buildings pathway target number of building retrofits by intervention type

Interventions	Domestic sector	Non-domestic sector
Cavity wall insulation	885,000	84,000
Solid wall insulation	1,295,000	232,000
Loft insulation (top-up or virgin)	2,433,000	**
Glazing improvement	3,093,000	316,000
Domestic Hot Water (DHW) saving measures	3,093,000	316,000
Floor insulation	1,499,419	**
Building energy operation*	3,914,000	314,000
Lighting and appliance efficiency	4,720,000	419,000
Solar thermal installation	209,000	8,700
Heat pump installation and low temperature heating	3,257,000	372,600

*Refers to installation of smart controls on energy systems
**These interventions have not been included as separate measures within the non-domestic sector

4.3 Limits to scaling

Based on information provided by the GLA and from literature, a number of common factors, many of which are non-financial, inhibit the potential for growth and expansion of existing levers. Those experienced with respect to RE:NEW and RE:FIT offer some of the most recent and relevant examples.

Key limitations with RE:NEW, and other levers which target the owner occupied and private rented sector, are:

- the challenge in addressing non-financial barriers to uptake including lack of knowledge or understanding of benefits of retrofit;
- Unwillingness to endure the disruption of retrofit works (the value of savings is outweighed by the cost of disruption); and
- underdeveloped supply chains which deter householders from investing in building retrofit measures, even where funding/financial incentives are available.

Regulation which could act as a driving force to stimulate the market is likely to prove ineffective without enforcement strategies as well as a wider package of supply chain and financial support. The recently introduced new private rented sector Energy Efficiency Regulations 2015 which introduce Minimum Energy Efficiency Standard (MEES) are proving to be relatively weak and unlikely to induce change because of the lack of these supporting mechanisms.

Limitations with RE:FIT offer examples of barriers within non-domestic levers, particularly for the public sector. One of the significant challenges to RE:FIT has been the lack of senior buy-in from public sector clients which is deepened by an uncertainty in asset ownership, where clients are unsure whether their current assets will be within their portfolio in years to come. Recent cuts in the public sector pushed the sustainability agenda down the priority list, with energy and sustainability managers/teams often being first to suffer from budget cuts even though access to finance for energy efficiency interventions was readily available through Salix Finance or the London Energy Efficiency Fund (LEEF). Certain sectors such as the NHS and central government did report financial constraints due to reaching their borrowing limit.

These limits to scaling are typical of historic challenges, however a more recent and imminent challenge, particularly facing domestic levers of the future, is the post-Grenfell re-assignment of resources, with funding moving from building retrofit, towards health and safety as well as uncertainty of standards and liabilities in the supply chain. Going forwards, quality standards could play an important role in improving the quality of materials and skills.

5 Key findings and conclusions

5.1 Central scenario

Our application of the modelling tool identified lever package scenarios under which London delivers different rates of deployment of measures and related carbon emissions reduction. The Central scenario results from Arup's assessment of the potential for a defined set of levers to deliver a level of ambition consistent with the draft LES buildings pathway target interventions (see Table 3).

The rates of deployment were shaped by judgements by the project team on the timing and effectiveness of each lever package in each scenario. The judgements were based on evidence where available (e.g. the Government's Clean Growth Strategy); where evidence was lacking, the judgements were applied with consideration of current and potential future political limitations and the potential power of each lever package to influence the behaviour of building owners or investors.

The Central scenario primary levers are broadly characterised by the following:

- Local government-initiated programmes similar to RE:NEW and RE:FIT to support sub-groups of the market in most need of support e.g. fuel poor, social housing, public sector and SMEs.
- Fiscal incentives such as stamp duty, council tax and business rates variation according to EPC rating.
- Introduction of MEES to achieve EPC rating C across the whole building stock
- European market-initiated minimum energy performance standards on appliance products and lighting.
- National government-initiated support for radical transition from gas supplied heating to heat pumps in existing properties.
- Stronger planning regulation on the new build sector to drive wide scale uptake of low carbon heating solutions (heat pumps and solar thermal) and smart system controls as well as establishing MEES targets on the entirety of a property which is seeking planning permission for major renovation works.

5.1.1 Overview of results

As shown in Figure 6, the Central scenario enables cumulative savings of 380 TWh against the BAU - No action scenario through building retrofit[17] and a further 140 TWh from appliance energy efficiency. The Central scenario levers, however, do not achieve the draft LES buildings pathway ambition for annual energy demand by 2050, showing a gap of 15 TWh.

[17] By building retrofit we refer to a package of interventions including fabric efficiency measures, smart heating controls, DHW saving measures and lighting replacement.

Within the Central scenario, the bulk of the energy efficiency improvements are made by 2030 in line with the aspirations made in the Clean Growth Strategy. After this, the increase in energy demand is driven by new-build construction. The Central scenario is built up from annual deployment of energy efficiency interventions and therefore shows a more gradual energy demand pathway against the draft LES buildings pathway which is built up from linear interpolation between 2015, 2025 and 2050.

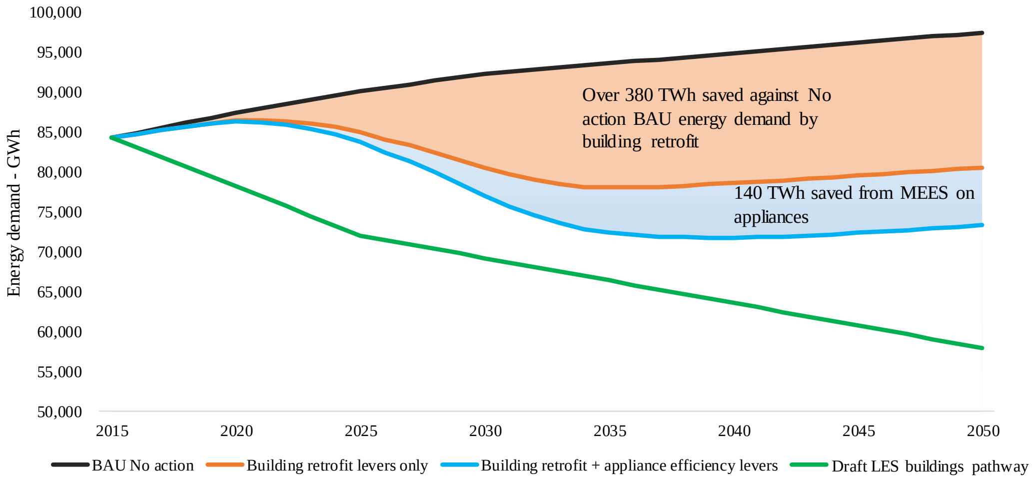

Figure 6 Energy demand pathway enabled by Central levers

Figure 7 below, presents a more complete picture of the Central scenario as fuel switching and grid decarbonisation are captured within the All Levers emissions pathway. Our analysis indicates that between 2015 and 2050, further cumulative savings of 90 $MtCO_2e$ are required to align with the draft LES buildings pathway.[18] The Central scenario pathway descends to an annual emissions level of 6 $MtCO_2e$ per year by 2050, three times the draft LES buildings pathway target of 2 $MtCO_2e$ per year in 2050.

As highlighted, the impact of appliance energy savings is diluted by the grid decarbonisation such that the savings are barely perceptible. Nonetheless, over the period considered these account for 9 $MtCO_2e$ of emissions saved. A further 39 $MtCO_2e$ of emissions are saved between 2030 and 2050, primarily due to the replacement of gas boilers with heat pumps.

[18] Note that this comparison is used for context only.

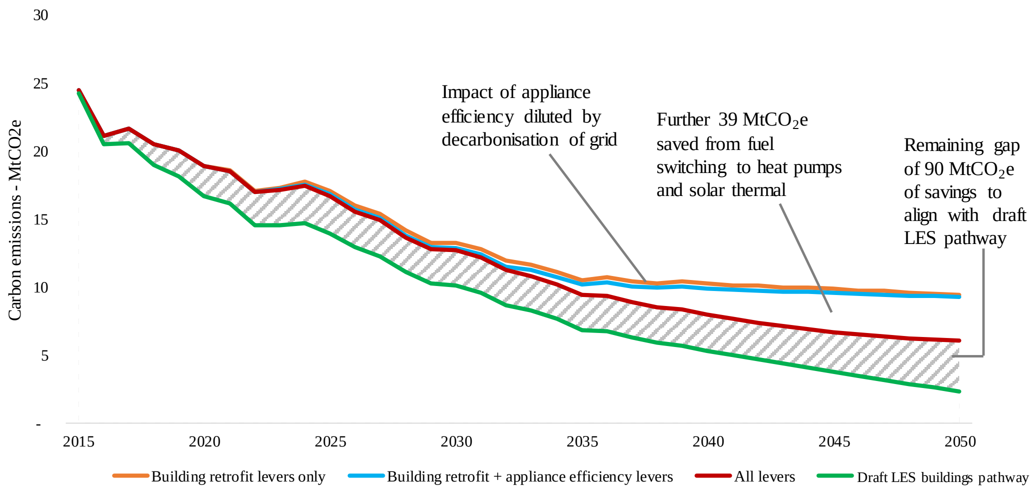

Figure 7 Comparison of Central scenario with draft LES buildings pathway

5.1.2 Lever package deployment curves

The carbon emissions pathway emerges from the rate of deployment of interventions triggered by different lever packages. The following six figures demonstrate the annual rate of impact of lever packages in terms of number of buildings affected across the domestic and non-domestic stock.

For each lever package, there are a set of assumptions around the timing of the lever deployment (e.g. start year and end year), and the assumed effectiveness of the lever package. These assumptions dictate the 'shape' of the deployment profiles, with the total number of retrofits represented by the area under the curve, and the peak retrofits per year represented by the peak of each curve.[19].

Figure 8 to Figure 11 show the annual retrofit of properties by all the lever packages targeting the reduction of heat demand either through fabric efficiency, domestic hot water (DHW) saving measures or use of smart controls. The shapes of the curves reflect different interactions with the market. For example:

- the council tax variation lever package assumes a constant rate of building retrofits (parallelogram shape), incentivised by the fiscal policy during its lifetime.
- the domestic retrofit and whole house retrofit programmes show a rapid ramp up, followed by a period of continuous impact, and then a slow descent out to 2050. The shape of the descent reflects the ongoing impact of the lever on properties that are difficult to engage or hard to treat.
- MEES mandates accelerate over time in line with incremental introduction of higher EPC rating targets from E to C. A fixed deadline for compliance leads to a steep drop in retrofits after the deadline year. Because most properties in London are within the EPC band D, it is in the final years of the lever's

[19] For a more detailed justification of deployment assumptions, see the underlying model – Building Energy Efficiency Lever Deployment Tool (BEELDT)

operation that the largest number of properties are stimulated to deliver retrofit measures.

- The levers affecting new build, namely “Stronger planning requirement for smart controls” show a staggered curve reflecting new build construction projections between today and 2050.

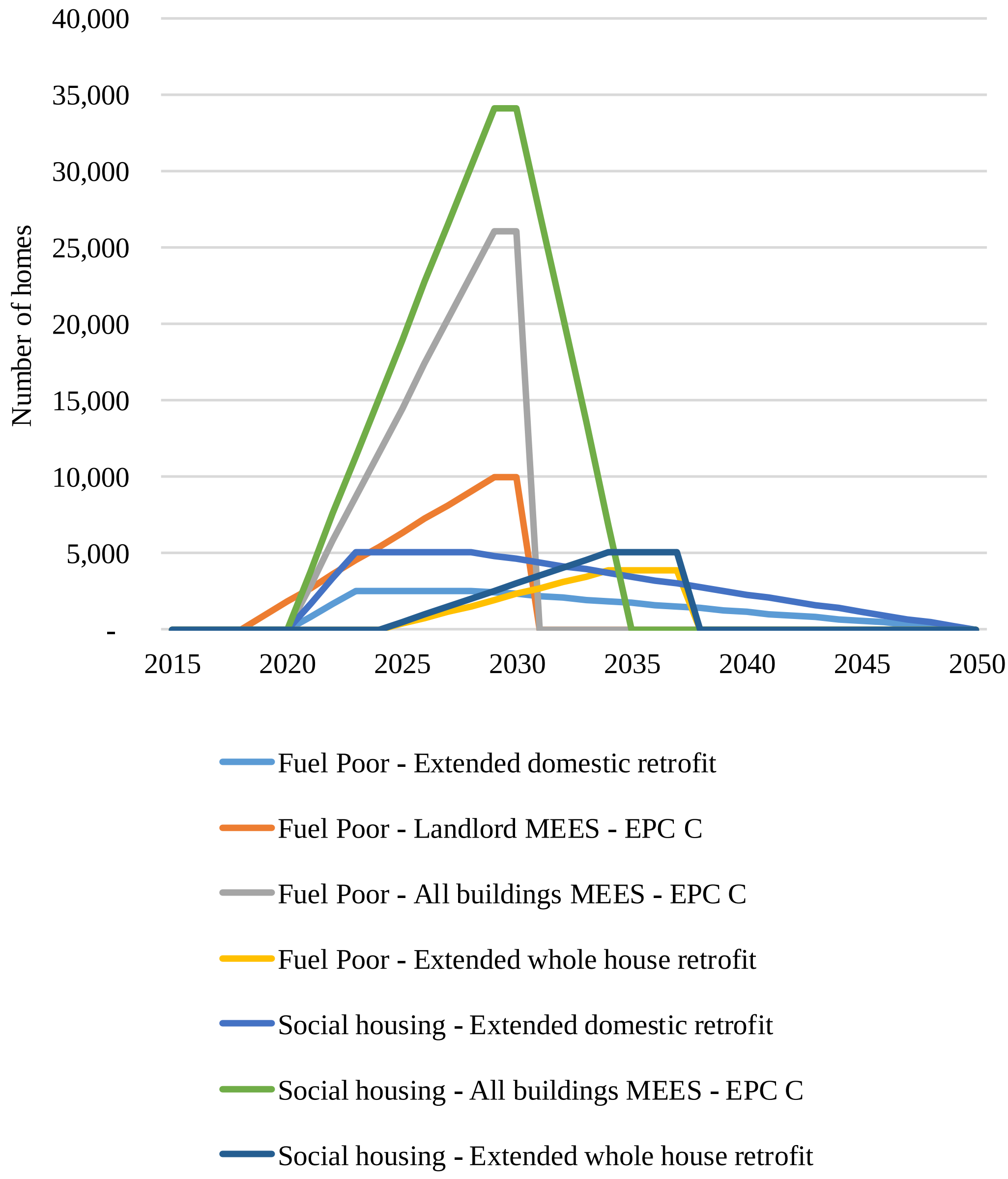

Figure 8 Fuel Poor and Social Housing homes retrofitted annually by lever packages targeting thermal efficiency

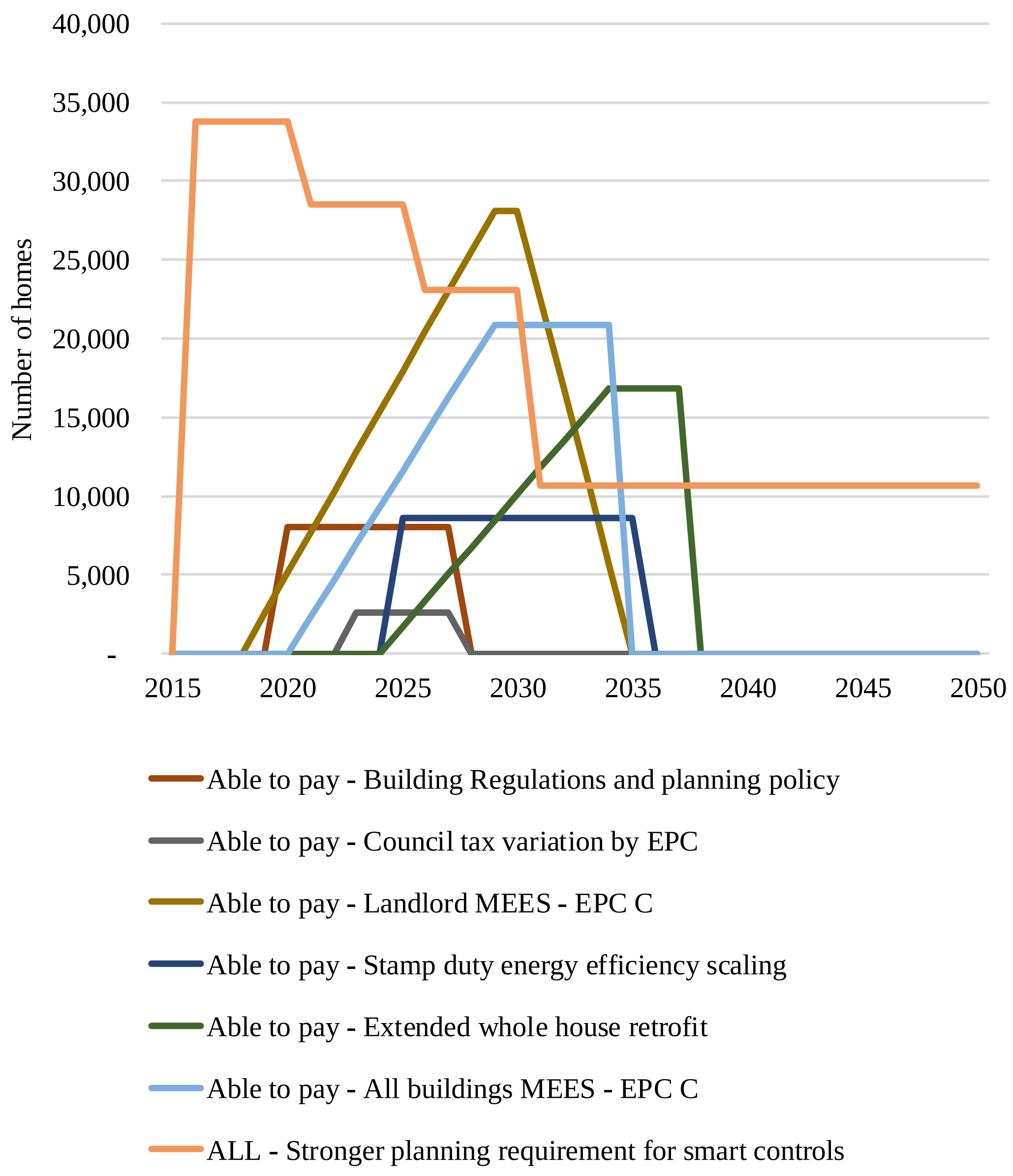

Figure 9 Able to pay homes retrofitted annually by lever packages targeting thermal efficiency, plus all-homes planning policy lever

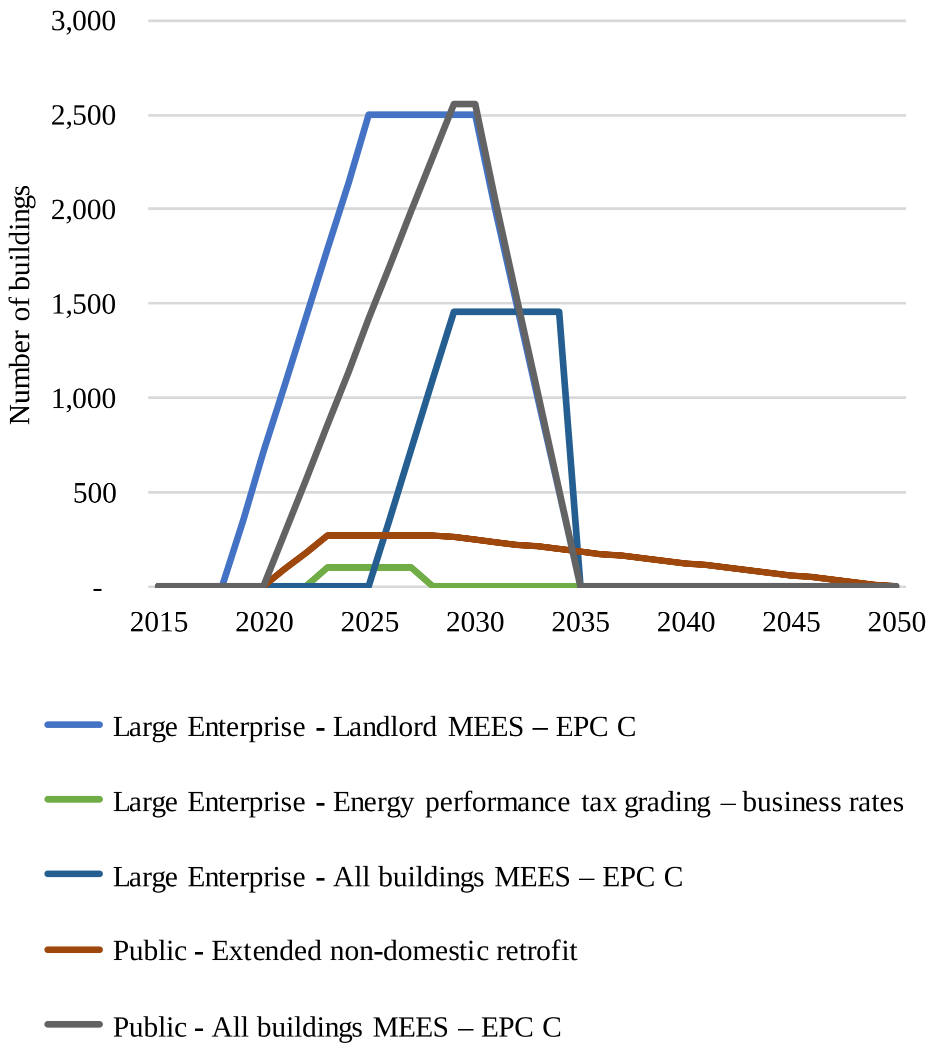

Figure 10 Non-domestic large enterprise and public-owned properties retrofitted annually by lever packages targeting thermal efficiency

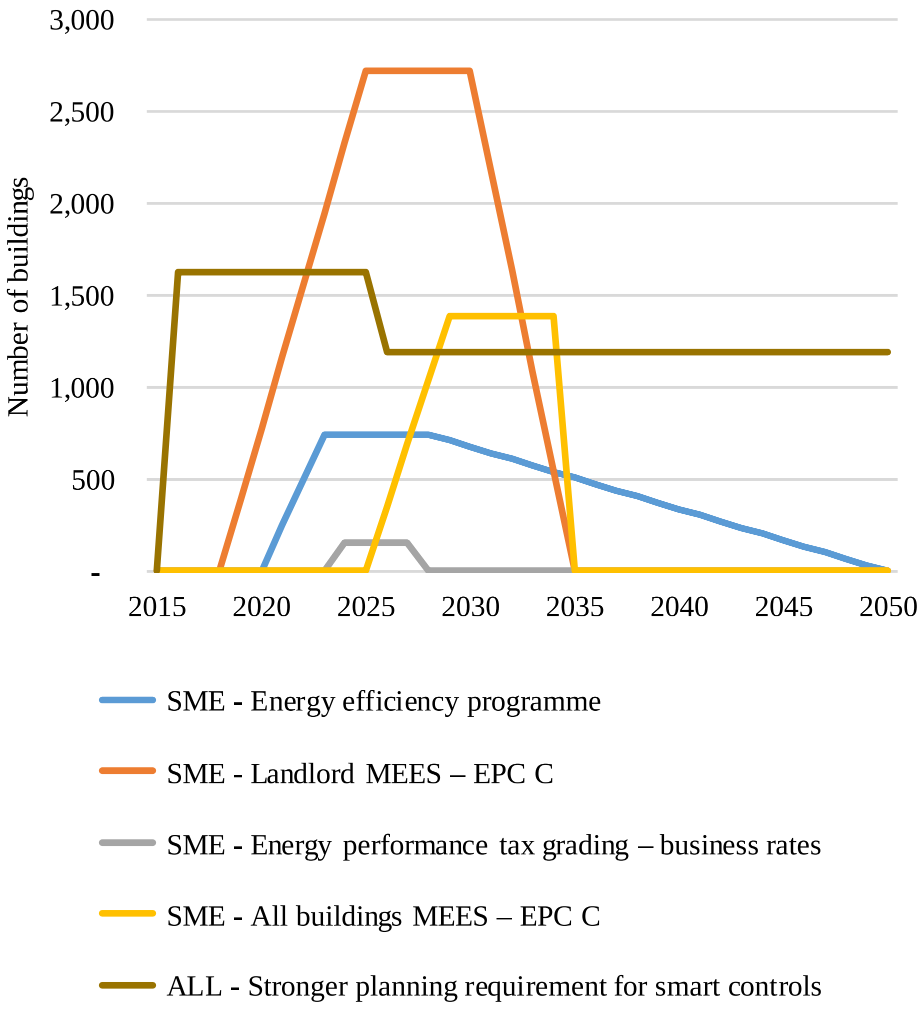

Figure 11 Non-domestic SME properties retrofitted annually by lever packages targeting thermal efficiency, plus all-non-domestic buildings planning policy lever

The following Figure 12 and Figure 13 show the deployment impact of minimum energy efficiency standards on appliance products and lighting. These levers act on both existing and new build properties given they affect all relevant available products on the market. The curve shapes emerge from the final deadlines of mid-2020s for lighting and 2030 for appliances after which the manufacturers and their supply chains must comply with the most demanding standards. The extended tail of uptake in properties adopting the highest efficiency appliances reflect the replacement cycle of appliances which is in the order of 10 to 15 years. In the case of lighting the uptake after the peak relates solely to the new build construction.

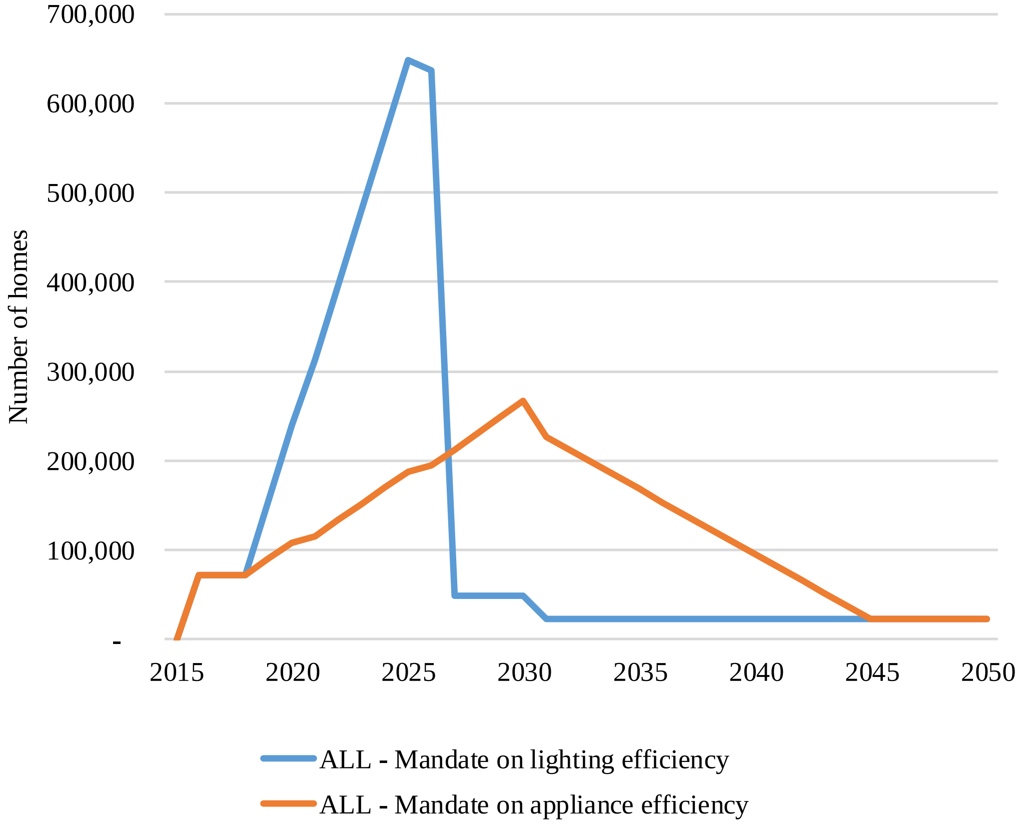

Figure 12 Homes retrofitted annually by lever packages targeting lighting and appliance energy efficiency

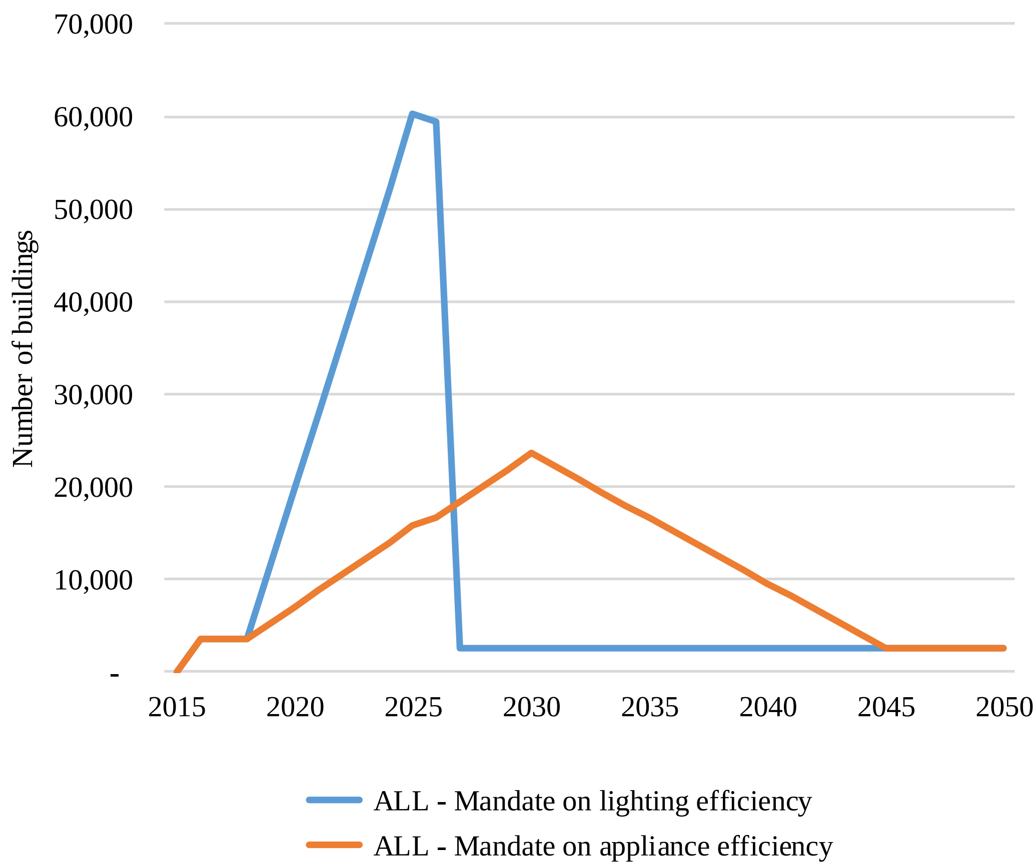

Figure 13 Non-domestic properties retrofitted annually by lever packages targeting lighting and appliance energy efficiency

Finally, levers delivering on fuel switching by installing heat pumps and solar thermal systems are shown in Figure 14 and Figure 15 below. Heat pump installations dominate, with 92% of installations attributed to heat pumps.

Within the existing building stock, lever packages are split into:

- London-initiated programmes (akin to previous initiatives such as the domestic gas boiler scrappage scheme), aimed at stimulating the market and providing technical assistance for delivery.
- National government-initiated transformative programmes (named “Accelerated low carbon heating system installation”).

The London-initiated programmes drive installation of low carbon systems at scale e.g. as a result of area-based removal of the gas supply. These low carbon technology levers were designed to accelerate take-up in the 2030s as the retrofit levers achieve the majority of retrofits. Within the non-domestic sector, it was designed that installations in the public sector could be ahead of those in the private sector.

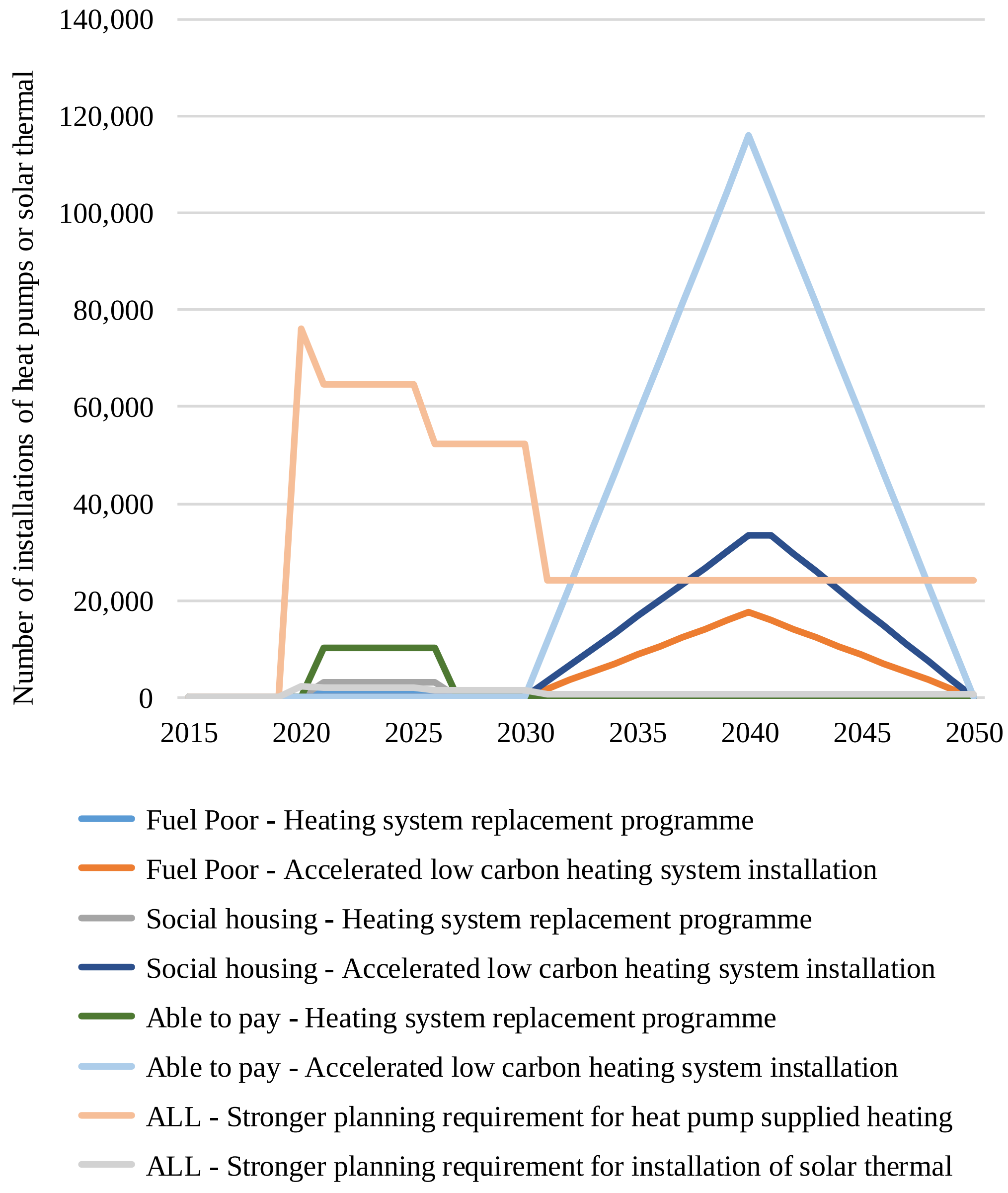

Figure 14 Installations of solar thermal and heat pumps in homes by lever packages

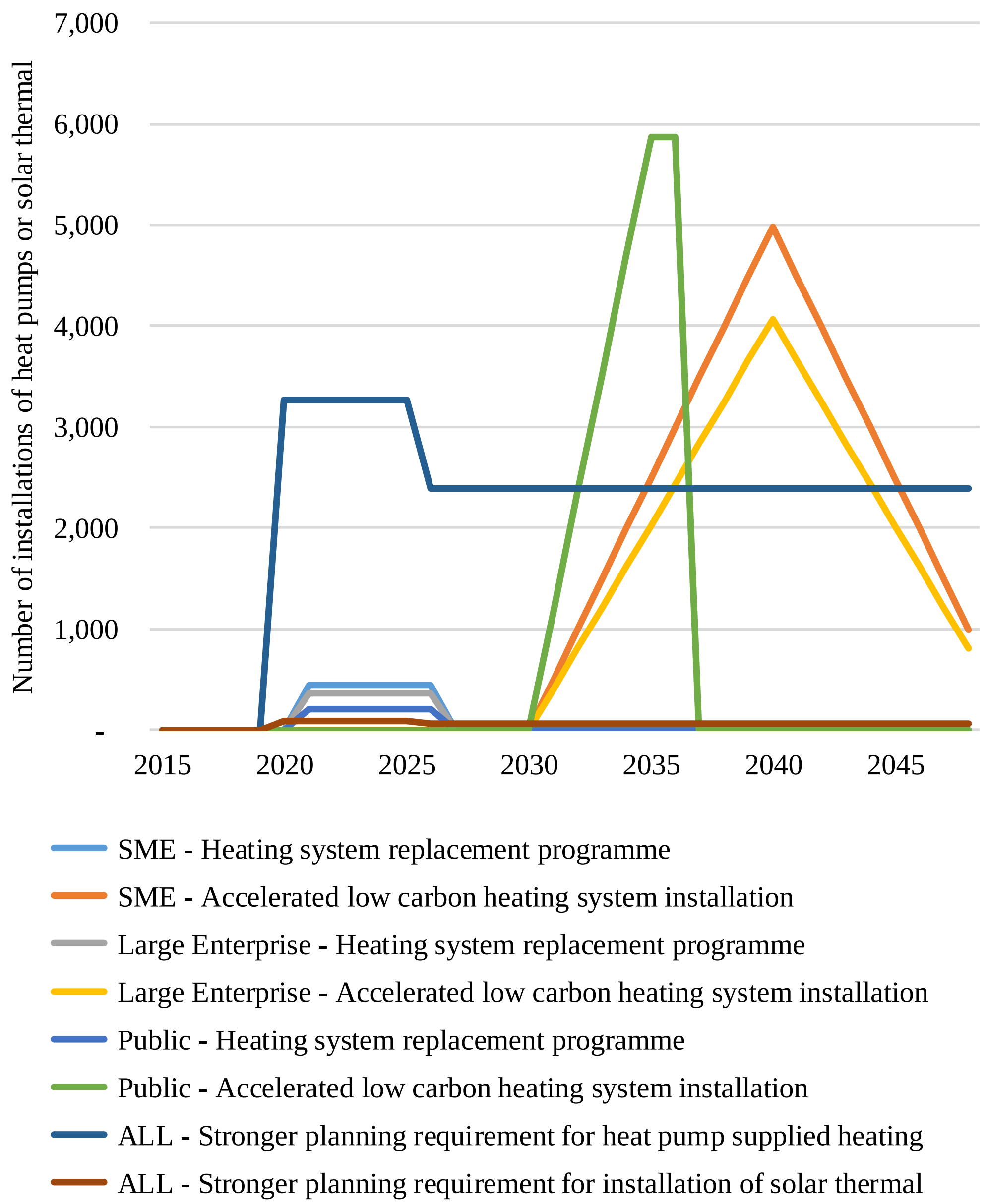

Figure 15 Installations of solar thermal and heat pumps in non-domestic properties by lever packages

5.1.3 Summary of resulting building retrofits by 2050

Figure 16 and Figure 17 respectively, show the performance of the Central scenario in terms of building retrofits achieved compared to the theoretical technical potential (see Table 3, above) split by heating, lighting and appliance efficiency interventions and heat pump installations. Overall, under the Central scenario, none of the levels of full technical deployment are met. Lighting and appliance efficiency are the most successful, reaching 90% of their building retrofit potential by the mid-2020s and mid-2040s respectively. The scenario underperforms most significantly across heating efficiency retrofits achieving just 50% and 40% of the potential for building retrofit in the domestic and non-domestic sector respectively. These reflect the challenges in inducing retrofit within the private sector which is the largest sub-set of the building sector.

We identified the most promising lever package to be Minimum Energy Performance Standards; however, we judged that 100% compliance is unlikely given enforcement will act at point of sale only and punitive measures for non-compliance are limited. When modelling domestic lever packages (such as MEES lever packages) that may be tied to transaction events – i.e. changes of owner or tenant – we took into account the turnover rate of domestic properties changing hands and how this may influence the uptake of energy efficiency and low-carbon interventions. These analyses were incorporated into the model by making appropriate adjustments to the effectiveness factor of the lever package.

A key constraint to heat pump deployment is the need for a building's fabric energy performance, defined as achieving EPC rating C, to be compatible for a heat pump.[20] As such, heat pump deployment is inextricably linked to the success in retrofit uptake and show similar numbers of deployment as retrofit uptake combined with the new build construction in absolute numbers. In percentage terms, heat pump installations are at 90% of target installations in the domestic sector because of lower ambitions of heat pump deployment relating to technical constraints, approximately 60% uptake, as opposed to 100% ambition within the non-domestic sector.

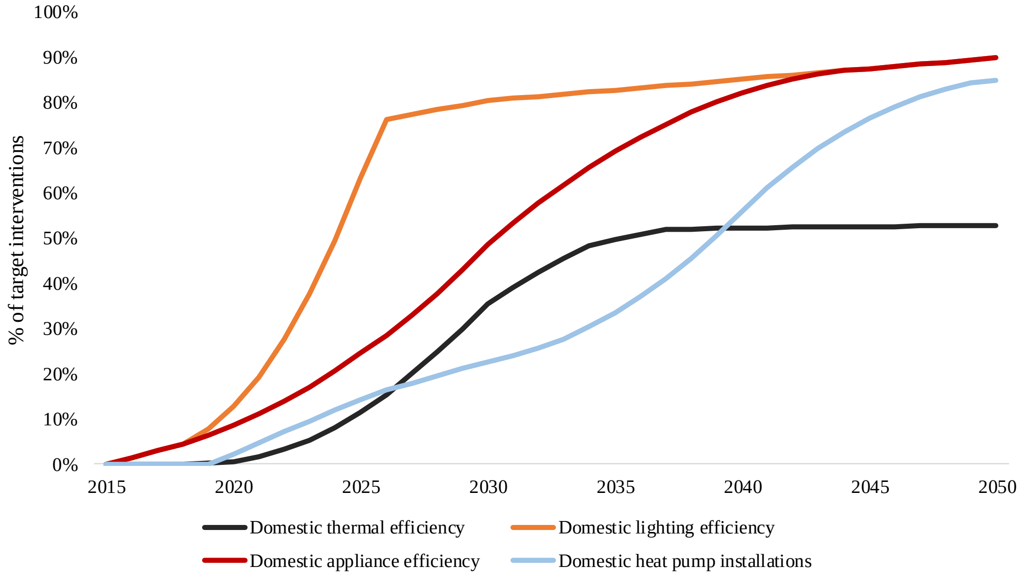

Figure 16 Performance of Central scenario against target interventions in the domestic sector

[20] This compatibility relates to guaranteeing efficient operation of the heat pump and comfort for occupants.

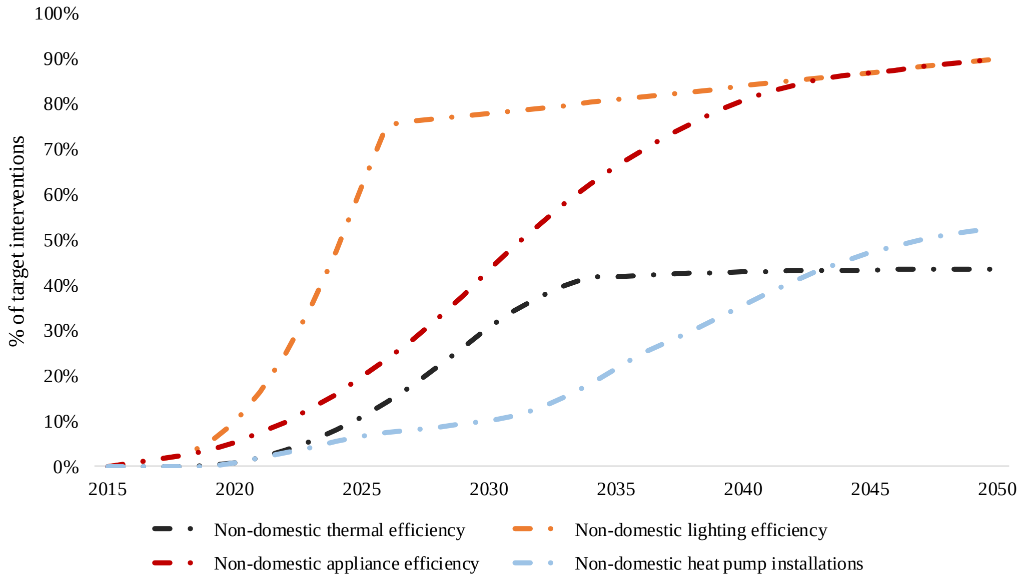

Figure 17 Performance of Central scenario against target interventions in the non-domestic sector

As shown in Figure 18, the Central scenario requires a considerable increase on past performance in achieving fabric retrofit, using cavity and solid wall insulation as a proxy for this. At its peak, the Central scenario requires four times more installations per year than previously achieved. The triangular shape of deployment of wall insulation emerges from the levers (i.e. a sum of the lever deployment curves shown in Figure 8) and responds to the deadline for MEES compliance to EPC rating C.

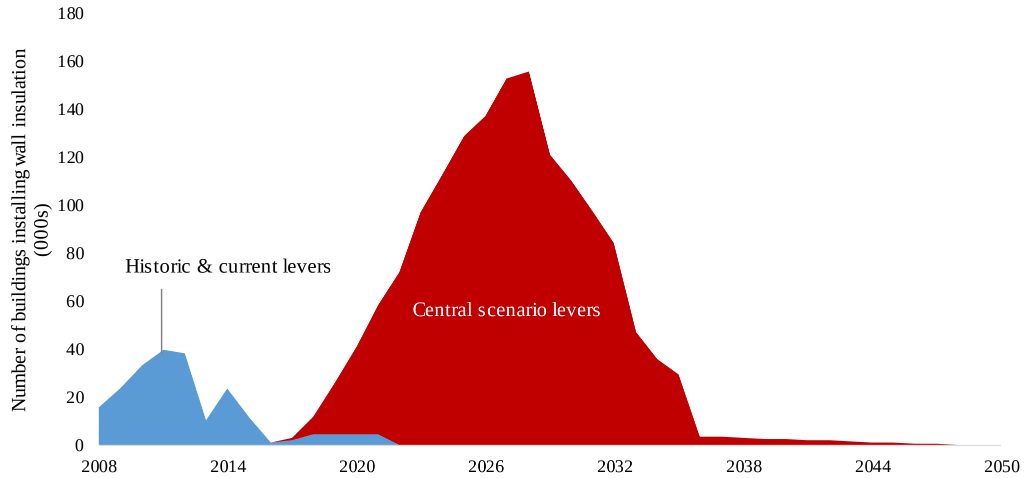

Figure 18 Comparison of historic and Central scenario levers' performance in installations of wall insulation

5.2 London versus national government-initiated action

Emission savings in the building sector will stem from a combination of London- and national government-initiated levers. Assuming no change in powers between national and city government, national government will greatly determine London's success due to its powers to introduce minimum energy performance standards and fiscal incentives for energy efficiency retrofit. Additionally, national government support is expected to be critical to enabling the transformative fuel switching from gas boilers to heat pumps.

According to our analysis, London government-initiated levers achieve 39 $MtCO_2e$ of cumulative savings of the Central scenario against the No action BAU, representing 31% of the total savings. The largest contribution stems from national government-initiated levers with 77 $MtCO_2e$ carbon savings, representing 61% of total emission savings. The savings from MEES on appliances and lighting products are assumed to continue to be driven EU product policy standards and contribute 11 $MtCO_2e$ or 9% of cumulative savings[21].

[21] Following the result of the United Kingdom European Union membership referendum on 23rd June 2016, the UK is currently preparing to leave the EU. However even after the UK has formally left the EU, we judge it is likely that the UK will continue to import EU products, compliant with EU product policy standards – so we believe that this lever package assumption remains relevant.

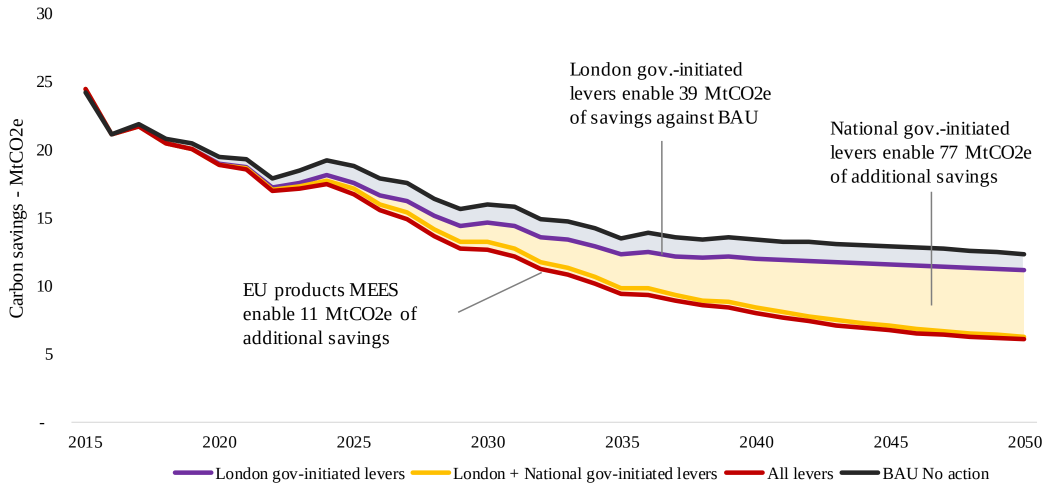

Figure 19 Comparison of carbon emissions achieved according to different driving actors: London, National government or European Union.

The split power relationship over interventions is reflected in the total CAPEX of interventions attributed to each, estimated to total £39 billion, of which the London government-initiated levers and national government-initiated levers represent £14 billion (38%) and £25 billion (62%) respectively, as shown in Figure 20.[22]

Further analysis is required to understand who will pay for these interventions and build a cost effective funding strategy combining local and national government grants and loans, private finance and consumer investment.[23] Nonetheless, the total undiscounted net present CAPEX of London-initiated levers is likely to dwarf the revenue from London's carbon offset fund.[24] We conclude that the offset fund should not be regarded as the entire, or even the main, solution to the problem of funding climate action in London's buildings.

---

[22] CAPEX was based on installation and commissioning costs and reflects expected changing costs over time associated with learning within supply chains and labour. Costs relate to the interventions enabled by lever packages only, except for appliances which were excluded given consumer appliances are highly uncertain to define because consumer preferences and technologies available in the future are all extremely uncertain. Note that the investment inn retrofit measures could arguably be perceived as lower where business as usual costs are taken into account e.g. the replacement of heating system.

[23] Although we have not outlined the mechanisms for funding of interventions and associated programme costs, we sought to identify supporting levers within packages that could respond to the funding problem. These are detailed in the Technical report.

[24] Based on GLA estimate of annual revenues of £30-40 million from carbon offset fund.

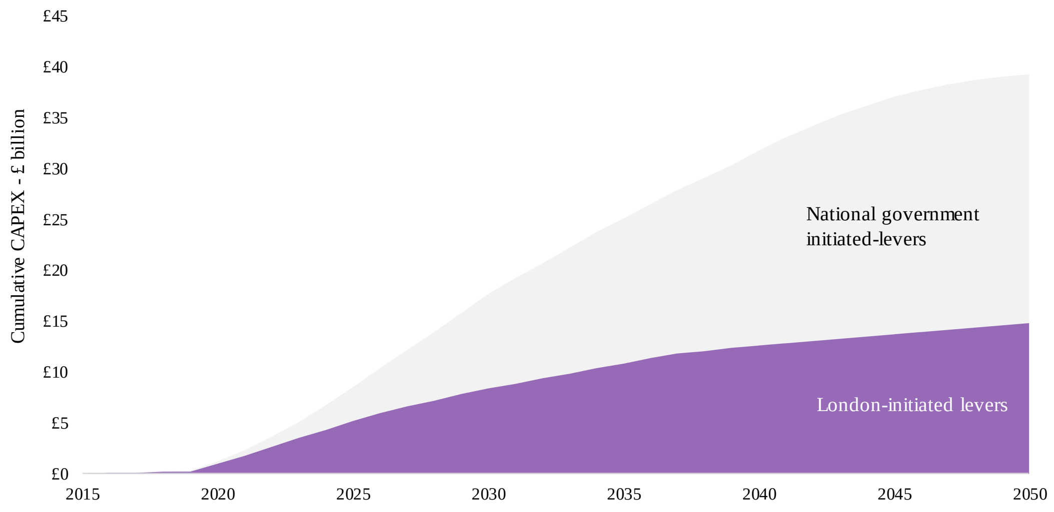

Figure 20 Capital cost of interventions split according to national government or London-initiated levers

With regard to the cost breakdown, total undiscounted CAPEX for energy efficiency and low carbon heat installations were estimated at £16 billion (42% of total CAPEX) and £23 billion (58% of total CAPEX) respectively.

5.3 Sensitivity analysis

Sensitivity analysis on the Central scenario was carried out in relation to timing and effectiveness:

- Two variants respectively tested the impact of driving levers earlier or later by up to five years;
- Two other variants respectively tested increasing or decreasing the effectiveness of the levers by up to ±40%.[25]

Figure 21 below shows the resulting emissions pathways for each sensitivity scenario against the Central scenario.

[25] Certain constraints were applied on the sensitivities meaning that not all lever packages had the exact transformation described above. For example, where lever packages were set to be introduced in 2022, the Early scenario was constrained to start implementation no earlier than 2020 i.e. two years earlier instead of five. Similarly, for the transformations to more effective, where lever package effectiveness was approaching 100% these were not increased by 40%.

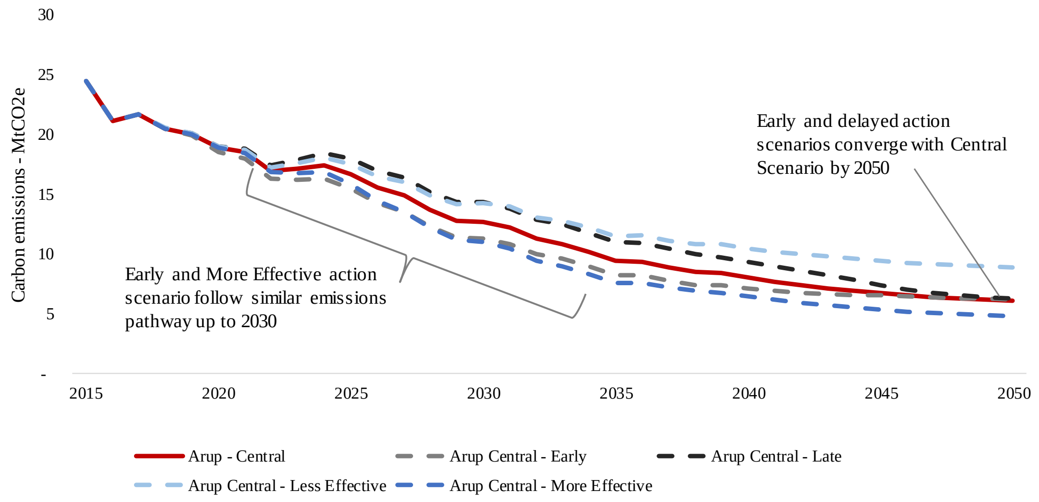

Figure 21 Comparison of emissions pathways of modelled sensitivity scenarios against the Central scenario

The pathways are aligned up to the 2020s because most levers are assumed to ramp up afterwards. The early and late scenarios deviate around the Central scenario only to converge on the 2050 emissions level (this reflects the inherent assumption that total deployment by 2050 in these variant scenarios is the same as the Central scenario). However, as result of their trajectories, the cumulative carbon emissions are lower or higher according to early or delayed deployment respectively.

The sensitivity on effectiveness shows the pathways diverge from 2020 and run in parallel to the Central scenario, either higher or lower in accordance with the effectiveness factor.

One of the key reasons for the differentiated carbon emissions is due to the impact on energy demand over time as shown in Figure 22 below. Earlier action leads to avoided energy demand in the first few years (to 2023) against the More Effective scenario although ultimately the latter performs better in cumulative energy demand with 2,560 TWh versus 2,720 TWh, a 6% difference[26].

After 2035, energy demand increases across the scenarios because retrofit interventions slow down whilst new construction of properties continues. Between 2020 and 2035, the impact of increased energy demand from new build is trumped by the reduction enabled by the retrofit of existing properties.

[26] Cumulative energy demand refers to the area under the energy demand graph i.e. the sum of the annual energy demand over the time period 2015 to 2050.

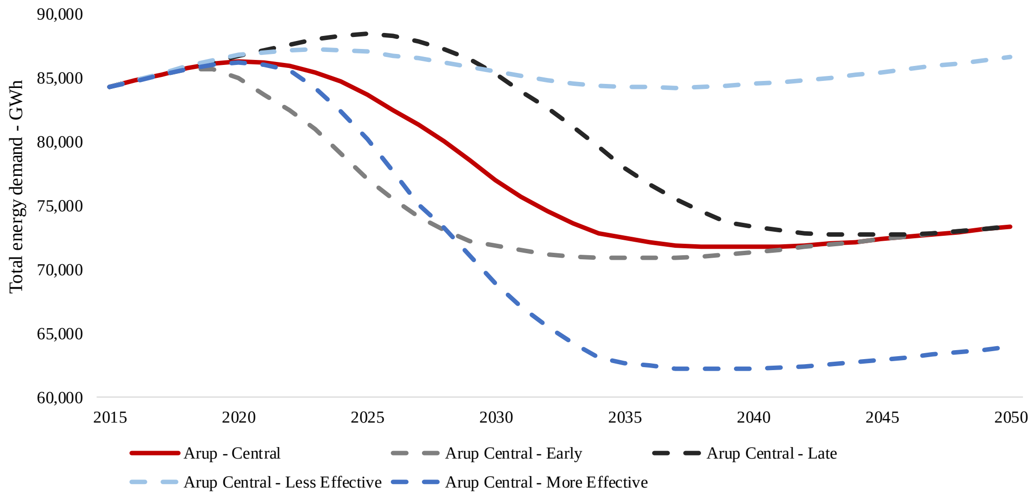

Figure 22 Comparison of energy demand trajectories of modelled scenarios

Overall, the More Effective scenario performs best showing cumulative carbon emissions 9% lower than the Central scenario at 406 MtCO_2e against 448 MtCO_2e, as shown in Table 4.

The Early scenario follows close behind with a total 422 MtCO_2e which translates as a 6% difference with the Central scenario. The Early Scenario shows the lowest cost per tonne CO2e saved because the high cumulative emissions are coupled with a total CAPEX similar to the Central scenario of £40 billion.

The More Effective scenario achieves marginally higher savings at the cost of a high number of interventions and results in high cost per tonne of CO_2e saved.

Delaying action is not recommended because cumulative emissions are 7% higher than under the Central scenario. Additionally, this scenario leads to the highest cost per tonne of carbon saved because of lower carbon savings albeit the reduced CAPEX overall, £36 billion versus £39 billion under the Central scenario.

The difference in CAPEX between the Early and Late scenario reflects the effect of the cost curves resulting in a £4 billion saving. The Less Effective scenario results in the highest cumulative emissions, 505 MtCO2_e and lowest overall cost given fewer interventions.

These figures should be used with caution as they do not provide a system-wide picture of costs and savings. Nevertheless, they provide a useful indicator of the trade-offs between early and late action and greater and less effectiveness of levers.

Table 4 Summary of results across all modelled scenarios

Scenario	Carbon emissions in 2050 ($MtCO_2e$)	Variance with Central scenario	Cumulative emissions between 2015 and 2050 ($MtCO_2e$)	Variance with Central scenario cumulative emissions	Total Capex (billions)	Lifetime Capex per tonne CO_2e saved
Central	6.1		448		£39	£308
Central - Early	6.1	1%	422	-6%	£40	£261
Central - Late	6.3	4%	481	7%	£36	£379
Central - Less Effective	8.8	46%	505	13%	£23	£323
Central - More Effective	4.8	-21%	407	-9%	£53	£314

The residual cost of premature replacement of existing heating systems (gas boilers and electric heating) due to the lever package deployment rates had a marginal impact on CAPEX, amounting to just 0.03% of the CAPEX at £13 million.

6 Summary of levers

The Central scenario was developed from judgements on the impact of a number of lever packages. These lever packages are defined by a primary lever but their overall effectiveness depends on a number of supporting levers notably through financial assistance mechanisms.[27] Table 5 and Table 6 summarise the lever packages, split by domestic and non-domestic sector, ranked by their impact in terms of achieved energy savings per year from all properties affected. A risk factor is included as an indicator of feasibility.

Overall, energy efficiency realised through retrofits reducing heat demand achieve the largest energy savings with 13,100 GWh of savings per year by all retrofitted properties. The most effective lever packages are the Minimum Energy Performance Standards (MEES) on buildings which when considering their impact across the building stock (i.e. residential, public and commercial) could enable 9,600 GWh energy saved per year. When split across domestic and non-domestic, the final energy savings are similar 4,700 GWh and 4,900 GWh per year respectively albeit retrofitting only a third of the properties in the non-domestic sector. This reflects the larger energy demand per property in the non-domestic sector.

The next greatest energy saving impact stems from mandated appliance efficiency on domestic and non-domestic appliances which together realise 7,300 GWh. This finding indicates that stronger regulation of energy efficiency standards in products is critical to reducing an important proportion of building’s energy consumption. Further analysis is required to reliably ascertain the potential energy

[27] More information on the selection of levers and a full description can be found in the Technical Report.

savings given the high uncertainty associated with consumer appliances (see Section 1.1).

Lighting energy efficiency is another important source of energy savings with up to 1,100 GWh per year possible provided effective regulation is introduced which can scale so that the most energy efficient lighting (assumed to be LEDs) are adopted in over 4 million properties.

From a GLA perspective, we see an important opportunity for widescale energy savings from retrofit programmes targeted at the fuel poor, social housing, SMEs and non-domestic public sector buildings and whole house retrofit programmes, estimated at enabling 1,600 GWh and 1,100 GWh respectively potential energy savings per year. Additionally, planning policy could enable 1,130 GWh of energy savings through more stringent building regulations enforcing fabric efficiency retrofit on properties requesting planning permissions for major works (300 GWh per year) and new build requirements to introduce smart building controls (400 GWh per year).

Some levers are more politically challenging than others. A stamp duty scaled according to energy efficiency and fiscal incentives associated with local tax rates (business rates and council tax) were identified as currently more challenging to implement. As a result, they were modelled in the Central Scenario as having low effectiveness, resulting in a combined total energy saving over their lifetime of just over 110 GWh.

With respect to transitioning from a current mix of gas boilers and electric heating, the role of London planning is much more significant than in energy efficiency. According to our analysis, effective use of planning policy could enable more than 1.3 million installations of heat pumps in new build properties (domestic and non-domestic), comparable to the 1.7 million achieved by nationally-initiated levers within the existing building stock. This is dependent on stringent requirements introduced as early as 2020 such that 90% of new-build properties install heat pumps[28]. Targeting new-build properties presents an unparalleled opportunity to design for a low carbon heating source and avoid the need for retrofit later on which are more challenging to undertake. The technical assistance programmes were assumed to achieve much lower uptake, enabling just 95,000 low carbon installations. Nonetheless, these programmes play an important role in piloting technologies to build consumer confidence and support supply chain development.

---

[28] This work only assessed individual heat pumps as a decarbonisation option that is in line with energy efficiency levers. As indicated in Section 10, another workstream - WP3 considered decarbonisation options that could be delivered through different technology solutions, e.g. district heating or decarbonised gas.

Table 5 Results of energy efficiency levers under Central scenario

Lever	Initiating authority	Start year	Total retrofits (no. of buildings)	Peak year retrofits (no. of buildings)	Maximum annual energy savings (GWh/yr)	CAPEX (millions)	Risk factor	Comments
Non-domestic - All Buildings Mandate on appliance efficiency	National government	2018[29]	383,000	25,000	3,900	N/A[30]	High	Products policy is an established mechanism in the EU and standards would be expected to continue to be raised from now to 2030; however, there is some uncertainty regarding (1) future alignment with EU products regulations post-Brexit and (2) future consumer appliances which could lead to increase in power load notwithstanding higher standards of energy efficiency.
Domestic - All Buildings Mandate on appliance efficiency	National government	2018	4,305,000	290,000	3,400	N/A[30]	High	Products policy is an established mechanism in the EU and standards would be expected to continue to be raised from now to 2030; however, there is some uncertainty regarding (1) future alignment with EU products regulations post-Brexit and (2) future consumer appliances which could lead to increase in power load notwithstanding higher standards of energy efficiency.
Domestic - All properties - MEES EPC C	National government	2020	638,000	81,000	3,200	6,000	Medium	Need to apply to all housing to achieve scale of impact. Challenges in incentivising Able to pay sector are limited to point of sale enforcement.
Non-domestic - All properties MEES EPC C	National government	2020	230,000	24,000	2,800	2,500	Medium	Need to apply to all buildings to achieve scale of impact. Challenges in incentivising Able to pay sector are limited to point of sale enforcement.

[29] Assuming continued application of EU product standards.
[30] Costs were not estimated for appliance efficiency because of uncertainty in future appliances.

Lever	Initiating authority	Start year	Total retrofits (no. of buildings)	Peak year retrofits (no. of buildings)	Maximum annual energy savings (GWh/yr)	CAPEX (millions)	Risk factor	Comments
Non-domestic - Landlord MEES – EPC C	National government	2018	57,000	5,200	2,100	900	Medium	Need to increase MEES rating to EPC C and provide finance and/or raise exemption threshold of cost.
Domestic - Landlord MEES - EPC C	National government	2018	323,000	38,000	1,500	3,000	Medium	Need to increase MEES rating to EPC C and provide finance and/or raise exemption threshold of cost.
Domestic - All Buildings Mandate on lighting efficiency	National government	2018	4,305,000	660,000	1,100	400	High	Products policy is an established mechanism in the EU and standards would be expected to continue to be raised from now to 2030. However, there is some uncertainty regarding future alignment with EU products regulations post-Brexit.
Domestic - Extended Whole house retrofit	GLA and London boroughs	2024	220,000	26,000	1,100	2,000	Medium	This approach is being pilot tested in London.
Domestic - Stamp duty energy efficiency scaling	National government	2025	94,000	8,600	400	700	High	This suggestion has been proposed for a number of years, but no political support achieved to date. Risk of loss of tax revenue but can be set to be revenue neutral.
Domestic - Extended domestic retrofit	GLA and London boroughs	2020	133,000	7.600	500	980	Low	Builds on existing RE:NEW programme in London but will require dramatic scaling up to meet target.
Non-domestic - Energy efficiency programme for SMEs	GLA and London boroughs	2020	13,000	700	400	170	Low	Builds on existing programme e.g. Carbon Trust Loans but will require dramatic scaling up to meet target.

Lever	Initiating authority	Start year	Total retrofits (no. of buildings)	Peak year retrofits (no. of buildings)	Maximum annual energy savings (GWh/yr)	CAPEX (millions)	Risk factor	Comments
Non-domestic - Extended non-domestic retrofit	GLA and London boroughs	2020	5,000	300	330	100	Low	Builds on existing RE:FIT programme in London but will require dramatic scaling up to meet target.
Domestic - Building Regulations and planning policy	GLA and London boroughs	2020	64,000	8,000	300	530	Medium	Planning policy is established mechanism to incentivise energy efficiency. However, as London planning is already above national policy, a more demanding standard may prove difficult.
Non-domestic - Energy performance tax grading – business rates	National and local government	2023	1,000	300	50	20	High	Currently limited political support. Will need leadership and careful communications. Risk of loss of tax revenue but can be set to be revenue neutral. Requires Government action to permit variation and then Council action to implement locally.
Domestic - Council tax variation by EPC	National and local government	2023	13,000	2,600	60	100	High	Currently limited political support. Will need leadership and careful communications. Risk of loss of tax revenue but can be set to be revenue neutral. Requires Government action to permit variation and then Council action to implement locally.
Non-domestic - All Buildings Mandate on lighting efficiency	National government	2018	383,000	60,000	N/A[31]	600	High	Products policy is an established mechanism in EU and standards would be expected to continue to be raised from now to 2030; however, there is some uncertainty regarding future alignment with EU products regulations post-Brexit.

[31] Energy savings were calculated against baseline energy demand. Conservative estimate from previous GLA modelling that energy demand remains constant albeit replacements with higher efficiency lighting.

Lever	Initiating authority	Start year	Total retrofits (no. of buildings)	Peak year retrofits (no. of buildings)	Maximum annual energy savings (GWh/yr)	CAPEX (millions)	Risk factor	Comments
Domestic - Stronger planning requirement for smart controls	GLA and London boroughs	2018	640,000	34,000	300	500	Medium	Planning policy is an established mechanism to incentivise energy efficiency. However, as London planning is already above national policy, a more demanding standard may prove too difficult.
Non-domestic - Stronger planning requirement for smart controls	GLA and London boroughs	2015	46,000	1,600	100	100	Medium	Planning policy is an established mechanism to incentivise energy efficiency. However, as London planning is already above national policy, a more demanding standard may prove too difficult.

Table 6 Results of low carbon heat supply levers under Central scenario

Lever	Initiating authority	Start year	Total installations	Peak installations	CAPEX (millions)	Risk factor	Comments
Domestic - Accelerated low carbon heating installation	National government	2030	1,548,000	153,000	10,000	High	Requires committed support from national government. High risk that use of market incentives will be insufficient.
Domestic - Stronger planning requirement for heat pump supplied heating	GLA and London boroughs	2020	1,142,000	76,000	8,000	Medium	Builds on established Zero Carbon planning policy however would require a higher carbon price or other mechanism to incentivise heat pump uptake more strongly. WP3 has considered alternative heat decarbonisation strategies based on heat networks etc.
Non-domestic - Accelerated low carbon heating installation	National government	2030	111,000	15,000	2,000	High	Requires committed support from national government. High risk that use of market incentives will be insufficient.

Lever	Initiating authority	Start year	Total installations	Peak installations	CAPEX (millions)	Risk factor	Comments
Domestic - Heating system replacement programme	GLA and London boroughs	2020	89,000	15,000	1,000	Medium	Builds on established programmes such as Boiler Scrappage Scheme. Requires accelerated intervention and significantly more funding.
Non-domestic - Stronger planning requirement for heat pump supplied heating	GLA and London boroughs	2020	79,000	3,000	1,000	Medium	Builds on established Zero Carbon planning policy however would require a higher carbon price or other mechanism to incentivise heat pump uptake more strongly. WP3 has considered alternative heat decarbonisation strategies based on heat networks etc.
Non-domestic - Heating system replacement programme	GLA and London boroughs	2020	6,000	1,000	110	Medium	Builds on established programmes such as Boiler Scrappage Scheme. Requires accelerated intervention and significantly more funding.
Non-domestic - Stronger planning requirement for installation of solar thermal	GLA and London boroughs	2020	2,000	80	80	Low	Builds on established Zero Carbon planning policy.
Domestic - Stronger planning requirement for installation of solar thermal	GLA and London boroughs	2020	35,000	2,000	120	Low	Builds on established Zero Carbon planning policy.

7 Findings and Recommendations

The key findings resulting from this analysis are the following:

- Recent trends point to a sharp decline in levers driving action on building retrofit in London. Building retrofit peaked in 2012 at 129,000 properties and declined significantly to 10,000 by 2017. This trend needs urgently to be reversed.
- The Central scenario enables savings of 380 TWh against the No action BAU scenario through building retrofit and a further 140 TWh from appliance energy efficiency. The Central scenario levers, however, do not achieve the draft LES buildings pathway ambition for annual energy demand by 2050, showing a gap of 15 TWh.
- The Central scenario shows cumulative emissions of 448 $MtCO_2e$. Further cumulative savings of 90 $MtCO_2e$ are required to align with the draft LES buildings pathway.[32]
- According to the Central scenario, the scale of action on deep retrofit (retrofits in line with reaching EPC band C) may need to achieve four times more than recent rates of action, from a recent peak of 40,000 per year to a future peak in the mid-2020s of 155,000 per year.
- London – through the Mayor and boroughs – can deliver around 31% of the impact on building energy and carbon reductions through levers it can control. A further 77% need national government action whilst the remaining 9% is expected to be driven by EU policy. Notwithstanding the assignment of local versus national and regional government responsibility for levers, engagement from the supply chain and wider consumer market will be critical to delivering the government-initiated action and could fill part of the energy and carbon gap.
- The cost curves have a significant impact on the costs of different pathways to 2050. This is most notable from the difference in CAPEX between the Early and Late scenarios, with the cost curves resulting in the Late scenario achieving a £4 billion saving. However, the uncertainty associated with such cost curves should be noted before drawing conclusions.
- Key primary levers identified to drive action were MEES regulation requiring all buildings to achieve EPC rating C as well as stringent standards on appliances. Complimented by effective enforcement and financial support (primarily for the former), these could affect over 1.2 million and 4.7 million properties respectively.

The key recommendations resulting from this analysis are the following:

- Further analysis is required to improve understanding of the potential effectiveness of levers both directly and in triggering self-initiated retrofit (associated with a change in perception towards energy efficiency).

[32] Note that this gap could be closed through alternative decarbonisation strategies.

- The GLA can lead pilot projects and scale up city-led programmes to develop the market and supply chain. Technical assistance and whole house retrofit programmes present an important opportunity to support key sectors of the market such as the fuel poor, social housing tenants, SMEs and the public sector.
- Additionally, updates to the London Plan to require zero carbon new non-domestic builds will encourage further low carbon heat, including heat pumps and energy efficiency measures, as well as smart controls.
-
- London cannot deliver on its ambitions without the support of the national and regional governments. The introduction of ambitious MEES relating to building performance (stipulated against EPC ratings), appliance and lighting products for all buildings is imperative to achieving higher levels of retrofit.
- High rates of retrofit are needed to meet London's carbon ambition. If demand for retrofit services is sustained (and is not start-stop), the retrofit supply chain will be able to grow to meet this demand. Training and technical assistance will be needed to help accelerate the growth in capacity of the supply chain.
- It will take time to build a consensus for some of the more politically challenging levers; engagement with the national government is needed now to build a coalition for action.
- Delaying action is likely to result in higher carbon emissions. Therefore, action on readily deliverable levers should be accelerated immediately. The Late scenario indicated a five-year delay could lead to 33 $MtCO_2e$ of additional carbon emissions compared to the Central scenario, representing a 7% increase.