Camden Carbon Scenarios for 2025 and 2030 - An update to the 2010 Study

Version 1.2 FINAL REPORT

21st May 2019

Prepared for: London Borough of Camden

Prepared by: Chris Dunham

Carbon Descent

www.carbondescent.org.uk T 020 7089 6971

carbondescent

Delivering a Sustainable Future

Abbreviations/Terms of Reference

BEIS	Department for Business, Energy and Industrial Strategy
BRE	Building Research Establishment
BAU	Business as usual
C & I	Commercial and industrial
CHP	Combined heat and power
CO_2	Carbon dioxide
DECC	Department for Energy and Climate Change
DfT	Department for Transport
EU	European union
FiT	Feed in Tariff
GLA	Greater London Authority
GWh	Gigawatt hours
kg	Kilograms
km^2	Square kilometres
ktpa	Kilo tonnes per annum
kW	Kilowatt
kWe	Kilowatts electrical
kWh	Kilowatt-hour
LCTP	Low Carbon Transition Plan
m^2	Square meters
MLSOA	Middle layer super output area
MRP	Maximum resource potentials
MW	Megawatt
MWe	Megawatt electrical
MWh	Megawatt–hour
NI	National Indicator
NO_x	Nitrous oxides
NPV	Net present value
PV	Photo voltaic
RHI	Renewable Heat Incentive
SME	Small and medium sized enterprise
UK	United Kingdom
VP	VantagePoint

Table of Contents

Table of Figures

Table of Tables

Executive Summary

This study was undertaken to provide the London Borough of Camden with an update to the 2010 Report 'Delivering a Low Carbon Camden' in light of:

- the approaching end of the current target period (2020)
- the need for new targets for the next 10 years
- the many changes in terms of technologies and technology costs over the last 10 years
- the emphasis on electrification given the dramatic fall in emissions from grid electricity
- validating recent GLA Zero Carbon Pathways analysis to deliver a 1.5 Degree compatible plan at a local level[1]

This report is not intended to act as a detailed action plan for Camden, but instead it seeks to highlight the likely route to a low carbon Camden in 2030.

The report was commissioned before the recent Climate Emergency declarations but will be used to inform Council policy supporting borough wide carbon reduction.

A key difference between this study and the 2010 study is that no target has been set for 2030 – rather scenarios have been modelled based on what might be achieved in Camden based on a combination of current national government, GLA and Camden policies (that might be reasonably adopted within the constraints of Camden's powers/resources).

This work has been undertaken by developing an hourly model of Camden's baseline energy use and emissions using the software energyPRO.

Baseline

Carbon reductions have been set against a baseline year of 2005 to ensure consistency with previous studies. The most recent year for which actual carbon emission data is available from BEIS is 2016, so this data has been used to generate the first year in the model. Each year until 2030 has then been modelled in energyPRO.

Scenarios Modelled

In all scenarios the rates of newbuild and demolition for both the commercial and industrial and domestic sectors have been included - factoring in the energy performance improvement delivered through this stock replacement. Furthermore, it has been assumed that from 2022 all new buildings both commercial and residential would have the heating and hot water supplied by heat pumps. Similarly, Camden/GLA projections for the penetration of Electric Vehicles and modal shift giving a reduction in overall vehicle kilometres have been included in all scenarios.

In scenarios 1 and 2 we have projected a domestic retrofit program of both insulation and air source heat pumps. The installation rates assumed are relatively conservative but would still represent a challenge given Camden's current powers and budgetary constraints.

In scenario 1 we have assumed no improvement in grid decarbonisation beyond the 2018. In scenario 2 we have modelled the projection of how electricity will be generated nationally from the Treasury's Independent Advisory Group (IAG).

Lastly in scenario three we have retained the Treasury grid factor projections from scenario 2 but have taken a much more radical approach to the electrification of heat with an assumption that any gas boilers coming to the end of their lives are replaced with air source heat pumps from 2022.

---

[1] https://www.london.gov.uk/what-we-do/environment/climate-change/climate-action-plan

Results

Scenario 1 Conservative Heat Pump - Static Grid

In 2016 Camden had already achieved a reduction of 34% over the 2005 baseline. If no further grid decarbonisation was achieved nationally beyond the 2018 grid factor then a reduction of 45% could be achieved by 2030 based on the relatively conservative mix of measures proposed. These include gas boilers being replaced in newbuild from 2022, a programme of retrofit Air Source Heat Pumps (ASHPs) in existing homes with a total of 4,800 installed by 2030, reductions in vehicle mileages and Electric Vehicle (EV) penetration in both the private vehicle and bus fleet of 64% of vehicle km.

Scenario 2 Conservative Heat Pump - IAG Grid Decarbonisation

If the Treasury/IAG grid factor is applied with the same basket of measures as scenario 1, then a saving of 57% of CO2 emissions would be achieved against the 2005 baseline. The breakdown of emissions by fuel and sector is shown below. In this scenario by 2030 over 50% of emissions will come from gas use mainly used for space heating, hot water and cooking, a significant increase, proportionally, from the mix in 2005 due to major grid decarbonisation.

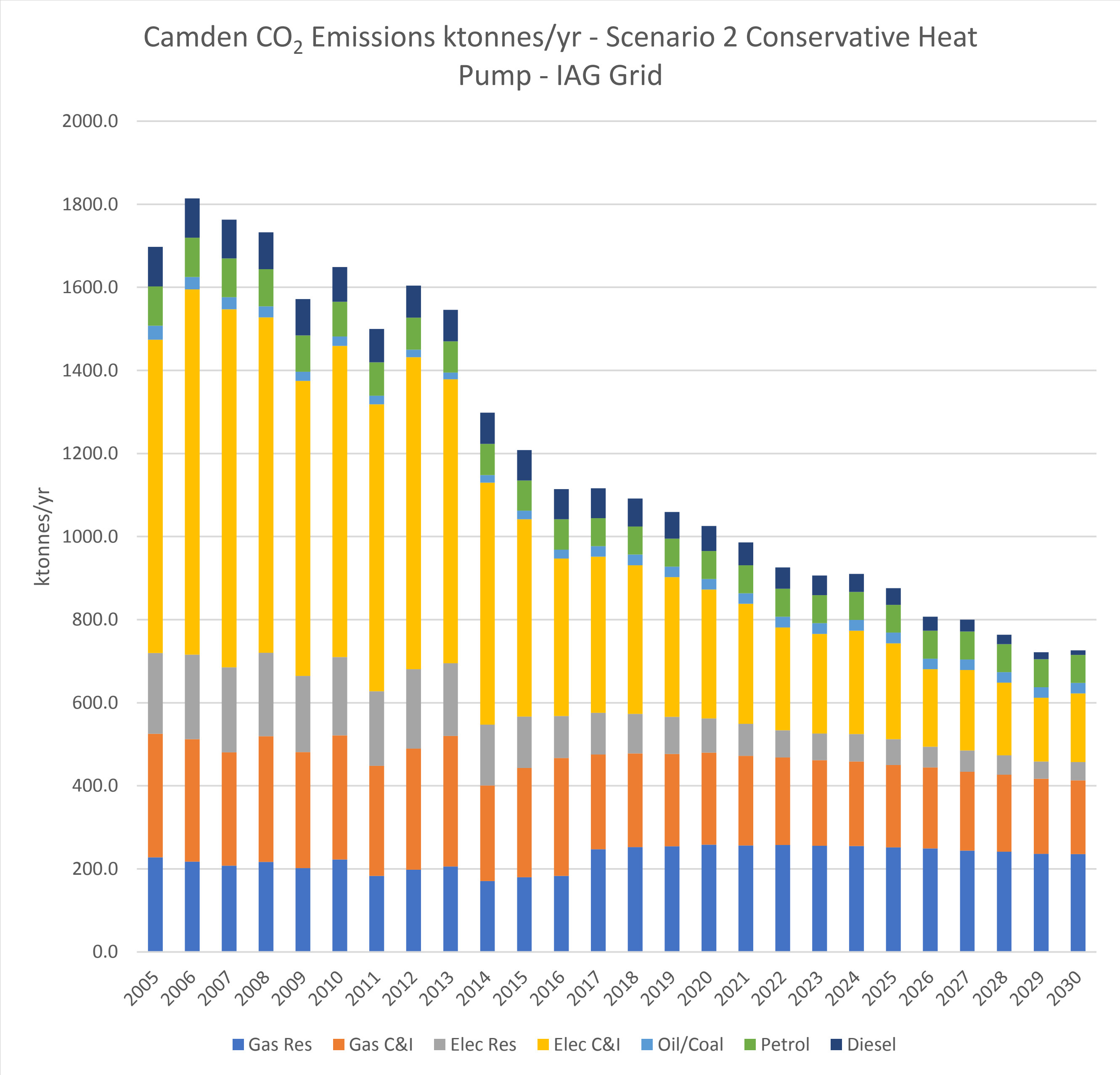

Figure 1 Camden Historic CO_2 Emissions (ktonnes/yr) 2005-16 and Projected Emissions 2017-2030 by Sector/Fuel

Scenario 3 Radical Heat Pump - IAG Grid Decarbonisation

Under a more radical approach to the decarbonisation of heat, if the retrofitting of gas boilers was prohibited by 2022, a reduction of 68% could be achieved. This would require central government action as Camden don't currently have the powers to implement such an approach.

Conclusion

Impressive progress has been made since 2005 in reducing carbon emissions, but whilst reductions in the emissions associated with electricity generation and therefore usage have halved, the challenge now lies in tackling the heat and transport sectors. In Camden transport emissions are relatively small but heat remains a significant sector. Although this report hasn't specifically looked at what would be required to achieve net zero carbon by 2030, the likely approach would require the removal of all gas appliances, boilers, ovens and hobs to be replaced with electric heat pumps either in each building on connected via district heating. A zero carbon emission zone for transport would need to be established so that only pure battery electric vehicles could drive through the borough. And to ensure that the additional electricity required through this electrification approach could be supplied without any associated carbon, a vast increase in solar PV capacity would be needed on Camden's buildings.

1 Introduction

1.1 Background

The London Borough of Camden wishes to update the 2010 Report Delivering a Low Carbon Camden in light of:

- the approaching end of the current target period (2020)
- the need for new targets for the next 10 years
- the many changes in terms of technologies and technology costs over the last 10 years
- the emphasis on electrification given the dramatic fall in emissions from grid electricity
- validating recent GLA Zero Carbon Pathways analysis to deliver a 1.5 Degree compatible plan at a local level[2]

This report is not intended to act as a detailed action plan for Camden, but instead it seeks to highlight the likely route to a low carbon Camden.

The report was commissioned before the recent Climate Emergency declarations but will be used to inform Council policy supporting borough wide carbon reduction.

A key difference between this study and the 2010 study is that no target has been set for 2030 – rather scenarios have been modelled based on what might be achieved in Camden based on a combination of current national government, GLA and Camden policies (that might be reasonably adopted within the constraints of Camden's powers/resources).

This work has been undertaken by developing an hourly model of Camden's baseline energy use and emissions using the software energyPRO.

This is different to the approach applied previously where Carbon Descent's Vantage Point software was used. The advantage of using energyPRO was to enable an estimate of hourly and therefore peak demands and the ease and accuracy of modelling technologies such as air source heat pumps whose efficiency varies based on outdoor air temperature. This would potentially enable the net impact of the electrification of heating, transport and cooking on Camden's peak electricity demands, to be modelled.

Another advantage is that detailed time of day tariffs can be analysed to assess the financial benefit of any scenario.

1.2 Robustness of the modelling

energyPRO is a tried and tested software modelling tool widely used internationally to model complex energy systems. It is often used for engineering design and so represents a reliable approach to modelling. However with all modelling the quality of the output is dependent on the quality of the inputs. Perhaps the most significant area of doubt is around the future decarbonisation of the grid particularly in light of recent announcements in the replacement of nuclear power stations many of which are due to close over the next 10 years. We therefore have included a scenario (scenario 1) with no further grid decarbonisation beyond 2018.

[2] https://www.london.gov.uk/what-we-do/environment/climate-change/climate-action-plan

2 Methodology

2.1 Assumptions & Methodology

2.1.1 Emissions Scope

The baseline emissions used for this modelling is the BEIS Local Authority Dataset[3]. This dataset excludes motorway related emissions, industrial emissions that fall under EU emissions trading and land use/land use change. The logic for this is that these emissions tend to fall outside of any local authority influence. For Camden, lacking motorways, large industry and large areas of countryside this makes little difference – using the full dataset would add just 0.2% to emissions. Land use in Camden does represent a small net negative impact – presumably relating to growth in park trees but this equates to 0.2ktonnes – just 0.02% of emissions. Generally the approach is a “production” approach to emissions accounting – emissions are quantified based on where they are produced: gas burnt in boilers, petrol and diesel burnt as cars move around on Camden’s roads etc. The exception is electricity where emissions are allocated to Camden based on consumption. This approach also means that all shipping and aviation emissions fall outside the scope – an issue in national policy as well.

Emissions from this dataset broken down by sector for 2005 and 2016 can be seen below.

Sector	Emissions in 2005 (ktpa)	Emissions in 2016 (ktpa)
Domestic	412.96	287.44
Commercial & Industrial	1,028.87	681.12
Transport	171.15	146.29
Total	**1,612.98**	**1,114.84**

Table 1: Sector CO_2 emissions in 2005 and 2016

2.1.2 Setting up an energyPRO model the Camden

This involved populating an energyPRO model with the appropriate fuels carbon emissions factors and energy prices including tariff structures.

2.1.3 Creating a model of energy consumption for 2016

This was done in Excel by taking the BEIS 2016 carbon emissions for Camden and converting CO_2 back into energy using the appropriate carbon factor. These were then further split into end uses such as heating, hot water and cooling based on assumptions around boiler and chiller efficiencies. This resulted in a baseline of end use delivered energy broken down by sector (domestic, commercial and industrial and transport). The figures were then loaded into the energyPRO model set out in step one.

2.1.4 Reference Scenario

The next step was to create a reference scenario which included only the impact of national government projections for the decarbonisation of electricity and the impact of new build and demolition. Many different projections were available for the future decarbonisation of the grid including the National Grid future energy scenarios (FES) work, the Committee on Climate Change (CCC) projections and lastly the Treasury Independent Advisory Group (IAG) projections. These offer broadly similar outlooks as can be seen below.

[3] https://data.gov.uk/dataset/723c243d-2f1a-4d27-8b61-cdb93e5b10ff/emissions-of-carbon-dioxide-for-local-authority-areas

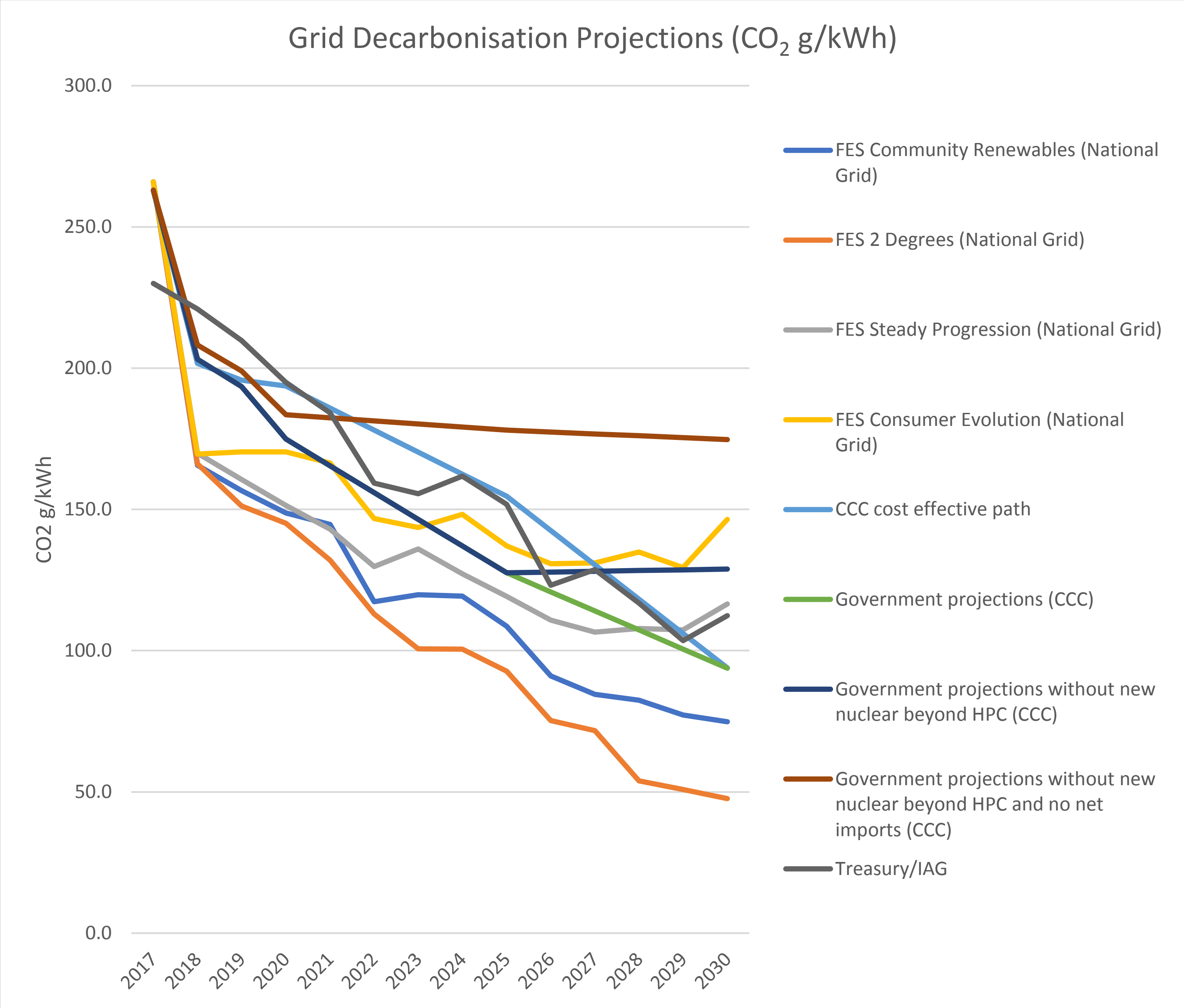

Figure 2 UK Grid Decarbonisation Projections 2017-2032

The Treasury/IAG projections were selected as a central projection which seem to fit the progress being made in 2018. In scenario 1 we applied a grid factor which remained static at the 2018 level. This is broadly in line with the government projections without new nuclear beyond Hinkley point and no net import scenario.

Our approach to modelling the impact of development in Camden was derived from a combination of data sources. For the domestic sector the government publishes EPC data for each quarter broken down by local authority area. This is further broken down into new build and existing homes. From this data we were able to calculate the number of new homes in Camden by dwelling type (bungalow, house, flat and maisonette) and their predicted energy consumption by end use for regulated emissions. We then estimated non-regulated emissions i.e. appliances and cooking from BREDEM 12 methodology based on floor area and occupant numbers. Actual newbuild numbers were available for 2016, 2017, and three quarters of 2018.

For the period 2019 to 2030 it was assumed that newbuild homes continue to be built at the average annual rate for the period 2015-2018 (1320 homes pa). For each year it was assumed that 236 existing homes were demolished. This was based on numbers provided by Camden planning team. This means a net gain of over 1000 homes per annum. It was further assumed that the 236 homes demolished were responsible for an average of the energy consumption for the domestic sector in 2016. Whilst it might be true that homes being demolished are of a poorer energy performance per square metre of floor area than the average Camden home, it’s also likely that they are generally smaller than the average Camden home.

For the commercial and industrial sector a similar approach was taken except that both new build and demolition numbers were provided by Camden planning team (rather than relying on newbuild numbers from new build EPC's as we did for the domestic sector). This is because the government doesn't provide nondomestic EPC data split into new build and existing.

A further assumption for both the domestic and non-domestic newbuild was that progressive improvements in standards would be the achieved through building regulation requirements implemented every four years beginning in 2020 but with a one year lag in impact. Improvements were set at 40% over the previous building regulations but this was only applied to space heating demand. In the domestic sector this resulted in a figure in line with PassivHaus standards by 2028.

2.1.5 Heating systems

To decarbonise the heat sector we have used electric air source heat pumps (ASHPs) as the default technology. These can replace gas boilers and have the advantage that they can achieve an efficiency of 250% or more and use electricity which is rapidly decarbonising. High or low temperature heat pumps are available. Low temperature heat pumps may require radiators to be replaced to maintain the same heat output at lower temperatures. High temperature heat pumps are more expensive but don't require replacement of radiators. Heat pumps with other heat sources such as ground-source and water-source may offer better efficiency, but are much more reliant on site context and location so were not considered as an appropriate default.

An alternative scenario would be to assume that at a national level the UK decarbonises the gas supply by producing hydrogen either from surplus electricity or from methane and injecting this into the existing gas network. This approach has a number of disadvantages – introducing inefficiencies by converting electricity into hydrogen and then into heat, or continued reliance on imported natural gas. It also requires the replacement of gas boilers and cookers with hydrogen versions. Perhaps most importantly from Camden's perspective it leaves the local authority dependent on national measures which may never materialise. Camden at least has some influence over the roll out of heat pumps. For this reason hydrogen rollout has not been included in any scenarios.

3 Scenarios and results

3.1 Scenarios

Three scenarios have been modelled (these are described in more detail in the appendix):

Scenario 1 – Conservative Heat Pump - Static Grid

A relatively conservative mix of measures are modelled. These include gas boilers being prohibited in newbuild from 2022, a programme of retrofit insulation and retrofit ASHPs in existing homes (with a total of 4800 installed by 2030) reductions in vehicle mileages and EV penetration in both the private vehicle and bus fleet of 64% of vehicle km.

Scenario 2 – Conservative Heat Pump - IAG Grid Decarbonisation

The same mix of measures is modelled as per scenario 1 but in this case allowing grid decarbonisation in line with Treasury projections.

Scenario 3 – Radical Heat Pump - IAG Grid Decarbonisation

The only change in scenario 3 from scenario 2 was to include a more aggressive approach to the decarbonisation of heat with gas boiler retrofit prohibited from 2022 and instead replaced by air source heat pumps.

3.2 Analysis of results

3.2.1 Scenario 1

In 2016 Camden had already achieved a reduction of 34% over the 2005 baseline. If no further grid decarbonisation was achieved nationally beyond the 2018 grid factor then a reduction of 45% could be achieved based on the relatively conservative mix of measures.

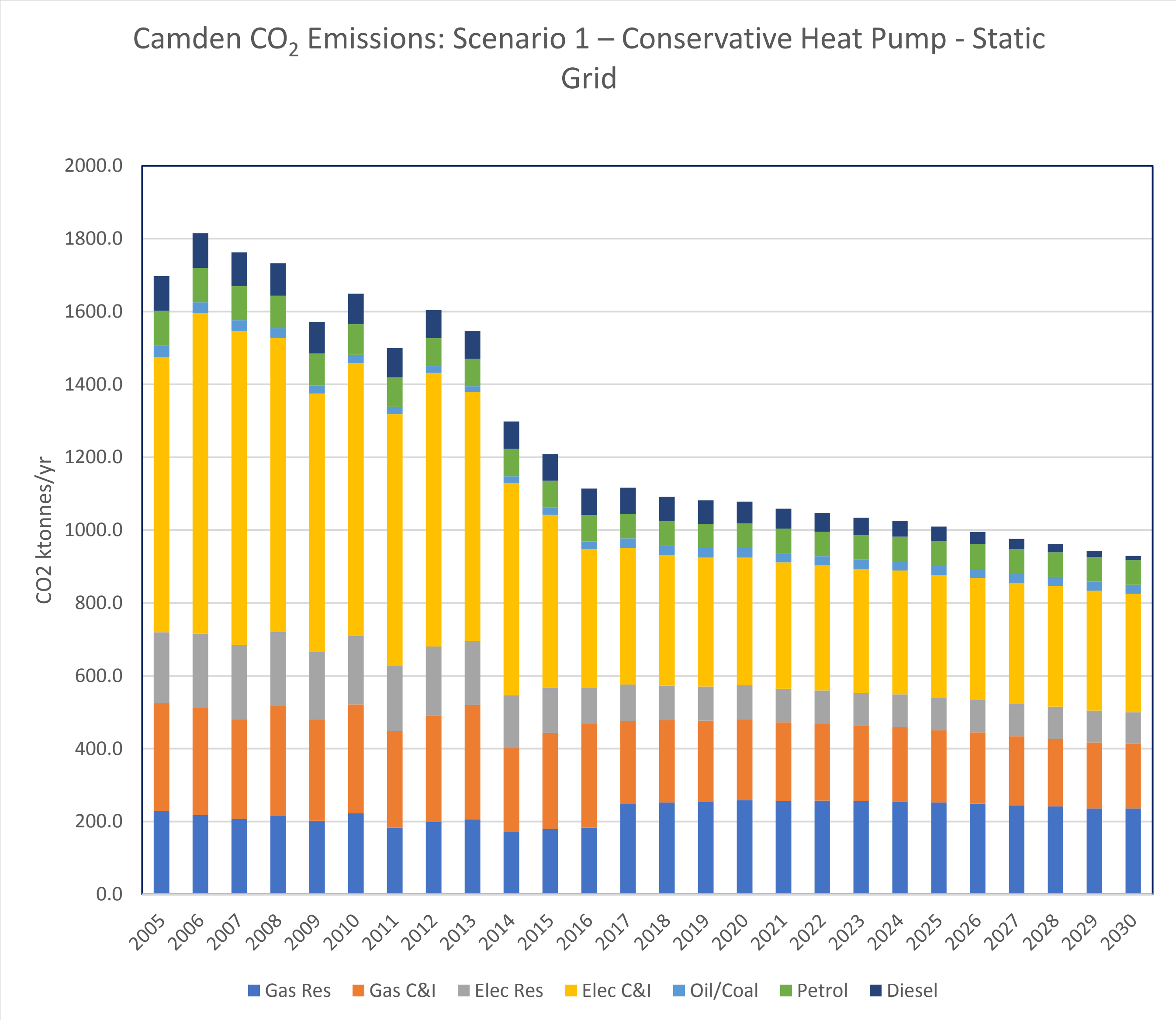

Figure 3: Camden Historic CO_2 Emissions 2005-16 and Projected Emissions 2017-2030 by Sector/Fuel - Static Grid Factor Scenario

3.2.2 Scenario 2

If the Treasury/IAG grid factor is applied then a saving of 57% of CO2 emissions would be achieved against the 2005 baseline. The breakdown of emissions by fuel and sector is shown below. By 2030 over 50% of emissions will come from gas use - mainly for space heating, hot water and cooking.

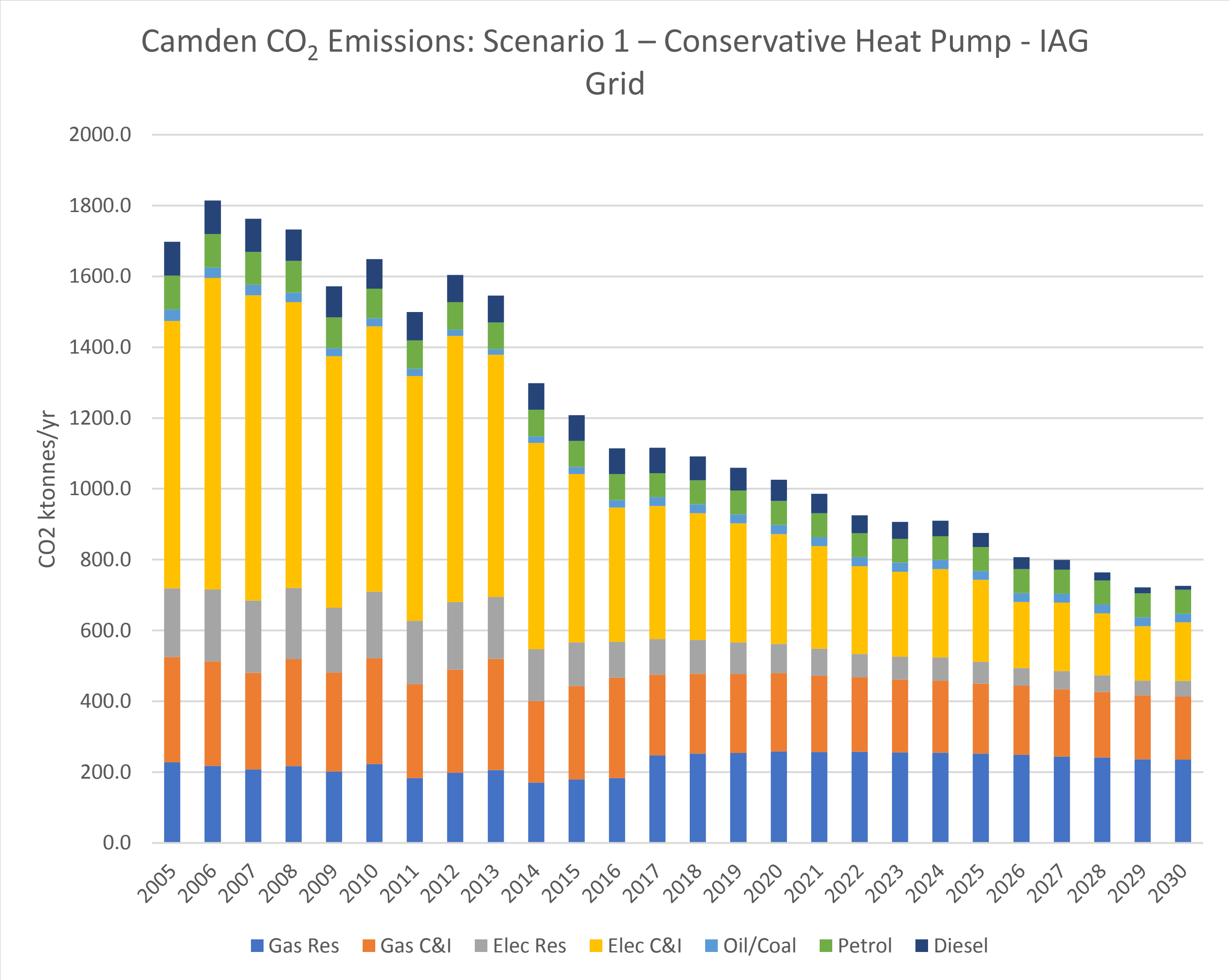

Figure 4: Camden Historic CO_2 Emissions 2005-16 and Projected Emissions 2017-2030 by Sector/Fuel - Treasury Grid Factor Scenario

3.3 Scenario 1 and 2 Net Electricity Demand Impact

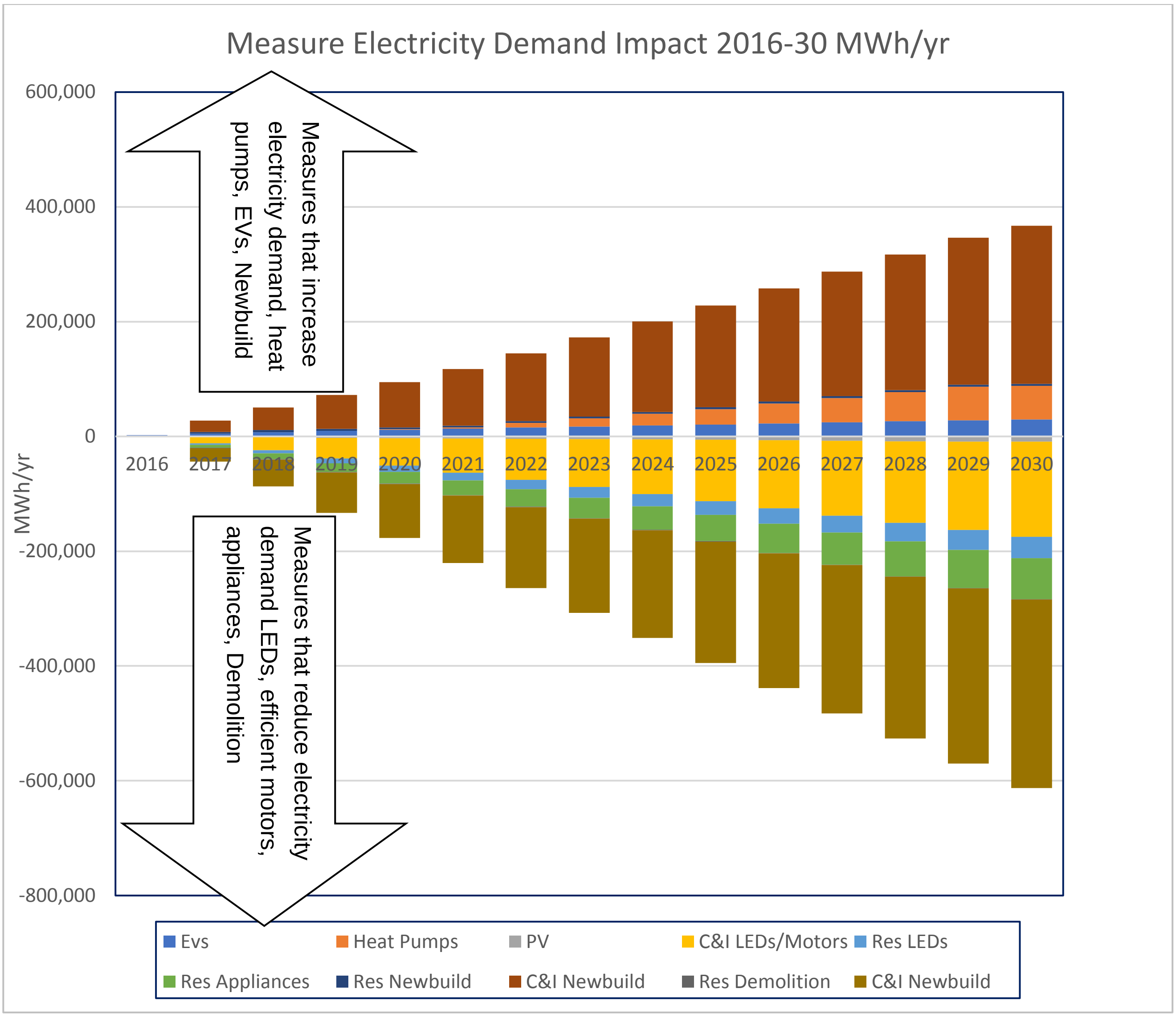

Figure 5 Electricity Demand Impact By Measure for Scenarios 1 and 2

The above figure shows the net impact in terms of electricity demand (including PV's impact as a demand reduction). It shows that the increase in demand as a result of the electrification of heating and transport is more than outweighed by efficiency improvements in lighting, motors and newbuild/demolition. These figures are calculated on an annual basis – the net hourly impact might not always be so favourable.

3.3.1 Proportion of Heat (MWh/yr) from Heat Pumps

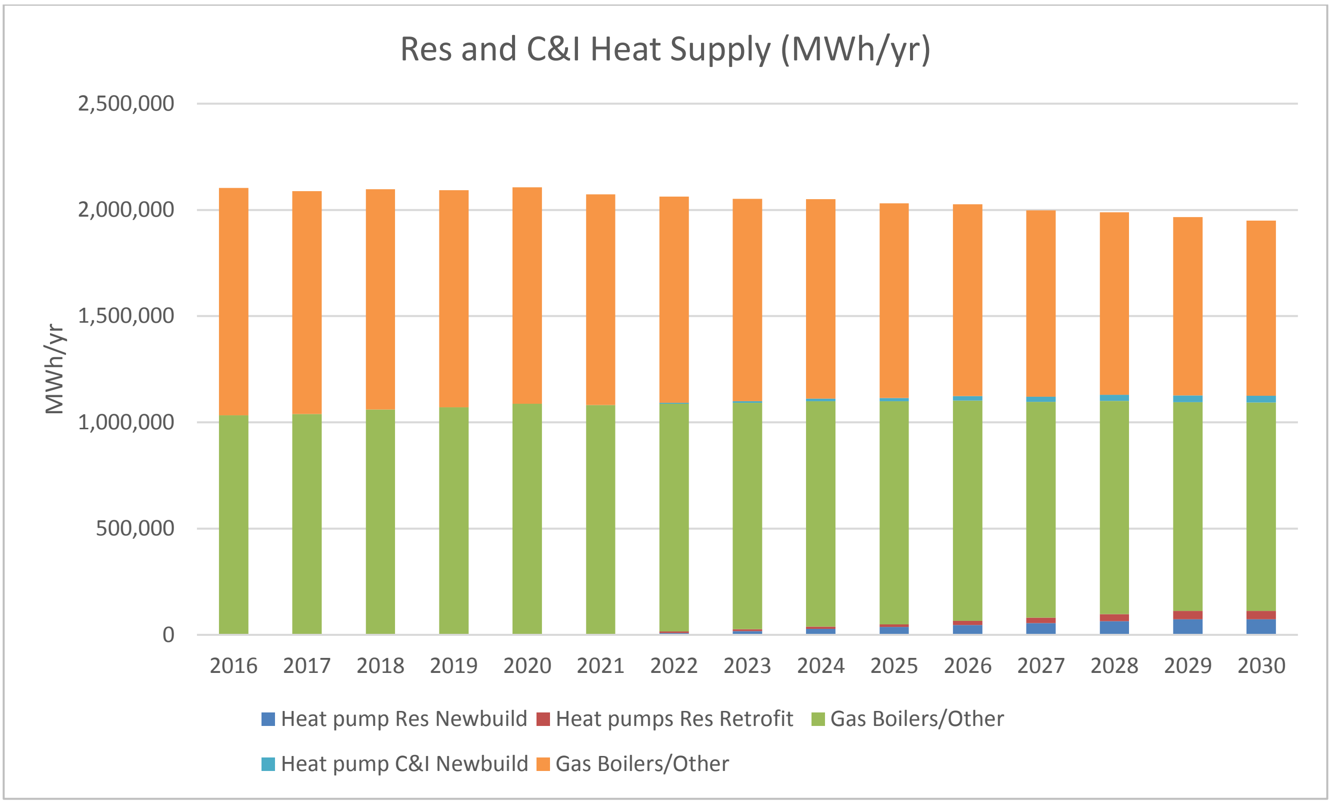

Figure 6 Residential and Commercial and Industrial Heat Supply by Source

The above chart shows the relatively small penetration heat supplied by heat pumps in scenarios 1 and 2. By 2030 heat pumps would supply just 5% of heat demand. Overall heat demand is reducing despite the increase in homes and commercial floor space due to both retrofit of existing buildings and improvements through replacement of existing stock with new buildings – providing a reduction in heat demand of 12% by 2030 on 2016 levels.

3.3.2 Financial analysis

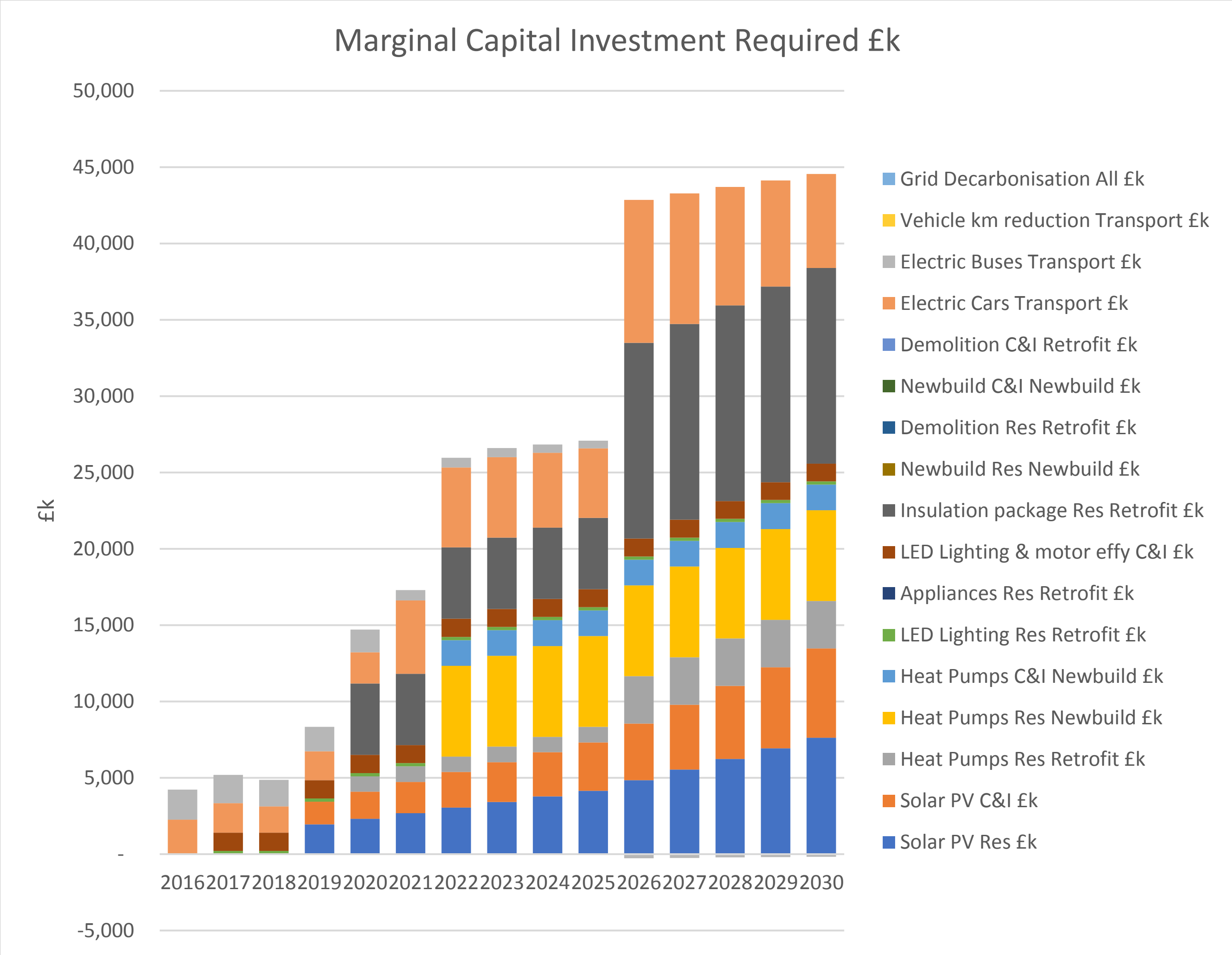

Figure 7: Capital costs (£k) by Measure by year 2016-2030 Scenarios 1 or 2

Capital costs for the scenarios 1 or 2 (from Camden's point of view there's no change between the two scenarios) are shown above in £k. These are expressed in terms of marginal costs over the counterfactual of replacement of the existing system with the same (ie gas boilers with gas boilers). The largest single item is the domestic insulation retrofit (dark grey segment) – because of the significant cost of solid wall insulation. In 2030 the capital investment required will be just under £45m per year and a cumulative spend to 2030 of £378m. Marginal cost assumptions are explained in the appendix.

3.4 Scenario 3 – Radical Heat Pump Approach

3.4.1 CO_2 Emissions

If the Treasury/IAG grid factor is applied together with a more radical approach to replacing gas boilers with heat pumps – ie banning the retrofit of gas boilers from 2022 - then a saving of 68% of CO2 emissions would be achieved against the 2005 baseline. The breakdown of emissions by fuel and sector is shown below.

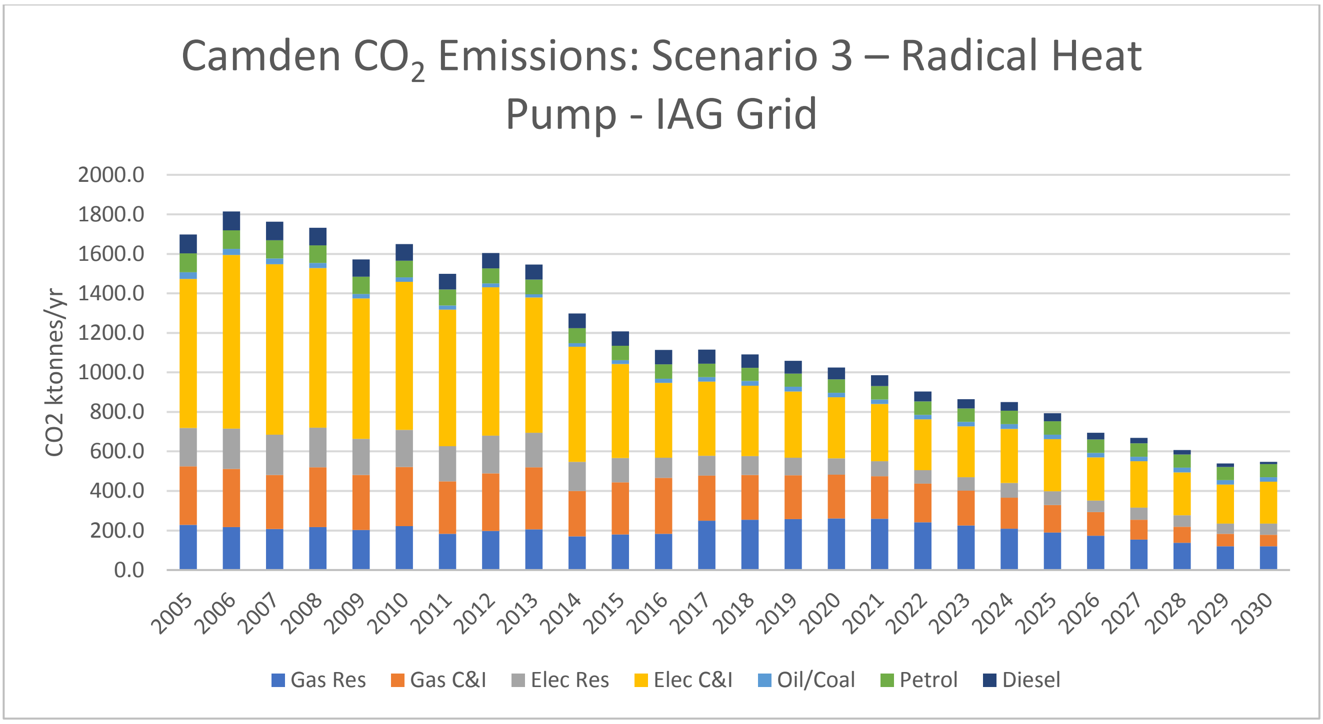

Figure 8: Camden Historic CO_2 Emissions 2005-16 and Projected Emissions 2017-2030 by Sector/Fuel - Radical Heat Pump Scenario

3.4.2 Heat from Heat Pumps

As can be seen from the graph below this would mean that heat pumps still supply only 60% of Camden's heat. This is because the lifetime of gas boilers is around 15 years and gas boilers would not be eliminated until 2036. In order to eliminate them completely would require the early retirement of working gas boilers – possibly through a cash incentive. The financial impact of this would be significant as current high temperature heat pumps such as the Daikin Altherma HT cost around £12,000 installed per household – though lower temperature varieties are available at around £7,500 installed. This additional cost over a gas boiler is – at least partially - recovered currently through the Renewable Heat Incentive where householders are paid for the heat produced over the first seven years of operation – for the non-domestic version of the scheme this is 25 years. This scheme is due to come to an end in 2022.

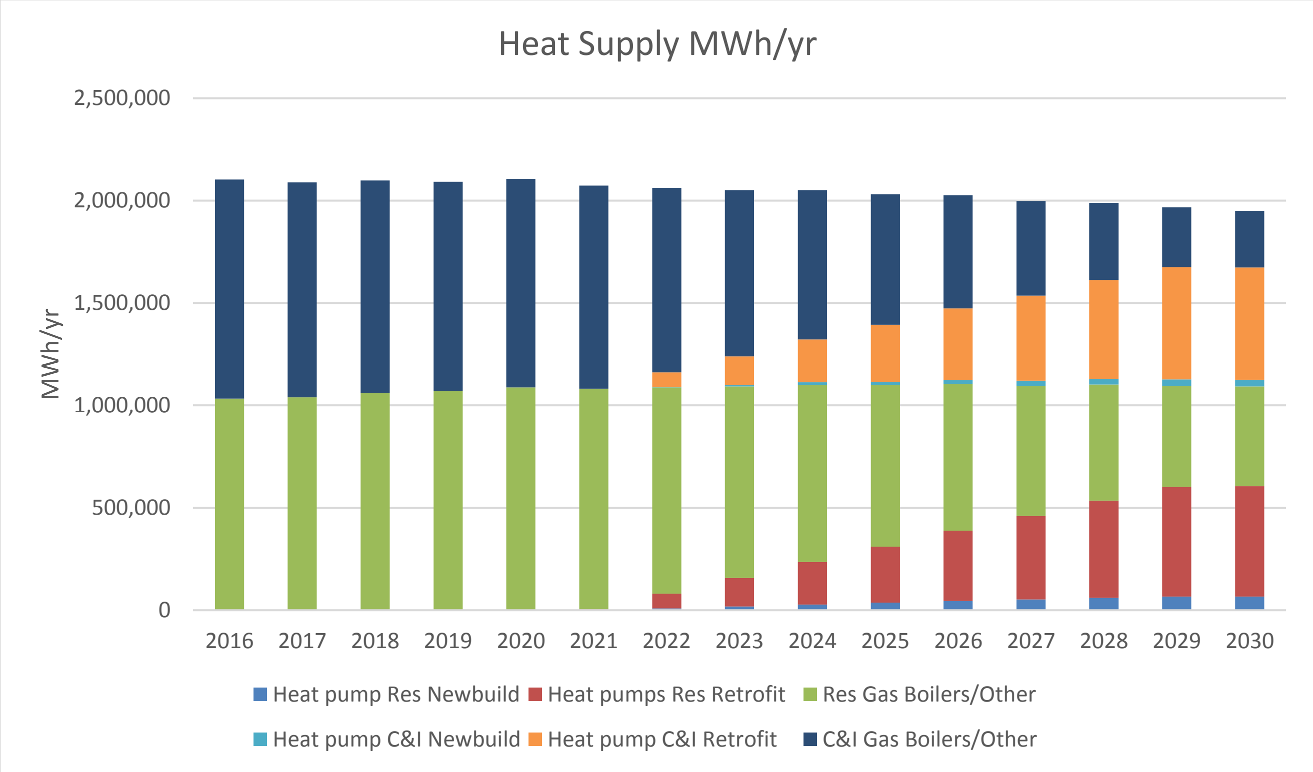

Figure 9 Heat Supply by Source and Sector

3.4.3 Impact on Peak Electricity Demand

The impact of this more aggressive strategy on electricity demand can be seen below in 2030. It shows that the peak demand would increase from 450MW to 700MW. The grid in large parts of Camden is already constrained (as can be seen from the PICLO website where bids are invited to relieve grid capacity constraints) and without care this might entail the largescale replacement of transformers and cables to cope with the increase in peak demand.

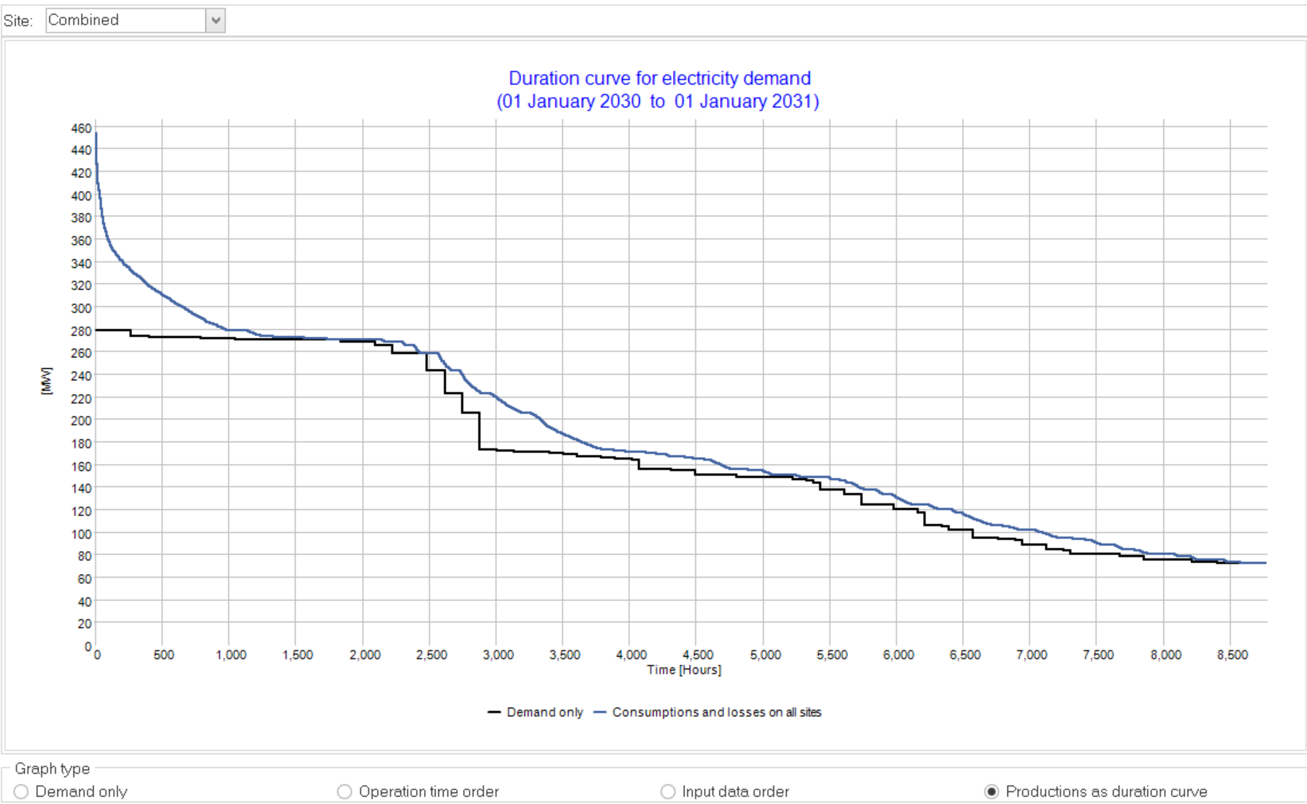

Figure 10 Reference Scenario Electricity Load Duration Curve in 2030

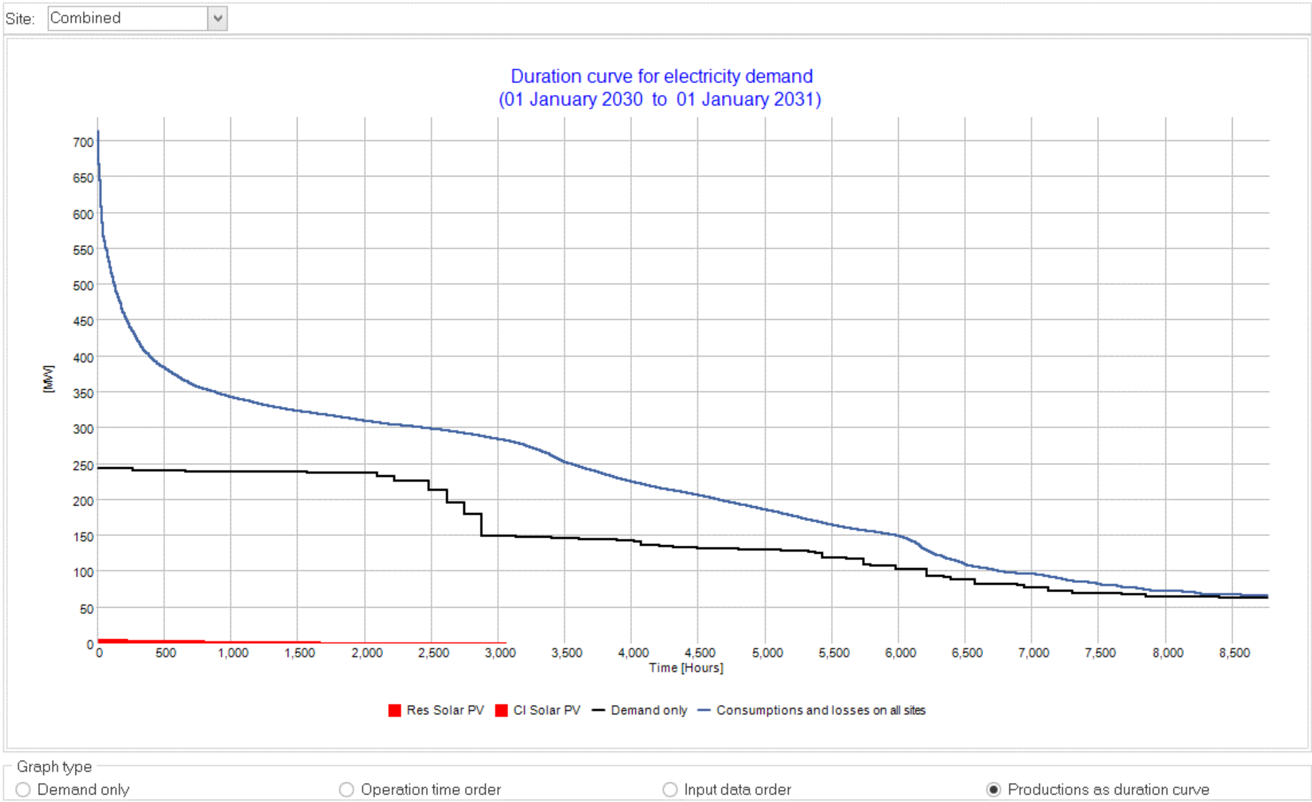

Figure 11 Electricity Load Duration Curve for Radical Heat Pump Scenario

3.4.4 Financial Impact

As the graph below shows this strategy would increase the marginal capital cost from £45m in 2030 to around £73m – and cumulatively to £908m.

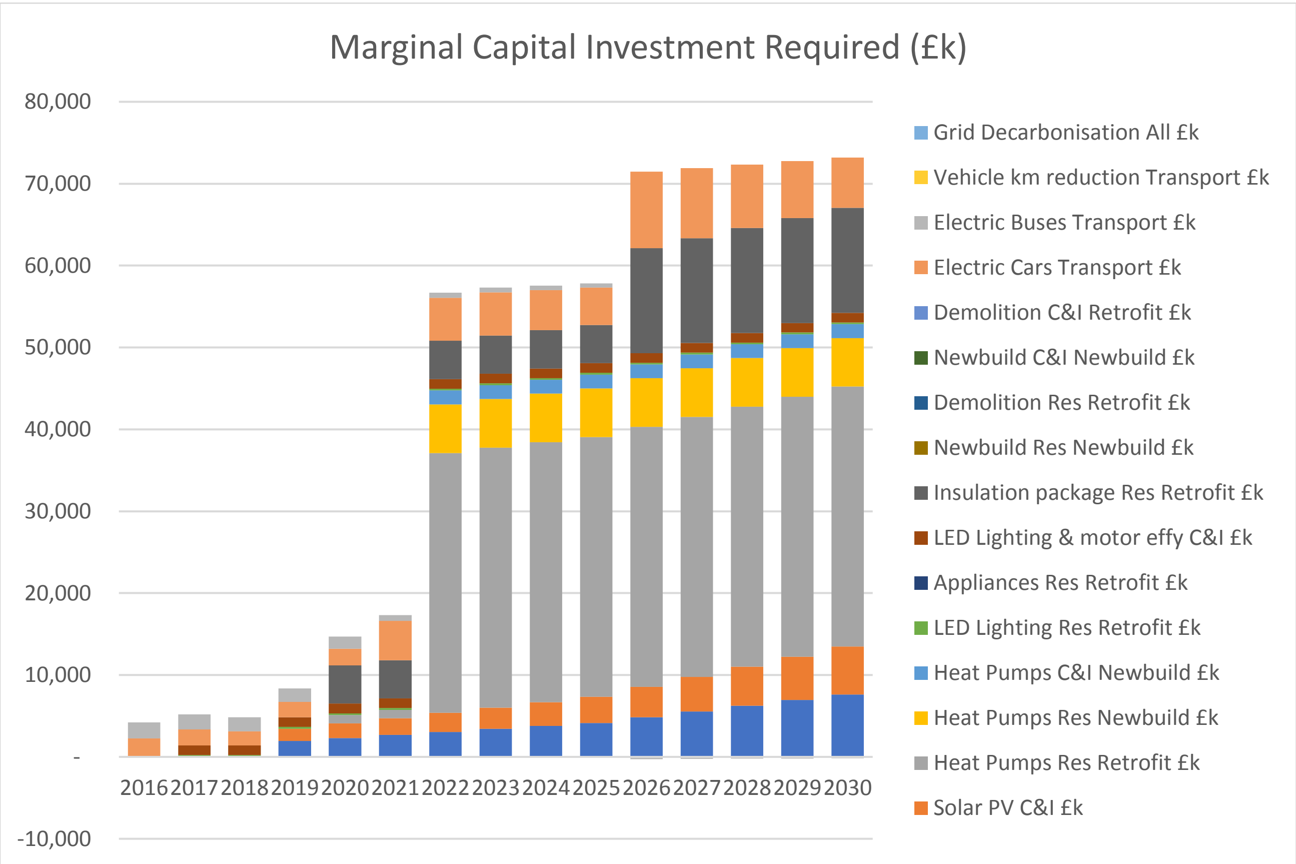

Figure 12 Marginal Capital Investment (£k) Required for Scenario 3

4 Conclusion

This update to the 2010 work (when only 2007 baseline data was available) shows that significant progress has already been made up to 2016. It is clear that a significant proportion of that progress has been through decarbonisation of the grid - much of this happened nationally through the switch from coal to gas fired power generation and wind power – though Camden has played a part in this through installations of gas CHP and solar PV – both of which are included in the national electricity emission factor figures.

The challenge now, as grid decarbonisation continues, is to decarbonise heat and transport - and Camden's role in this is arguably more significant in these sectors.

This work has shown that a reduction of 57% should be achievable with a conservative approach to the uptake of measures. However this conservative approach is still challenging given the constraints it faces - both legal and budgetary.

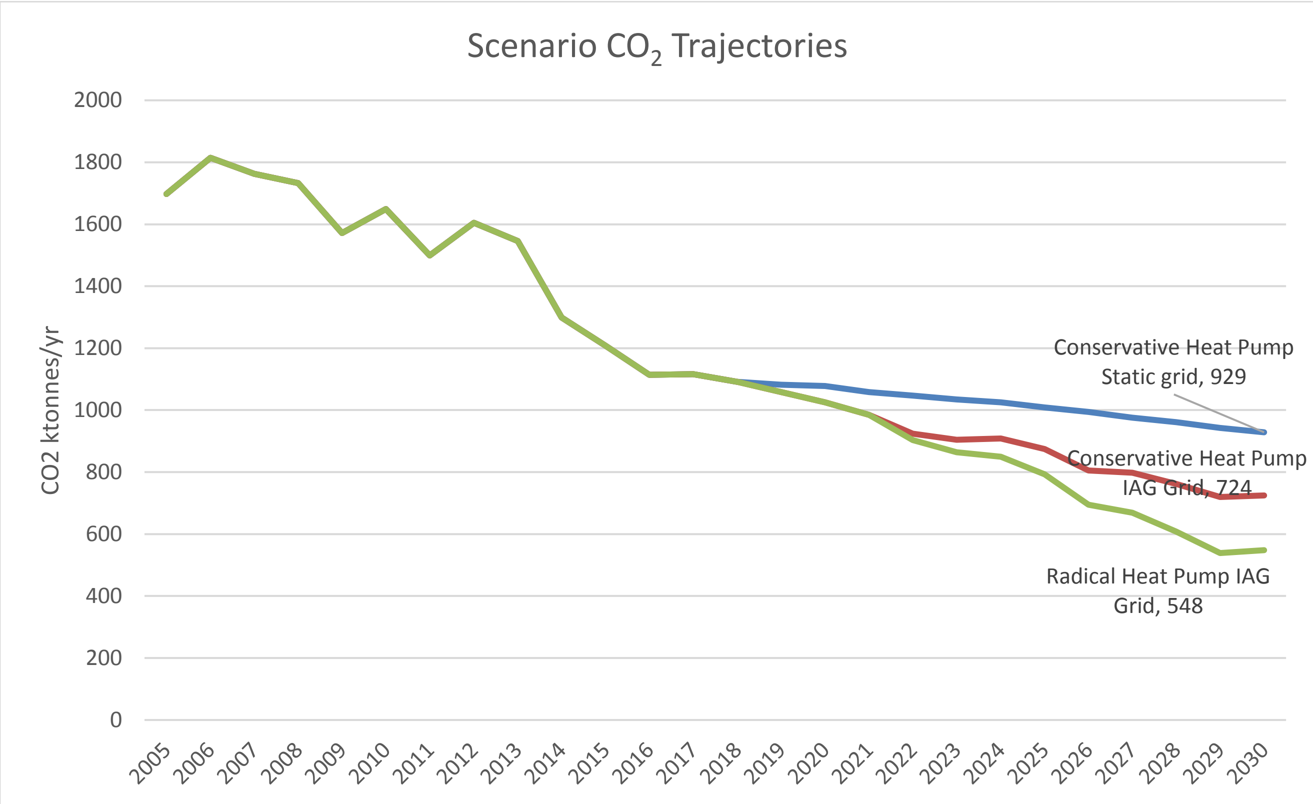

Figure 13 Scenario CO_2 Trajectories

As can be seen above even with the radical approach of prohibiting the retrofit of gas boilers (from 2022), Camden still wouldn't achieve a net zero carbon target by 2030. There are four reasons for this. The first is that the lifetime of a gas boiler is estimated to be around 15 years so with a ban from 2022 it wouldn't be until 2037 that all gas boilers had been replaced with heat pumps. Similarly, there will still be a large proportion of conventionally fuelled vehicles in Camden in 2030 according to the GLA projections. Thirdly we have not modelled any switch of gas hobs and ovens to electricity. Lastly even if all heating and transportation were electrified by 2030 then the electricity that supplies them would still have some carbon content according to the Treasury's own projections.

Net Zero Carbon by 2030

So how could Camden achieve the goal of net zero carbon by 2030? This question was not part of the original brief for this work but Camden's declaration of a Climate Emergency and forthcoming Citizen's Assembly has brought this question to the fore. Putting aside offsetting outside of Camden through tree planting or some other process, reaching zero net carbon by 2030 would require not just the prohibition of gas boiler retrofitting but also the early retirement of gas boilers before the end of their life perhaps through a "cash for clunkers" scheme or similar. A similar approach would be required to the installation and replacement of gas hobs and ovens with electric equivalents. Preventing the use of non-electric vehicles would arguably be easier through a zero emission zone strategy encompassing the whole of Camden that would prevent non-battery electric vehicles driving through the borough. Lastly to deal with the issue of grid electricity not reaching zero carbon by 2030 the large-scale installation of solar PV would be required to supply all of Camden's annual electricity demand on a net basis. So the net in net zero carbon would in this case be applied to the exchange of electricity across different times of the year where in the winter Camden would need to import electricity and in the summer, export solar electricity. The surface area required for such an ambitious programme of solar PV installation would equate to approximately 60% of the area of Camden. This is unlikely to be feasible so the installation of heat pumps would need to be combined with a major increase in the insulation retrofit program in order to reduce demand. An alternative strategy would be to offer district heating to every building in Camden. This would enable the use of more efficient larger water source heat pumps and "prosuming" whereby the extraction of heat for heating from borehole water provides free cooling as a by-product. This would also open up the opportunity for the inclusion of secondary heat sources such as tube ventilation shafts and transformers. Given the high cost of individual heat pumps and the likely need to replace much of the electricity distribution network because of the increased demand they would necessitate, this might be a more optimal solution - both technically and financially.

5 Appendix

5.1 Mix of technologies in Each Scenario

5.1.1 Scenario 1 – Conservative Heat Pump Static Grid

Error! Reference source not found. summarises the measures that have been included in scenario 1 and the number installed in each year (not cumulative).

Measure	Sector	Retrofit or Newbuild?	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Solar PV	Res		kW				1,058	1,257	1,457	1,656	1,855	2,055	2,254	2,633	3,012	3,390	3,769	4,148
Solar PV	C&I		kW				1,293	1,536	1,780	2,024	2,268	2,511	2,755	3,218	3,681	4,144	4,607	5,070
Heat Pumps	Res	Retrofit	Homes					225	225	225	225	225	225	690	690	690	690	690
Heat Pumps	Res	Newbuild	Homes							1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320	1,320
Heat Pumps	C&I	Newbuild	MWh heat							4,111	4,111	4,111	4,111	4,111	4,111	4,111	4,111	4,111
LED Lighting	Res	Retrofit	Homes		7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556
Appliances	Res	Retrofit	Homes		7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556	7,556
LED Lighting & motor effy	C&I		MWh		12,041	12,007	11,973	11,939	11,905	11,871	11,837	11,802	11,768	11,734	11,700	11,666	11,632	11,598
Insulation package	Res	Retrofit	Homes					504	504	504	504	504	504	1,384	1,384	1,384	1,384	1,384
Newbuild	Res	Newbuild	Homes	985	1265	1503	1320	1320	1320	1320	1320	1320	1320	1320	1320	1320	1320	1320
Demolition	Res	Retrofit	Homes	236	236	236	236	236	236	236	236	236	236	236	236	236	236	236
Newbuild	C&I	Newbuild	000s m2	149	149	149	149	149	149	149	149	149	149	149	149	149	149	149
Demolition	C&I	Retrofit	000s m2	101	101	101	101	101	101	101	101	101	101	101	101	101	101	101
Electric Cars	Transport		vehicle mkm	4	8	12	16	19	27	35	43	50	58	76	93	110	127	144
Electric Buses	Transport		vehicle mkm	1	2	3	4	5	6	6	6	7	7	7	7	7	6	6
Vehicle km reduction	Transport		vehicle mkm	451	444	437	430	423	417	413	410	406	403	400	396	393	389	386
Grid Decarbonisation	All		kgCO2/kWh	288	230	221	221	221	221	221	221	221	221	221	221	221	221	221

Table 2: Scenario 1 Measures

5.1.2 Changes in Scenario 2 – Conservative Heat Pump, IAG Grid Decarbonisation

The only change made in Scenario 2 was to allow grid decarbonisation in line with the Treasury projections.

Measure	Sector	Retrofit or Newbuild?	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Grid Decarbonisation	All	N/A	kgCO2/kWh	288	230	221	210	195	184	159	156	162	152	123	129	117	104	112

Table 3 Scenario 2 Changes from Scenario 1

5.1.3 Changes in Scenario 3 – Radical Heat Pump, IAG Grid Decarbonisation

The only change in scenario three from scenario 2 was to include a more aggressive approach to the decarbonisation of heat with gas boiler retrofit prohibited from 2022 and instead replaced by air source heat pumps.

Measure	Sector	Retrofit or Newbuild?	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Heat Pumps	Res	Retrofit	Homes					225	225	7,053	7,053	7,053	7,053	7,053	7,053	7,053	7,053	7,053
Heat Pumps	C&I	Retrofit	MWh heat							69,415	69,415	69,415	69,415	69,415	69,415	69,415	69,415	69,415
Grid Decarbonisation	All	N/A	kgCO2/kWh	288	230	221	210	195	184	159	156	162	152	123	129	117	104	112

Table 4 Scenario 3 Changes from Scenario 1

5.2 Measure Assumptions

The table below briefly describes the assumptions used for each measure.

Measure	Sector	Retrofit or Newbuild?	Units	Source
Solar PV	Res		kW	GLA projections for Camden. These were GWh were back calculated in installed kW peak and these were then modelled in energyPRO using 2017 hourly solar radiation data.
Solar PV	C&I		kW	As above. The split between Res and C&I was based on the ratio of installed capacity in 2018.
Heat Pumps	Res	Retrofit	Homes	Assumed all newbuild from 2022 will be fitted with heat pumps. COP for the heat pumps were based on the Daikin HT air source heat pump. Each home retrofitted was assumed to have the space heating and DHW consumption of an average Camden 2016 home. Camden provided estimates of deliverable projects across tenure. For scenario 3 it was assumed that 1/15th of all existing residential gas boilers were replaced with heat pumps each year from 2022. This was on the assumption that the average lifespan of a boiler is 15 years.
Heat Pumps	Res	Newbuild	Homes	Assumed all newbuild from 2022 will be fitted with heat pumps. COP for the heat pumps were based on the Daikin LT air source heat pump. The space heating and hot water projections for newbuild were used to estimate the heat output of each heat pump.
Heat Pumps	C&I	Newbuild	MWh heat	Assumed all newbuild from 2022 will be fitted with heat pumps. The space heating and hot water projections for newbuild were used to estimate the heat output of each heat pump.
LED Lighting	Res	Retrofit	Homes	BEIS dataset energy consumption UK tables were used. These provide a breakdown of lamp types in homes nationally. It was assumed that Camden homes were typical of the national figures. The dataset provides numbers of lamps by type i.e. GLS, halogen, CFL and LED. Savings were calculated by assuming a linear replacement of all non-LED lamp types with LEDs by 2030. In 2016 19% of lamps were still non-LED according to the BEIS dataset.
Appliances	Res	Retrofit	Homes	The same BEIS dataset used for LEDs was used for appliances. In this case we estimated the trend rate of improvement in energy consumption relating to appliances. This national trend rate was then apportioned to the Camden housing stock and it was assumed that the trend would continue to 2030 at a linear rate. The calculated saving annually was 48 kWh per home. This means that the average annual consumption from appliances would fall from 2270 kWh in 2016 to 1600 kWh per home by 2030.

LED Lighting & motor efficiency	C&I		MWh	Commercial and industrial efficiency improvements were restricted to lighting and motors. While this might appear narrow, motors are one of the largest single sources of electricity use in the sector and are used to drive pumps, fans and compressors which are the main source of energy consumption in ventilation and air-conditioning systems. The BEIS dataset showed that, for computing, reductions in energy consumption had stalled in the last few years so it is assumed that this sector remains static. Again trend rates in efficiency were derived from the BEIS dataset.
Insulation package	Res	Retrofit	Homes	The approach to insulation was to include four measures: solid wall insulation, cavity wall insulation, loft insulation and double glazing. Energy Saving Trust (EST) figures were used to derive savings per home. EST give figures for different dwelling types i.e. detached or semi-detached et cetera. The saving figures were then weighted according to the dwelling type mix across Camden. However the remaining number of uninsulated lofts walls and windows varies greatly in Camden. To combine the measures into a single retrofit measure further weighting was applied based on the maximum potential for each measure.
Newbuild	Res	Newbuild	Homes	The number of newbuild homes was provided by Camden planning department and as described earlier energy consumption by end use was calculated from EPC certificate data for Camden – with an incremental reduction in heating demand from tightening of national Building Regulations assumed.
Demolition	Res	Retrofit	Homes	The number of homes demolished each year was provided by Camden planning department and as described earlier energy consumption by end use was calculated assuming the demolished home had the consumption of the 2016 average.
Newbuild	C&I	Newbuild	000sm2	The number and floor area of newbuild commercial and industrial was provided by Camden planning department and as described earlier energy consumption by end use was calculated from EPC certificate data for Camden.
Demolition	C&I	Retrofit	000sm2	The number and floor area of newbuild commercial and industrial was provided by Camden planning department and as described earlier energy consumption by end use was calculated from EPC certificate data for Camden.
Electric Cars	Transport		vehicle mkm	GLA projections from the Mayor's transport strategy for Camden were utilised.
Electric Buses	Transport		vehicle mkm	GLA projections from the Mayor's transport strategy for Camden were utilised.
Vehicle km reduction	Transport		vehicle mkm travelled	Figures from the draft Camden transport strategy were used. A straight line interpolation was applied to derive figures for each year.

Grid Decarbonisation	All	kgCO2/kWh	Based on the Treasury/IAG projections for grid carbon emissions. These were weighted to the mix of demands in Camden as the figures are provided for each type of customer. The average grid emission factor was selected. Under the static grid factor scenario no change beyond 2018 was projected.

Table 5 Measure Assumptions

5.3 Measure Marginal Capital Costs Assumptions

Sector	Retrofit or Newbuild?	Units	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Res		£/kW			1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840	1,840
C&I		£/kW			1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153	1153
Res	Retrofit	£/home	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500	4500
Res	Newbuild	£/home							4500	4500	4500	4500	4500	4500	4500	4500	4500
C&I	Newbuild	£/MWh							411	411	411	411	411	411	411	411	411
Res	Retrofit	£/home	28	28	28	28	28	28	28	28	28	28	28	28	28	28	28
Res	Retrofit	£/home	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C&I		£/MWh		100	100	100	100	100	100	100	100	100	100	100	100	100	100
Res	Retrofit	Homes	9260	9260	9260	9260	9260	9260	9260	9260	9260	9260	9260	9260	9260	9260	9260
Res	Newbuild	Homes															
Res	Retrofit	Homes															
C&I	Newbuild	000sm2															
C&I	Retrofit	000sm2															
Transport		£/vehicle mkm	540,000	495,000	450,000	505,000	560,000	615,000	670,000	675,000	630,000	585,000	540,000	495,000	450,000	405,000	360,000
Transport		£/vehicle mkm	1,885,714	#### ####	#### ####	#### ####	#### ####	#### ####	1,371,429	#### ####	#### ####	#### ####	#### ####	942,857	857,143	771,429	685,714
Transport		vehicle mkm travelled															
All		kgCO2															
Battery cost per kWh			165	157.5	150	142.5	135	127.5	120	112.5	105	97.5	90	82.5	75	67.5	60
EV grant			4500	4500	4500	3500	2500	1500	500	0							

Table 6 Measure Capital Cost Assumptions

5.3.1 Measure Capital Cost Assumption Sources

Measure	Sector	Retrofit or Newbuild?	Source	Notes
Solar PV	Res		https://www.gov.uk/government/statistics/solar-pv-cost-data	no price reduction between 2015-18
Solar PV	C&I		https://www.gov.uk/government/statistics/solar-pv-cost-data	0
Heat Pumps	Res	Retrofit	https://www.which.co.uk/reviews/ground-and-air-source-heat-pumps/article/air-source-heat-pumps-explained	Marginal cost over boiler 2500
Heat Pumps	Res	Newbuild	https://www.which.co.uk/reviews/ground-and-air-source-heat-pumps/article/air-source-heat-pumps-explained	Newbuild will be cheaper but so will boilers in newbuild so marginal cost the same
Heat Pumps	C&I	Newbuild	Star refrigeration £500 per kWth heat pump assuming 5000 run hours per year	0
LED Lighting	Res	Retrofit	https://robinhoodenergy.co.uk/news/energy-saving-light-bulbs/	£4 per bulb and 28 non LED bulbs per household but against £3 per bulb for CFLs
Appliances	Res	Retrofit	https://www.currys.co.uk/gbuk/freestanding-washing-machines/laundry/washing-machines/332_3119_30206_xx_ba00010669-bv00308556-ba00013307-bv00312406/xx-criteria.html	For dishwashers and washing machines v little relation between price and energy label
LED Lighting & motor effy	C&I	0	https://www.any-lamp.co.uk/led-lights/led-tubes/t8-led-tubes?replacer_for_lamp_power=37621	10W saving per lamp assuming 3000hrs operation = £3 per 30kWh saved or £0.1/kWh/yr
Insulation package	Res	Retrofit	calculated on R retrofit page	
Newbuild	Res	Newbuild		
Demolition	Res	Retrofit		
Newbuild	C&I	Newbuild		
Demolition	C&I	Retrofit		
Electric Cars	Transport		https://www.ucsusa.org/sites/default/files/attach/2017/09/cv-factsheets-ev-incentives.pdf?_ga=2.108452610.1630188791.1517413160-1434713090.1436805699	£5000 additional cost of e car over conventional. Each car 10,000km per year
Electric Buses	Transport			
Vehicle km reduction	Transport			
Grid Decarbonisation	All			

	Battery cost per kWh	https://www.ucsusa.org/sites/default/files/attach/2017/09/cv-factsheets-ev-incentives.pdf?_ga=2.108452610.1630188791.1517413160-1434713090.1436805699	prices converted to £ at .75 dollar exchange rate and 60kWh battery assumed
	EV grant		