APPENDIX F – MACC ASSUMPTIONS

Marginal Abatement Cost Curves (MACC) are regularly used by organisations concerned with the climate change. They help visualise complex data about carbon costs and emissions volumes. It is a way of ranking and comparing different technologies, actions or projects by cost and GHG saving. The MACC is an aid to decision making that provides a simple way of identifying which projects are the most cost effective per unit of CO_2e abated and which options offer the greatest abatement potential.

Projects which have the lowest cost per CO_2e reduction appear to the left, with projects with the least savings to the right; with the actual amount of savings (either lifetime or per annum) denoted by the width of the project along the x-axis. Projects which appear below the horizontal axis (and have a marginal abatement cost of less than £0) save money over their lifetime, while those above the axis increase overall costs over the project life.

The development of a MACC allows the size and cost of carbon reduction options to be compared.

The creation of the MACC curve for each of the goals modelled for the Combined Authority involves a number of steps. The following parameters are considered:

- total project costs (CAPEX)
- project implementation year (i.e. when CAPEX is committed/savings start)
- project lifetime (i.e. how long savings continue for)
- annual energy or other OPEX savings, split by fuel (excluding carbon price or other financial incentives / support mechanisms)
- fuel prices
- carbon emission factors for the fuels

From the above data, the Net Present Value (NPV) of each intervention and the lifetime GHG savings can be calculated.

In (NPV) calculations, cash inflows are traditionally shown as positive values and cash outflows are negative values. However, the notation for MACC curves is that a positive NPV equates to a negative carbon abatement cost (i.e. the lifetime cost is a net saving).

The Marginal Abatement Cost is therefore calculated by dividing the negative value of the NPV of the cashflows by the lifetime GHG savings, which is not discounted. The NPV value considers the current year (e.g. 2021) as year 0, with all cash flows discounted back to this year using the specified discount rate (3.5% in this case). Discounting reflects the fact that the cost or savings today are more valuable than a similar cost or saving in the distant future. Low discount rates increase the long-term net benefit of a technology compared to its initial cost and so brings more technologies under the zero line of the MACC.

The Marginal Abatement Cost in £/tCO_2e is obtained by dividing the negative of the NPV of the project (in today's prices) by the total CO_2e abated by the project over its lifetime. In line with current World Bank guidance, the CO_2 saving itself is not discounted over time.

The results for each measure are then stored in ascending order of £/tCO_2e (y-axis of MACC curve) with the largest negative figure first (i.e. measures which result in a net cash inflow) and the largest positive figure last, (i.e. measures with a net cash outflow). Next to each of the projects the lifetime and annual carbon savings (tCO_2) are presented (x-axis of MACC curve).

A MACC can be used to aid decision making; however, it does not replace technical knowledge and experience; it does not tell you which projects to implement and which not. It simple provides a graphical representation of the least cost approach to meeting carbon targets. Similarly, it does not necessarily consider which technologies are mutually exclusive or inter-dependent or factor in risk in any way.

In preparing the Marginal Abatement Cost Curve for each of the goals, a number of assumptions were made. These are listed below.

Global Assumptions

The following data sources were used across the model

- Retail Gas Prices - Treasury Green Book, Table 5, Central Estimate
- Retail Electricity Price - Treasury Green Book, Table 5, Central Estimate
- Retail Petroleum Price – BEIS Fossil fuel price assumptions: 2019
- Gas Emissions Factor (static value) – BEIS Greenhouse gas reporting: conversion factors 2020
- Electricity Emissions Factors to 2041 - Treasury Green Book, Table 1
- Petroleum Emissions Factor (static value) – BEIS Greenhouse gas reporting: conversion factors 2020

Domestic Energy Efficiency

This goal considered a basic retrofit package considering the potential of a number on measured designed to reduce heating consumption. These have been assumed to be applicable to homes which currently do not have the technology and where it may be installed (e.g. 14% of dwellings with cavity walls are insulated). Whilst the key measures are listed below there are other methods of reducing heating and domestic hot water consumption such as improving air tightness or fitting tap aerators. Behavioural change is also not captured below; this has the potential to have significant impact but will require long-term, continual action to maintain. Alternatively, whole-house retrofits (such as enerphit) may be employed and have even larger impact.

	APPLICABILITY	BUNGALOW	FLAT	TERRACED	SEMI-DETACHED	DETACHED	OTHER
Smart Thermostats	94%	£150	£150	£150	£150	£150	£150
Smart Meters	69%	£-	£-	£-	£-	£-	£-
Cavity Wall Insulation	14%	£500	£300	£350	£480	£550	£436
Solid Wall Insulation	27%	£5,000	£4,300	£5,500	£7,000	£8,900	£6,140
Loft Insulation	18%	£430	£180	£180	£180	£220	£238
Double Glazing	7%	£5,800	£1,200	£3,200	£4,800	£5,000	£4,000

Energy savings are based on a reduction in gas consumption, though broadly similar savings could be achieved if an air source heat pump were assumed.

	2021 TO 2041	2021 TO 2026
Discount Rate	3.50%	3.50%
NPV	-£874,128,835	-£1,027,110,445
Total Carbon Saving (tCO_2)	7,425,781	33,908
Marginal Abatement Cost (£/tCO_2)	£117	£1,620

Domestic Heat Pump Retrofit

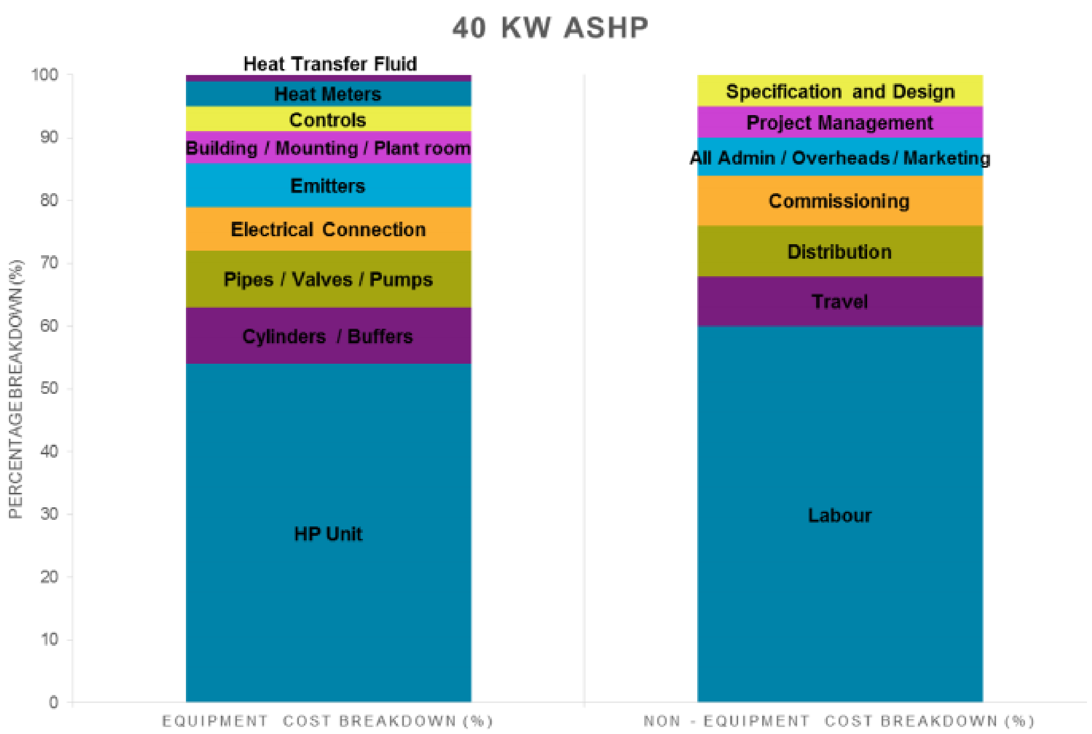
This goal considers the benefit of replacing current fossil fuel heating systems (predominantly gas boilers) within dwellings with nominally air source heat pumps. An average (existing) gas boiler efficiency of 75% is assumed and heat pump COP of 2.65. wider costs around modifying heating distributions systems are not considered as are electrical infrastructure upgrades.

	BUNGALOW	FLAT	TERRACED	SEMI-DETACHED	DETACHED	OTHER
Capex per unit	£7,700	£6,900	£8,100	£8,100	£10,800	£6,934
No of Properties	48,390	251,980	358,610	373,520	130,660	15,100

The capital costs above are based on present day installation costs for individual units. These are like to reduce, because:

- **Legislation** – the ban on gas boilers due to come in force in 2025 will push widespread take up of this technology allowing for further competition (new entrants into the market place) and economies of scale
- **Training** – currently there are relatively few heating engineers qualified to install a heat pump. As the number of people trained up increases the labour costs are more likely to fall.
- **Standardisation** – Standardisation of installations may mean less time is required to design and maintain systems while also opening up installation to less qualified personnel.
- **Mass Rollout** – By undertaking a mass roll out, the economies of scale could be further achieved via centralised purchasing
- Removing the 20% VAT rate on heat pump equipment and the 5% VAT rate on heat pump labour costs[1]

Figure 1 - Current cost breakdown of a 40 kW ASHP (retrofit)[2]



Domestic Photovoltaic Systems

This goal considers the impact of installing rooftop solar on existing dwellings. An installed cost of £800 per kWp has been assumed here which is less than the current market rate for domestic systems. There are several bulk solar

[1] https://www.london.gov.uk/sites/default/files/heat-pump-retrofit-in-london-v2.pdf
[2] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf

purchasing schemes operational within the UK. Data from Solar Together London suggests that on average bulk purchasing has reduced costs by 35%. The 35 per cent average discount of the panels over market prices ranges from 10 per cent discount for the smallest solar photovoltaic system in the scheme (four panels) to 41 per cent for the largest system of 36 panels. The most common system of 10 panels comes in at 31 per cent below the baseline market price[3].

What is proposed by this project is an order of magnitude higher than the reference projects, so there are potential further savings to be had, but, as this is already a commercialised technology this will be more on the installation costs than the cost of equipment.

Commercial Energy Efficiency

This goal considered the energy abatement potential of a range a non-domestic building types. The cost for abatement were pro-rataed from the table below for the building stock in the Combined Authority.

Figure 2 - Abatement Potential by Sector[4]

Sector	Capital Expenditure required to deliver abatement potential (£ billion)	Baseline		Abatement potential		
		Annual electrical energy consumption (GWh/year)	Annual non-electrical energy consumption (GWh/year)	Annual electrical energy savings (GWh/year)	Annual non-electrical energy savings (GWh/year)	Overall reduction (%)
Retail	5.8	21,670	5,670	7,250	2,180	34
Offices	6.8	18,840	8,780	6,270	4,280	38
Hospitality	1.8	8,760	8,230	2,040	2,260	25
Industrial	4.6	11,320	14,410	4,520	7,190	46
Storage	2.5	7,440	5,670	2,430	2,690	39
Health	1.7	6,240	11,140	2,350	4,730	41
Education	2.1	4,930	10,100	1,670	5,090	45
Emergency services	0.6	1,260	2,970	530	1,610	51
Military	0.3	690	1,150	380	610	54
Community, arts & leisure	2.2	3,680	8,110	1,450	3,640	43
Total	**28.4**	**84,820**	**76,240**	**28,870**	**34,290**	**39**

Commercial Heat Pump Retrofit

This goal considers the benefit of replacing current fossil fuel heating systems (predominantly gas boilers) within commercial properties with nominally air source heat pumps. A slightly higher CoP of 2.75 is assumed here. A cost of £27 per sqm is assumed here for a building level air source heat pump system with refrigerant distribution to fan coil units and a separate system for domestic hot water preparation.[5]

[3] https://www.london.gov.uk/press-releases/mayoral/mayor-expands-solar-panel-scheme
[4] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/565748/BEES_overarching_report_FINAL.pdf
[5] https://www.london.gov.uk/sites/default/files/low_carbon_heat_-_heat_pumps_in_london_.pdf

Commercial Photovoltaic Systems

This goal considers the impact of installing rooftop solar on existing commercial properties. An installed cost of £750 per kW has been assumed here which is typical for a medium sized commercial system.

Industrial Energy Efficiency and Fuel Switching

This goal has not been included within the MACC due to the level of uncertainty around the costs for full implementation. Resources should be devoted around research and development as well as working with local actors to trial projects and technologies.

Industrial Photovoltaic Systems

This goal considers the impact of installing rooftop solar on existing industrial properties. An installed cost of £750 per kW has been assumed here which is typical for a medium sized commercial system. Other renewable technologies are also possible especially around usage of biomass and wastes as well as via the use of circular economy principles.

Transport Demand Reduction

This goal considers the potential of reducing the need to demand and digitisation of services. This is already underway with the increase in working from home, (especially during the recent pandemic), as well as growth in online shopping. The cost attributed to this goal is related to providing ultrafast broadband to all dwellings within the WMCA. The current penetration of ultrafast broadband varies across the seven local authorities from 71% to 93% of dwellings[6]. In total the number of dwellings that are still without are in the region of 180,000. The cost of providing broadband to homes averages less than £500 per dwelling[7], though it is likely the outstanding dwellings are those considered harder to reach.

The true cost of this goal is associated with ensuring rebound effects are limited. This includes:

- Creating local flexible working spaces which reduces commuting distances and allows people to reach offices by walking or via active travel. It is likely that in the future many people would still choose to not fully work from home and this would facilitate this and provide a halfway house between working from home and travelling to large central offices.
- Many homes also do not have adequate space for a home office and so working from home in the long term would be unsustainable (working from bedrooms, in noisy environments or on kitchen counters may have physical and mental health implications). There is a role in planning in ensuring all new dwellings have adequate home working spaces and also understanding the changes that may be needed to existing dwellings.
- Creating local community spaces which centralise deliveries. The key here is to reduce the number of LGV deliveries that go street to street and instead have local delivery locations where people can reach via walking. This goes hand in hand with other freight exchange initiatives.

Transport Modal Shift

This goal has not been included within the MACC due to the level of uncertainty around the costs for full implementation and indirect impacts. There are some known costs associated with proving additional infrastructure say to facilitate active and public travel (cycle pathways, BRT routes etc). But wider costs are more difficult to estimate. In order to create transport modal shifting, there will also require a change in planning such that destinations

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[6] https://www.wmca.org.uk/media/2230/infrastructure.pdf
[7] https://www.ispreview.co.uk/index.php/2019/06/ofcom-uk-examines-the-cost-of-deploying-full-fibre-broadband.html

are co-located next to public transport rather than only being accessible by cars (transport-orientated developments). This would be a rapid shift in how cities are planned. Another consideration is demand management measures to reduce the reliance on cars; this includes increasing the cost of driving to make it less desirable.

Bus and Taxi Fleets

There are over 21,000 licensed taxis in the Combined Authority and the analysis is based on each operated 30,000 miles per annum. The figures have been obtained from the Low Carbon Vehicle Partnership[8] and only the additional costs (over what is assumed to be committed) included.

	CAPEX	OPEX
Electric Taxi (e.g. Nissan Leaf)	£25,190	£1,255
Normal Taxi (e.g. Skoda Octavia)	£19,810	£2,936
Additional cost	£5,380	-£1,681

A similar source was used to estimate the capital and operational cost for electric buses. The capex was assumed to be £105,000 more to purchase and £18,000 per annum cheaper to operate[9].

In both of these cases the infrastructure costs associated with developing charging hubs at key locations are not included.

Heavy Goods Vehicle Fleet

This goal has not been included within the MACC due to the level of uncertainty around the costs for full implementation. As HGVs operate nationally as well as internationally there is a wider need for co-operation and linking thinking to prevent stranded assets.

Accelerated EV uptake

This goal has not been included within the MACC due to the level of uncertainty around the costs for full implementation. The goal is linked to the assumptions made by the Committee on Climate Change and would need considerable resources to ensure adequate infrastructure is in place. Planning will also play a major role as will local initiatives similar to the electric vehicle experience centre in Milton Keynes.

Land Use Natural Capital

The costs presented here includes the cost woodland planting and establishment costs and woodland management costs. The cost of these activities exceed £230 million. The key point here is that there is no nature payback or income stream mechanism considered. It is likely income will be available either from sale of timber or the proposed government ELM scheme.

Land Use Renewables

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[8] http://www.lowcvp.org.uk/assets/reports/LowCVP_Low_Emission_Taxi_Guide-March_2019_Update.pdf
[9] http://www.lowcvp.org.uk/assets/presentations/7.%20Fast%20Charging%20in%20Nottingham%20-%20Steve%20Cornes,%20NCC.pdf

The present-day costs of photovoltaics include cost of modules, inverters, grid costs, balance of system costs etc. the rental of land is also included as a minor cost. The total cost is estimated to in the region of £500,000 per MWp. Equipment costs are likely to drop over the next ten years.

BEIS electricity generation costs are used to estimate the installed cost of wind at £1m per MW[10].

There are no obvious income mechanisms currently and therefore it is assumed there is an income from Power Purchase Agreements (PPA) at around £50 per MWh.

[10] https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020