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How do cities support electric vehicles and what difference does it make?

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ABSTRACT

Many cities publish climate change mitigation strategies and other policy measures to support the wide spread uptake of Electric Vehicles (EVs). This paper investigates the effectiveness of these strategies and the provision of infrastructures in 30 UK cities, with a specific emphasis on those strategies that are within the remit of cities and local authorities. The climate mitigation strategies and supporting documents were obtained from 30 UK cities recommended by the Urban Audit Methodology. We show that 13 cities mention EVs in their strategies. Analysing EV registrations and the EV infrastructures that is provided by cities we found that there is no statistical difference in the number of charging points or EVs between the cities that have EVs as part of their climate change mitigation strategy and those that do not. It was shown that EV uptake was more generally associated with other factors (such as local vehicle population or income) rather than any documented EV/climate mitigation strategy. We demonstrate that local strategies are failing in achieving the much needed step change and make suggestions how to improve EV uptake as an even more radical thinking and policies may become necessary to achieve carbon reduction targets.

1. Introduction

It is generally agreed that the global atmospheric concentrations of Greenhouse Gases (GHG) such as CO_2 have increased markedly as a result of human activities since the industrial revolution and humans are clearly influencing the climate system (IPCC, Climate Change 2013: The Physical Science Basis, 2013). The largest growth in anthropogenic GHG emissions between 1970 and 2004 was attributed mainly to energy supply, industry and transport. Transport in particular relies strongly on fossil fuels and accounts for about a quarter of global energy-related GHG emissions (IEA 2016). Transport is a key enabler for economic growth that supports the productivity within conurbations and their catchment areas, by getting people to work and allowing the transfer of goods and services, which are all keystones of the economy. It is therefore important to reconcile the need for travel with the need to reduce carbon emissions from transport. This is particularly challenging in a post-2008 age of austerity where economic growth and productivity have, at least, as high a political priority as decarbonisation.

There is an urgent need to concentrate on cities and their sustainable transport strategies for dealing with the challenges (and opportunities) that climate change may bring. Today 54% of the world's population live in urban areas which is anticipated to increase to 66% by the year 2050 (United Nations, 2015). International and national commitments influence European city strategies positively (Heidrich et al., 2016). Urban areas in general and cities in particular are the hub of innovation, power and wealth (Bettencourt and West, 2010) and can shape socio-technical transitions (Hodson and Marvin, 2010), but are also responsible for some 70% of global energy related carbon emissions (IEA, World Energy Outlook, 2008). Nevertheless, a self-reported survey of 36 megacities demonstrated that cities believe that they have the power and opportunities to take action to mitigate climate change (ARUP, 2011).

In the UK, the Climate Change Act (AoP, The Climate Change Act, and Acts of Parliament (AoP), 2008) placed a duty onto the country to ensure that net carbon account for the year 2050 is at least 80% lower than the 1990 baseline. The Act aims to improve carbon management and help the UK's transition towards a low carbon economy. Whilst the country's total GHG emissions were 29% lower in 2013 compared to 1990 levels (DECC, 2013), the emissions from the transport sector remained nearly constant in 2013 compared to 1990 levels. 58% of the GHG emissions from the transport sector are attributed to cars and taxis, 12% to light vans and 21% to other road vehicles such as buses and Heavy Good Vehicles (HGVs) (DfT, 2013). It is evident that emission reductions from the transport sector are required to meet the

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overall reduction targets and since a large share of the emissions are coming from cars and light vans, climate change mitigation strategies are promoting the uptake of ultra-low carbon vehicles for road transport (DfT, 2011; OLEV, 2011).

One potential strategy for the reduction of emissions from cars and light vans is the electrification of the fleet through the replacement of existing vehicles with an electric equivalent. Research within this field has shown that EVs produce a decrease in the well to wheel emissions for CO_2 in a country with a less carbon intensive power grid (Doucette and McCulloch, 2011; Ensslen et al., 2017) but demonstrate a reduced benefit when the full life cycle assessment of the EV is considered (Hawkins et al., 2013). Despite the larger amount of embedded carbon within the life-cycle of the EV it is possible that recent developments regarding the acknowledged gap between test cycle and real world emissions may show that the on-road benefits of EVs may be even greater than previously calculated (Duarte et al., 2016).

A recent study has highlighted the current state on policy goals in the UK and Germany to decrease GHG emissions with the fast introduction and diffusion of low emission vehicles and simultaneously the development or preservation of their automotive industry and its competitiveness (Mazur et al., 2015).

In 2011, the DfT committed £400 million for the development, supply and use of ultra-low emission vehicles. This package included over £300 million funding for the Plug-in car grant which reduces the upfront cost of purchasing EVs and qualifying Plug-in Hybrid Electric Vehicles (PHEV) plus £30 million for recharging infrastructure provision through the Plugged in Places Programme (OLEV, 2011). The first eight Plugged in Places Project aimed to install up to 8500 charging posts across Central Scotland, the East of England, Greater Manchester, London, the Midlands, Milton Keynes, the North East of England and Northern Ireland. Since then, the UK Government has announced a further £37 million investment into public recharging infrastructure at train stations, on public sector estate and on-street and rapid charging networks (Office for Low Emission Vehicles, 2013a, 2013b).

Despite Government efforts to promote the uptake of EVs, their market share is falling short of Government and industry expectations (Steinhilber et al., 2013), with some authors suggesting that they will remain a niche market over the next 20 years (Tran et al., 2013). The UK market share of EVs in 2015 was just over 1% (IEA, 2016). If the UK is to meet its reduction targets, the Committee on Climate Change (the CCC) estimates that the ultra-low emission vehicles should reach a market share of 60% by 2030 (CCC, 2015) indicating that drastic measures are needed to reach these market shares.

A range of studies have investigated the incentives and policy requirements that can increase EV uptake (Bohnsack et al., 2014; Gardner et al., 2013; Pasaoglu et al., 2014; Tran et al., 2013), but little is known if and how local policies and/or strategies do impact on EV usage and its supporting infrastructure (Roelich et al., 2015). To our knowledge, this paper reports for the first time the impact local climate change mitigation strategies have on the EV uptake and the provision of public charging infrastructure. To achieve this aim, the paper addresses the following objectives:

1. Report on climate change mitigation strategies published by 30 UK cities,
2. Analyse car ownership, EV registrations and the provision of public EV infrastructure
3. Conduct statistical testing and modelling to determine the impact EV strategies have on the uptake of EVs and the charging infrastructure provided at the city-levels
4. Provide explanations of the findings and recommendations for cities to promote EV and infrastructures effectively.

2. Data collection and research methodologies

2.1. Cities policies and strategies collection

To facilitate the analysis of mitigation efforts, the climate change policies and/or strategies were collected at the city level, i.e. the city is defined by its administrative and/or political boundaries and can be referred to as an Urban Area. Cities (urban areas) were selected following the Urban Audit Methodology (Eurostat, 2010; Morais and Camanho, 2011; Schwarz, 2010). The Urban Audit aims to provide a balanced and representative sample of European cities and applies the following rules for including cities in the database (Eurostat, 2007):

1. Approximately 20% of the national population should be covered by Urban Audit;
2. National capital cities and where possible regional capitals are included;
3. Some large (more than 250,000 inhabitants) and medium-sized cities (minimum 50,000 and maximum 250,000 inhabitants) are included; and
4. Cities should be geographically dispersed within countries.

The Urban Audit lists 30 UK cities/urban areas that are deemed a good representation of the UK as a whole and we included all these cities in our research. The Urban Audit Cities represents a population of around 17,300,000, including two Welsh (Wrexham and Cardiff), three Scottish (Aberdeen, Edinburgh and Glasgow) and two cities from Northern Ireland (Belfast and Derry) alongside 23 English cities. By far the largest city (if indeed it could be referred to as one city) is London with a population of 7.6 million and the city with the smallest is Stevenage with a population 81,000 (Office for National Statistics, 2011). The greater area of London is most densely populated (4687.6 residents per km^2) and Wrexham the least densely populated city with 257 residents per km^2 in 2006 (Eurostat, 2010, 2011). The 8 largest economies (outside London) in England are referred to as Core Cities (Birmingham, Bristol, Leeds, Liverpool, Manchester, Newcastle, Nottingham and Sheffield). These cities, forming the economic and urban cores of their surrounding areas, are major centres of regional and national economic growth (Champion and Townsend, 2011), are part of this research.

We gathered and analysed the climate change policies and/or strategies from the 30 UK urban areas (cities) by retrieving them from the website and/or by contacting the city directly (Heidrich et al., 2013). Of the 30 UK Urban Audit cities, 28 have published climate change policies or strategies outlining how they will tackle climate change mitigation. In the UK, cities are part of larger Metropolitan, District and County Councils and some cities do refer to regional strategies. For example Stoke on Trent Council does refer to the “South Staffordshire Council Climate Change Strategy” (South Staffordshire Council, 2008) and Gravesham Council to the “Kent's Adaptation Plan Action Plan 2011-13” (Kent County Council, 2011).

In total, 307 documents were provided by the local authorities. Based on an assessment of suitability for analysis (i.e. strategies that state climate change in its title or abstract), 52 documents were analysed in detail. The documents are published at various dates and by different departments, for example, the Climate Change (CC) action programme for Aberdeen is the oldest ‘live’ document, published in 2002 (Aberdeen City Council, 2002). The mitigation and adaptation strategies for London underwent various stages of consultation over recent years and were finally approved and published in October 2011. Out of the 52 documents, 18 defined the scope as the activities that are controlled by the council and 32 are covering activities across the council i.e. household, industry and business activities. Only documents from Gravesham and Stoke have not stated the scope of the strategy i.e. if the strategy is for the councils own operation only or if it does cover households, industry etc. Derry-Londonderry (Northern Ireland) and

Wrexham (Wales) have not published an official document at the time of writing (Heidrich et al., 2013).

Car ownership data and household composition data were collected from the Office for National Statistics for England and from the National Records of Scotland for Scottish cities. National travel data were used from the DfT's National Travel Survey. In order to evaluate the effectiveness of climate change strategies, the number of charging points from the National Charge Point Register, the proportion of EVs registered and the relative change in registered EVs from the DfT and the SMMT were analysed for the cities which have an EV strategy and those cities who do not using the Shapiro-Wilk test and a multi-variable regression model.

3. Results

3.1. Climate change mitigation measures

All 30 cities acknowledge climate change being a threat and that their city is tackling this issue by adapting and mitigating with various levels of planning and success. Transport is listed in 45 (92%) documents by 26 (93%) of the cities with the aim of mitigating climate change by improving transportation (see Fig. 1). Transport measures proposed are wide ranging from providing green travel plan for its staff (Champion and Townsend, 2011), introducing flexible working hours and low carbon vehicle fleet (Birmingham City Council, 2010) to developing a specific project such as the Bristol Rapid Transit Project (Bristol City Council, 2010) and supporting EVs (either supporting infrastructure or actual vehicles) as mentioned by 46% of cities and 33% of the documents.

With regard to EVs, 12 of the 25 Local Authorities had strategies promoting EVs in one shape or form. For example Aberdeen council stipulated in its Carbon Management Programme that part of its 13 Business Travel Projects one will be responsible for the installation of EV charging points in selected Council car parks (by 2015). In Cambridge (CC plan 2008) the Waste and Fleet Management would trial electric powered vans and introduce recharging facilities for EVs in car parks. Another example is Exeter City Council (Exeter City Council, 2008) which recognised in its climate change strategy that 21% of its carbon emissions in 2004 came from road transport and, in partnership with the Transport Authority, wants to encourage public transport providers to invest in transport fleet to deliver carbon efficiencies using e.g. hybrid models. Finally, Manchester City Council (Manchester City Council, Manchester, 2009) stipulated that EVs will be the vehicles of choice, and making highly visible charging stations available across the city.

To see how these strategies had an impact on EV uptake and infrastructure Table 1 summarises UK Urban Audit cities, their number of registered cars (where such data is available), their climate change strategies and whether these strategies explicitly mention EVs as one means to mitigate climate change. In addition to that, the number of installed charging points within 5 miles of those cities has been listed (Anon., 2014). 5 miles was the smallest searchable area for each city which means that for smaller cities charging points in the surrounding areas were also counted. Table 1 also shows the number of EVs registered per city or region as reported by the DVLA to the House of Commons Transport Select Committee. This column however does not tell the full story. Many EV drivers lease their cars rather than buying them outright. Those vehicles are often registered by leasing companies which are located in London and the South East of Britain. The stark figure here is for Newcastle where over 500 Nissan LEAFs are leased by workers at the nearby Nissan factory but their home location is recorded at Nissan's head office elsewhere. The local EV charging service provider in Newcastle and the local area (Charge Your Car) had over 800 EV owning members in in 2014, confirming that Newcastle is a major EV hub.

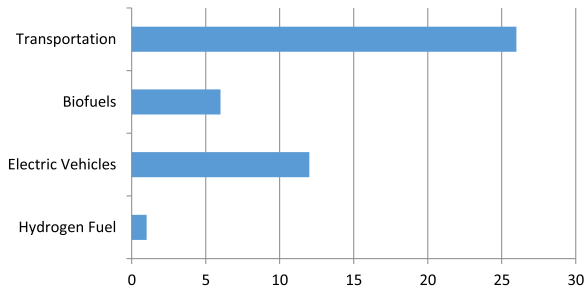

Fig. 1. Climate change mitigation measures (mentioned by the 28 cities).

It was possible to use Electric Vehicle Registration data encompassing quarterly registration up to January 2016 (DfT, 2015). This data is shown in the final four columns of Table 1 and was used to create an additional metric representing the rate of increase in EV uptake. The argument is that if the climate change strategies are effective, then they will not only lead to an increase in the absolute number of EVs, but they will also contribute to the rate of increase in uptake for EVs. The data in Table 1 was used in the statistical tests.

3.2. Public charging infrastructure

The limited range of electric vehicles is still seen by many as the key barrier to the mass uptake of EVs. This could be addressed in one of two ways: either the actual range of the cars needs to be improved or through an abundance of public charging infrastructure which would give drivers the confidence that they could complete their journeys and top up their charge as and when it was needed. Even though cities can address the lack of public recharging infrastructure (Namdeo et al., 2014; Roelich et al., 2015), this has not been followed through by the cities which mentioned EVs in their mitigation strategy documents as demonstrated by the analysis undertaken in this paper. Moreover, even in cities with significant EV charging infrastructure such as Newcastle (Namdeo et al., 2014), many EV drivers still believe that more public infrastructure is needed (Robinson et al., 2013). It was found that 30% of charge events took place at public charging infrastructure with 20% of EV drivers using public charging infrastructure as their primary means of charging. Yet, lack of public charging infrastructure was still quoted as one of the main barriers to the uptake of EV even by those drivers who extensively used public charging facilities. This suggests that cities may have to rethink the locations they choose for EV charging points and choose highly visible and strategic locations for the placement of new charging infrastructure.

Fig. 2 shows both the average electric vehicle density (i.e. numbers of EV in a region per square kilometre) plus the number of installed charge points within a fixed distance of each urban audit city. Due to a lack of comparable data it was not possible to visualise data for Wales, Scotland or Northern Ireland. The data for this visualisation was retrieved from the same source as Table 1, from the DfT Statistical data set “All licensed vehicles and new registrations VEH01” (DfT, 2015).

3.3. Statistical test for the effectiveness of the strategies

The number of charging points, the proportion of EVs registered and the relative change in registered EVs were analysed. The Shapiro-Wilk test showed that both the number of charging points and the number of EVs were not normally distributed. This and the small sample size meant that non-parametric tests were used to test whether mentioning EVs in their climate change strategies influenced the uptake of EVs on a city-level. The Wilcoxon rank sum test was used to compare the two groups of cities. As shown in Table 2, there was no statistical difference between those cities who had an EV strategy and those who did not in terms of the uptake of EV and the number of public charging posts. There is therefore no statistical difference between those cities that promote EVs in their climate change mitigation strategies and those

Table 1
UK Urban Audit cities (excl. Northern Ireland) and climate change (CC) strategies; number and percentage of total vehicles for electric vehicles (EV) registered; as reported in the evidence to the Transport Select Committee by the DVLA (Birmingham City Council, 2010) and in DfT statistics (Bristol City Council, 2010). Bold represents the total for the UK Urban Audit cities.

City	# Registered cars	CC strategy	Mentioned EV	# Charge points (2014)	# EVs (2011)	Cumulative EVs (2012)	Cumulative EVs (2013)	Cumulative EV's (2014)	Cumulative EV's (2015)
Aberdeen	91,546	Yes	Yes	12	2 (0%)	8 (0.01%)	22 (0.02%)	56 (0.06%)	132 (0.14%)
Belfast	108,800	Yes	No	19	4 (0%)	18 (0.02%)	36 (0.03%)	83 (0.08%)	178 (0.16%)
Birmingham	578,756	Yes	Yes	33	41 (0.01%)	128 (0.02%)	247 (0.04%)	1837 (0.32%)	4216 (0.73%)
Bradford	184,883	Yes	No	0	0 (0%)	0 (0%)	22 (0.01%)	65 (0.04%)	197 (0.11%)
Bristol	208,666	Yes	No	2	9 (0%)	42 (0.02%)	85 (0.04%)	199 (0.1%)	338 (0.16%)
Cambridge	42,445	Yes	Yes	11	5 (0.01%)	13 (0.03%)	15 (0.04%)	30 (0.07%)	76 (0.18%)
Cardiff	133,189	Yes	No	2	4 (0%)	9 (0.01%)	19 (0.01%)	63 (0.05%)	102 (0.08%)
Coventry	121,037	Yes	No	15	15 (0.01%)	18 (0.01%)	32 (0.03%)	75 (0.06%)	137 (0.11%)
Derry	46,200	No	No	9	0 (0%)	4 (0.01%)	8 (0.02%)	28 (0.06%)	43 (0.09%)
Edinburgh	161,834	Yes	No	7	9 (0.01%)	27 (0.02%)	50 (0.03%)	113 (0.07%)	216 (0.13%)
Exeter	52,037	Yes	Yes	6	3 (0.01%)	10 (0.02%)	13 (0.02%)	35 (0.07%)	69 (0.13%)
Glasgow	204,359	Yes	Yes	46	8 (0%)	28 (0.01%)	46 (0.02%)	170 (0.08%)	402 (0.2%)
Gravesham	50,774	Yes	No	0	0 (0%)	0 (0%)	2 (0%)	14 (0.03%)	34 (0.07%)
Kingston u. Hull	82,399	Yes	Yes	0	3 (0%)	6 (0.01%)	14 (0.02%)	22 (0.03%)	51 (0.06%)
Leeds	341,566	Yes	Yes	0	16 (0%)	37 (0.01%)	53 (0.02%)	179 (0.05%)	648 (0.19%)
Leicester	134,046	Yes	No	21	21 (0.02%)	30 (0.02%)	22 (0.02%)	59 (0.04%)	142 (0.11%)
Lincoln	39,800	Yes	No	5	2 (0.01%)	6 (0.02%)	6 (0.02%)	16 (0.04%)	32 (0.08%)
Liverpool	133,601	Yes	Yes	0	9 (0.01%)	15 (0.01%)	24 (0.02%)	40 (0.03%)	101 (0.08%)
London	2,542,734	Yes	Yes	184	895 (0.04%)	1041 (0.04%)	1398 (0.05%)	2703 (0.11%)	5014 (0.2%)
Manchester	130,404	Yes	Yes	56	4 (0%)	12 (0.01%)	26 (0.02%)	70 (0.05%)	119 (0.09%)
Newcastle u. Tyne	84,818	Yes	Yes	198	14 (0.02%)	22 (0.03%)	33 (0.04%)	96 (0.11%)	155 (0.18%)
Nottingham	83,147	Yes	No	14	7 (0.01%)	16 (0.02%)	20 (0.02%)	55 (0.07%)	106 (0.13%)
Portsmouth	90,589	Yes	No	0	12 (0.01%)	21 (0.02%)	53 (0.06%)	120 (0.13%)	340 (0.38%)
Sheffield	200,979	Yes	Yes	0	38 (0.02%)	49 (0.02%)	30 (0.01%)	106 (0.05%)	248 (0.12%)
Stevenage	34,898	Yes	No	2	0 (0%)	0 (0%)	3 (0.01%)	10 (0.03%)	27 (0.08%)
Stoke-on-Trent	100,318	Yes	No	16	1 (0%)	4 (0%)	14 (0.01%)	50 (0.05%)	104 (0.1%)
Wirral	139,717	Yes	No	0	3 (0%)	9 (0.01%)	20 (0.01%)	42 (0.03%)	110 (0.08%)
Wolverhampton	94,701	Yes	Yes	5	0 (0%)	3 (0%)	5 (0.01%)	28 (0.03%)	85 (0.09%)
Worcester	50,667	Yes	No	4	0 (0%)	127 (0.25%)	124 (0.24%)	91 (0.18%)	44 (0.09%)
Wrexham	63,303	No	No	0	0 (0%)	2 (0%)	6 (0.01%)	14 (0.02%)	40 (0.06%)
Total	**6,177,213**	**28**	**13**	**667**	**1125 (0.02%)**	**1705 (0.03%)**	**2448 (0.04%)**	**6469 (0.1%)**	**13506 (0.22%)**

that do not; and although it is still possible that there is an effect on EV take-up, it is clear that this is either smaller than the noise within the data or it is being masked by the effect of other variables. This is a worrying trend as reaching mitigation targets anticipates the uptake of EVs as a new means of urban transport. It is therefore important that cities begin to actively and effectively encourage the uptake of EVs and start to remove some of the barriers by for example providing improved infrastructure or run promotional campaigns etc.

To test for the potential masking effect of other factors over the existence of an EV strategy, a multi-variable regression model for EV uptake was created. The variables used in the model were those that were thought to have an impact on the uptake of EVs. The variables included the total number of all cars within each urban audit city, the level of local traffic flow, the presence of an EV/CC strategy, the local car population (within 30 km of the Urban Audit City), the local number of jobs, the average local income and the vehicle turnover in the local area. Other variables, such as local population totals or local population growth were also investigated but were found to have little effect.

Table 3 shows an example group of variables with their respective *P*-values. The linear regression model in Table 3 produced an R^2 of 0.775 with and adjusted R^2 of 0.60.

It was found that with a simple regression model it was possible to predict the uptake of EVs with an adjusted R^2 of 0.46 using just the local car population, the Local Job Level, the average local income and the Average Vehicle Turnover in the local area. Removing variables from the model with a low *P*-value (such as local traffic flow, EV strategy, CC strategy) improved the adjusted R^2 without significantly decreasing the raw R^2 value. The conclusion to be drawn from this is that the local EV growth is being strongly driven by factors which are not related to a local city EV or CC strategies and hence the conclusion drawn from Table 2 remains.

4. Discussion and conclusion

This paper summarises findings from research into the mitigation strategies as published by 30 UK Urban Audit cities, their influence on the uptake of EVs and the future prospects for affecting the vehicle fleet. The analysis presented in this paper has shown that having a climate change mitigation strategy which includes EVs has no statistically significant impact on the uptake of EVs or the introduction of public charging infrastructure. Our findings suggest that cities may pay lip-service mentioning EVs in their climate change mitigation strategies. Cities must begin to actively encourage the uptake of EVs, to improve the infrastructure required for the ergonomic use of EVs and to remove (or at least reduce) some of the factors preventing drivers from purchasing these cars, whether those factors are directly related to EVs or not.

In this work, we have argued that if there is an EV specific policy within the climate change mitigation strategy of a city, then it could only be judged successful if it leads to an increase in the number (or utility) of EVs within that city. Unfortunately, separating the exact causes behind any particular variation in EV numbers within a city would be almost impossible due to the number of contributing factors. However, by looking at the effect of EV polices en masse, it is possible to assess if they have led to an increase in EV usage.

Looking at the list of cities, their relative size and the measures they have in place, it is clear that the cities of London and Birmingham have the largest number of EV's, partially due to the Government/Corporate location of London and possibly due to the centre of the West Midlands car industry (Birmingham), which is likely to increase overall car turnover rates with the concomitant effect of increasing EV sales.

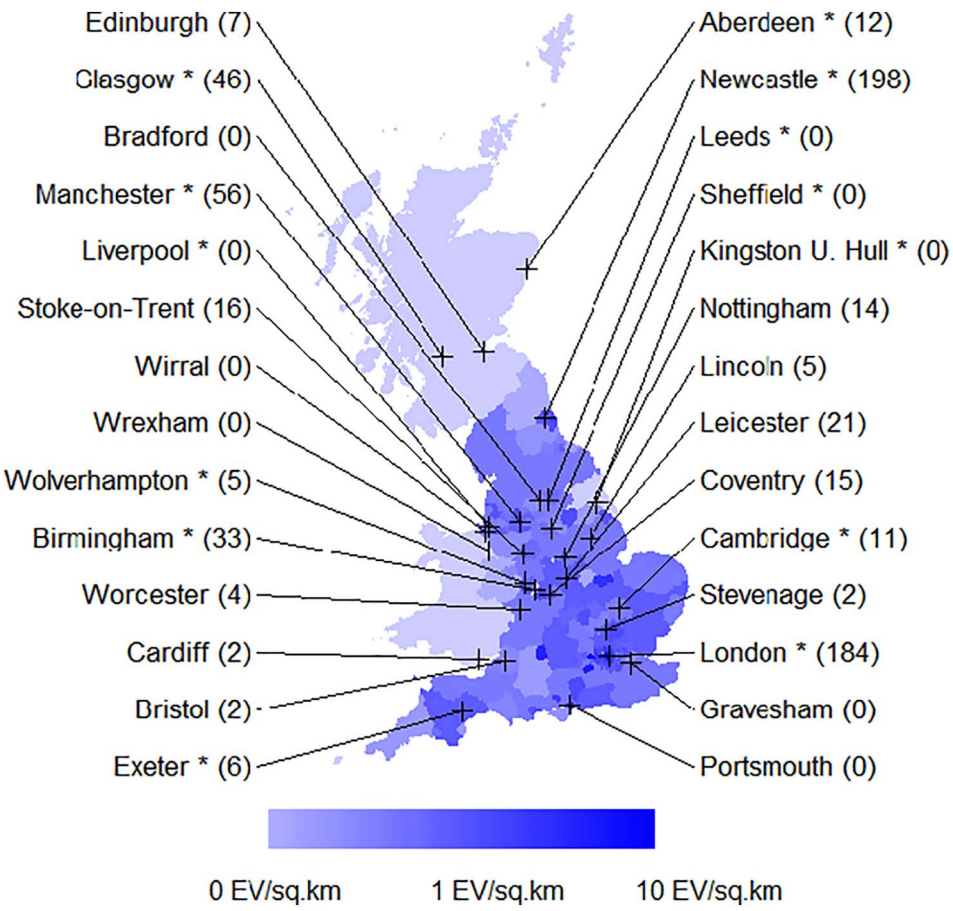

Fig. 2. EV registration density, # charging points (in brackets) and EV strategies (*) across 28 cities (excl. Northern Ireland).

Table 2
Results of the Wilcoxon rank sum test for the evaluation of effectiveness of urban EV strategies.

Measure	W	*P*-value
EVs as a percentage of registered vehicles in urban audit cities	39	0.661
Increase in registered EVs	126	0.094
Charging points in urban audit cities	138.5	0.2431

Table 3
Significance of variables to the uptake of EVs.

Variable	*P*-value
Local traffic flow	0.46
CC strategy (Yes/No)	0.22
EV strategy (Yes/No)	0.55
Local car population	0.0013
Local number of jobs	0.158
Average local income	0.058
Vehicle growth in local area	0.0065

Moreover, it is evident that there is more experience and knowledge of EV's and their operation in these cities which means the city authorities themselves have more expert advice on how to introduce effective measures to encourage uptake of EV's. This has been corroborated through the new policy initiatives from OLEV announced in mid-2015 through their GUL (Go Ultra Low) Cities initiative – where cities aspiring to foster more EV ownership are encouraged to learn from those cities that have been successful at this in the period 2010 to 2014 and add new innovations to these.

From the data shown here, none of the three main indicators of EV usage (EVs as percentage of registered vehicles, rate of increase in EV usage, number of EV charge points) show any reliable statistical relationship with the presence of a specific climate change and EV policies by the cities investigated. We can assume two possible reasons:

1. Either the motivating factors behind EV purchase and use are fundamentally beyond the abilities of cites to alter, or
2. The climate change policies published by the cities are ineffectual.

Aspects for the first point will be true for all cities. For example, in multiple surveys the price and range of EVs has been brought up as a limiting factor in the purchase of such a vehicle. Indeed, it may be the case that in the future consumers, specifically city dwellers, will move towards an alternative transport system such as electric bikes. These are factors which an individual city (beyond offering a subsidised purchase) is not able to alter. If the limiting factors for EV purchase are all on the national scale then it would be justified if cities did not include specific policies targeting EVs. It is possible that as the technology behind EVs improves, issues such as range and the general ergonomics of ownership will become less problematic.

The second possible reason is more difficult to quantify. Whilst it may be possible to assign a cost for the implementation of any given strategy, its effectiveness is more difficult to determine. Untangling the web of behavioural influences, financial decisions and unconscious biases mean that finding the “levers” that cities can pull and their effect on the populace is a complicated task. One possibility for future research would be to further split each cities climate change policy and strategy into its constituent parts and then separate each policy into a series of specific actions that were planned and taken. If an action was taken by a city (rather than simply included in the policy documents) then there should be a corresponding expected result, such as free parking and charging, EV access to ‘no car lanes’ and other policy friendly incentives. Any action with either no expected result, or a

result that cannot be measured would be flagged as a non-workable action. From this it should be possible to build up a picture of how individual actions taken by cities affect aspects of EV uptake.

Cross-sectoral implications for alternative transport strategies, including additional power generation and infrastructure requirements for electric vehicles has been highlighted as a constraint (Oxley et al., 2012). It has been concluded by Mazur (Mazur et al., 2015) that additional research on quantifying the environmental benefits is required and potential local transition policies do need to be consistent with governmental targets. In the UK, OLEV, the cross Departmental Government body tasked with providing national policy tools to support the roll-out of EV's and other Ultra Low Carbon Vehicles have recognised that the 'message' that EV's are not just a niche vehicle but something that is suitable and would benefit much of the driving population. Hence they have been awarded a significant budget for 'communication.', with the aim of providing lucid and compelling publicity that provide the public and business community information of the benefits of owning an EV, including running costs, decarbonisation and reduction in air pollution. Much of this money will be provided to individual local authorities and in particular those who have received recent GUL City funding, helping cities to solidify and take forward their mitigation strategies.

There is also the possibility that the EV specific policies at the city level are not necessarily the most important incentives of EV uptake. From the results showing the significance of the variables it could be seen that the most important factor to increase EV uptake was the number of local cars. It may be that to increase the proportion of EVs in a city, a city will have to implement policies that are "car friendly" in general rather than being seen as EV friendly specifically.

We recommend, due to the failure of current policies to increase uptake, cities must consider the local characteristic, to tailor the policies to increase EV uptake, whether this is from individual aspects of the policies already used or from city wide policies enacted both within the UK and further afield. In addition it must be considered whether there are aspects of EV uptake that are out of control of cities, e.g. consumer driven adoption of EVs that is motivated by either technological misgivings or cost considerations.

For example, one apparently successful policy has been to invest in a public charging infrastructure which is highly visible easily accessible for drivers. Yet, many cities do not seem to actively invest in public EV charging infrastructure despite their stated aims of supporting EV uptake as part of their climate change mitigation strategies. Two notable exceptions are London and Newcastle upon Tyne. Both cities have been at the forefront of the introduction of significant public charging infrastructure and have seen a subsequent uptake of EV. Others are now following this and we are beginning to see corresponding rapid charging infrastructure on the inter-urban network too (Neaimeh et al., 2015). The case study from the Switch EV trial in the North East of England has shown that electric vehicles could form a substantial part of a more sustainable urban transport system with proven carbon benefits. Expanding this into other cities and regions will allow the UK to meet its transport carbon commitments whilst delivering a user friendly transport system.

In addition there is a general public support for unilateral climate policies in India and the US (Bernauer and Gampfer, 2015), which has been recognised by central government. In the UK new resources are now being allocated to 'communications' and media campaigns to inform the public more on the benefits of owning an EV and debunking some of the myths regarding range, purchase and running costs and performance. Much of this is targeted at supporting the cities climate mitigation policies, as there is a need to illustrate the benefits of EV's more clearly. As our analysis has shown city planners and Government are running out of measures in their tool-boxes to enable them to meet their targets. Thus even more radical thinking and policies may become necessary.

It may be the case that in order for the UK to increase the fleet proportion of electric vehicles, it will need to look to other countries which have been successful in increasing their overall proportion. One example would be Norway which has seen electric vehicle market share rise to 29.1% in 2016. However, the rapid increase in EVs in Norway has come through extensive subsidisation and multiple "perks" (the ability to use bus lanes, for example) many of which are out of the ability of local government authorities in the UK to implement. Finally, it should be noted that many of the perks for EVs are beginning to show many unintended consequences, such as congestion in bus routes, and as such could be seen as both an exemplar and as a warning on the creation of strategies designed towards a single transport goal rather than viewing the whole system.

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