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Electric vehicles: The future we made and the problem of unmaking it

Jamie Morgan

Abstract: Uptake of battery electric vehicles (BEVs), subject to bottlenecks, seem to have reached a tipping point in the UK and this mirrors a general trend globally. BEVs are being positioned as one significant strand in the web of policy intended to translate the good intentions of Article 2 of the COP 21 Paris Agreement into reality. Governments and municipalities are anticipating that a widespread shift to BEVs will significantly reduce transport related carbon emissions and, therefore, augment their nationally determined contributions (NDCs) to emissions reduction within the Paris Agreement. However, matters are more complicated than they may appear. There is a difference between thinking we can just keep relying on human ingenuity to solve problems after they emerge and engaging in fundamental *social redesign* to prevent the trajectories of harm. BEVs illustrate this. The contribution to emissions reduction per vehicle unit may be less than the public initially perceive, since the important issue here is the lifecycle of the BEV and this is in no sense zero-emission. Furthermore, even though one can make the case that BEVs are a superior alternative to the fossil-fuel powered internal combustion engine (ICE), the transition to BEVs may actually facilitate exceeding the carbon budget on which the Paris Agreement ultimately rests. Whether in fact it does depends on the nature of policy that shapes the transition. If the transition is a form of *substitution* that conforms to rather than shifts against current global scales and trends in private transportation, then it is highly likely that BEVs will be a successful failure. For this *not* to be the case, then the transition to BEVs must be coordinated with a *transformation* of the current scales and trends in private transportation. That is, a significant reduction in dependence on and individual ownership of powered vehicles, a radical reimagining of the nature of private conveyance and of public transportation.

Key words: COP21; Paris Agreement; Battery Electric Vehicles; Embodied Emissions; Carbon budget

JEL: R4, O13, O2, N7

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Electric vehicles: The future we made and the problem of unmaking it[1]

Introduction

According to the UK Society of Motor Manufacturers and Traders (SMMT), the Tesla Model 3 sold 2685 units in December 2019, making it the 9th best-selling car in the country in that month (by new registrations; in August, a typically slow month for sales, it had been 3rd with 2082 units sold; Lea, 2019; SMMT, 2019). As of early 2020, Battery electric vehicles (BEVs) such as the new Hyundai Electric Kona had a two-year waiting list for delivery and the Kia e-Niro a one-year wait. Uptake of electric vehicles, subject to bottlenecks, seems to have reached a tipping point in the UK and this transcends the popularity of any given model. This possible tipping point mirrors a general trend globally (however, see later for quite what this means). At the regional, national and municipal scale, public health and environmentally-informed legislation are encouraging vehicle manufacturers to invest heavily in alternative fuel vehicles and, in particular, BEVs and plug-in hybrid vehicles (PHEVs), which are jointly categorized within 'ultra-low emission vehicles' (ULEVs).[2] According to a report by Deloitte, more than 20 major cities worldwide announced plans in 2017-18 to ban petrol and diesel cars by 2030 or sooner (Deloitte, 2018: 5). *All* the major manufacturers have or are launching BEV models, and so vehicles are becoming available across the status and income spectrum that has in the past determined market segmentation. According to the consultancy Frost & Sullivan (2019), there were 207 models (143 BEVs, 64 PHEVs) available globally in 2018 compared to 165 in 2017.

In 2018 the UK government published its *Road to Zero* policy commitment and introduced the *Automated and Electric Vehicles Act 2018*, which empowers future governments to regulate regarding the required infrastructure. *Road to Zero* announced an 'expectation' that between 50% and 70% of new cars and vans will be electric by 2030 and the intention to 'end the sale of new conventional petrol and diesel cars and vans by 2040', with the 'ambition' that by 2050 almost all vehicles on the road will be 'zero-emission' at the point of use (Department for Transport, 2018). Progress towards these goals was to be reviewed 2025.[3] However, on February 4th 2020, Prime Minister Boris Johnson announced that in the run-up to COP 26 in Glasgow, Britain would bring forward its 2040 goal to 2035. The UK is a member of the Clean Energy Ministerial Campaign (CEM), which launched the EV30@30 initiative in 2017, and its *Road to Zero* policy commitments broadly align with those of many European countries.[4] Norway has longstanding generous incentives for BEVs (Holtsmark and Skonhoft, 2014) and 31% of all cars sold in 2018 and just under 50% in the first half of 2019 in Norway were BEVs. According to the International Energy Agency (IEA), Norway is the per capita global leader in electric vehicle uptake (IEA, 2019).[5]

BEVs, then, are being positioned as one significant strand in the web of policy intended to translate the good intentions of Article 2 of the COP 21 Paris Agreement into reality (see Morgan, 2016; IEA, 2019, pp. 11-12). Clearly, governments and municipalities are anticipating that a widespread shift to electric vehicles will significantly reduce transport related carbon emissions and, therefore, augment their nationally determined contributions (NDCs) to emissions reduction within the Paris Agreement. And, since the BEV trend is global, the impacts potentially also apply to countries whose relation to Paris is more problematic, including the USA (for Trump and his context see Gills et al, 2019). However, matters are more complicated than they may appear. Clearly, innovation and technological change are important components in our response to the challenge of climate change. However, there is a difference between thinking we can just

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1 Thanks to two anonymous reviewers for extensive and useful comment –particularly regarding the systematic statement of issues in the introduction and for additional useful references.

2 ULEV refers to vehicles that emit less than 75 g$C0_2$ per km. This essentially means BEVs, PHEVs, range-extended (typically an *auxiliary* fuel tank) electric vehicles, fuel cell (non-plug-in) electric vehicles, and hybrid models (non-plug in vehicles with a *main* fuel tank but whose battery recharges and which drive short distances in electric mode).

3 Note, there is little sign of legislative and regulatory detail to plans as of early 2020. Furthermore, there is a difference between acknowledging that the uptake of alternatively fuelled vehicles, including BEVs, is growing and drawing the inference that UK government policy (channelled primarily via the Department for Transport) is as effective as it might be (see Environmental Audit Committee, 2016; National Audit Office, 2019; also later discussions).

4 CEM is coordinated by the IEA and is an initiative lead by Canada and China (but including a steadily growing number of signatory countries). The EV30@30 initiative aims to achieve a 30% annual sales share for BEVs by 2030.

5 IEA headline statistics include plug-in hybrids so 2018 becomes 46% for Norway (IEA, 2019: 10).

keep relying on human ingenuity to solve problems after they emerge and engaging in fundamental *social redesign* to prevent the trajectories of harm. BEVs illustrate this. In what follows we explore the issues.

The aim of this paper, then, is to argue that it is a mistake to claim, assert or assume that BEVs are necessarily a panacea for the emissions problem. To do so would be an instance of what ecological economists refer to as 'technocentrism', as though simply substituting BEVs for existing internal combustion engine (ICE) vehicles was sufficient. The literature on this is, of course vast, if one consults specialist journals or recent monographs (e.g. Chapman, 2007; Bailey and Wilson, 2009; Williamson et al., 2018), but remains relatively under-explored in general political economy circles at a time of 'Climate Emergency', and so warrants discussion in introductory and indicative fashion, setting out, however incompletely, the range of issues at stake. To be clear, the very fact that there is a range is itself important. BEVs are technology, technologies have social contexts, and social contexts include systemic features and related attitudes and behaviours. Technocentrism distracts from appropriate recognition of this. At its worse, technocentrism fails to address and so works to reproduce a counter-productive ecological modernization: the technological focus facilitates socio-economic trends, which are part of the broader problem rather than solutions to it. In the case of BEVs key areas to consider and points to make include:

- Transport is now one of, if not the, major source of carbon emissions in the UK and many other countries. Transport emissions stubbornly resist reduction. The UK, like many other countries, exhibits contradictory trends and policy claims regarding future carbon emissions reductions. As such, it is an error to simply assume prior emissions reduction trends will necessarily continue into the future, and the new net zero goal highlights the short time line and urgency of the problem.
- Whilst BEVs are, from an emissions point of view, a superior technology to ICE vehicles, this is less than an ordinary member of the public might think. 'Embodied emissions', 'energy mix', and 'life cycle' analysis all matter.
- There is a difference between 'superior technology' and 'superior choice', the latter must also take account of the scale of and general trend growth in vehicle ownership and use. It is this that creates meaningful context for what substitution can be reasonably expected to achieve.
- 1:1 substitution of BEVs for ICE vehicles and general growth in the number of vehicles potentially violates the Precautionary Principle. It creates a problem that did not need to exist, e.g. since there is net growth, it involves 'emission reductions' within new emissions sources and this is reckless. *Inter alia*, a host of fallacies and other risks inherent to the socio-economy of BEVs and resource extraction/dependence also apply.
- As such, it makes more sense to resist rather than facilitate techno-political lock-in or path-dependence on private transportation and instead to coordinate any transition to BEVs with more fundamental social redesign of public transport and transport options.

This systematic statement should be kept in mind whilst reading the following. Cumulatively, the points stated facilitate appropriate consideration of the question: What kind of solution are BEVs to what kind of problem? And we return to this in the conclusion. It is also worth bearing in mind, though it is not core to the explicit argument pursued, that an economy is a complex evolving open system and economics has not only struggled to adequately address this in general, it has particularly done so in terms of ecological issues (for relevant critique see especially the work of Clive Spash; and collected, Fullbrook and Morgan, 2019).[6] Since we assume limited prior knowledge on the part of the reader, we begin by briefly setting out the road to the current carbon budget problem.

Paris Purposes and the Future We Made

The United Nations Framework Convention on Climate Change (UNFCCC) was created in 1992. Article 2 of the Convention states its goal as, the 'stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' (UNFCCC, 1992: p. 4; Gills and Morgan, 2019). Emissions are *cumulative* because emitted $C0_2$ can stay in the atmosphere for well over one hundred years (other GHGs tend to be of shorter duration). Our climate future is made now. The Intergovernmental Panel on Climate Change (IPCC) collate existent models to produce a forecast range and have typically used atmospheric $C0_2$ of 450 ppm as a level likely to trigger a 2^0C average warming. This

[6] e.g. Spash (2020), Spash and Ryan (2012). One might also note the work of John O'Neill at Manchester University. Perhaps the most prominent 'realist' working on transport and ecology is Petter Naess, at Norwegian University of Life Sciences.

has translated into a 'carbon budget' restricting total cumulative emissions to the lower end of 3,000+ Gigatonnes of $C0_2$ ($GtC0_2$). In the last few years, climate scientists have begun to argue that positive feedback loops with adverse warming and other climatological and ecological effects may be underestimated in prior models (see Steffen et al, 2018; Hansen et al, 2017). Such concerns are one reason why Article 2 of the UNFCCC 'Conference of the Parties' (COP 21) Paris Agreement included a goal of at least trying to do better than the 2^0C target - restricting warming to 1.5^0C. This further restricts the available carbon budget. However, current Paris Agreement country commitments stated as 'nationally determined contributions' (NDCs) look set to exceed the 3000+ target in a matter of a few short years (UNFCCC, 2015; Morgan, 2016, 2017).

Since the industrial revolution began we have already produced more than 2,000 $GtC0_2$. Total annual emissions have increased rather than decreased over the period in which the problem has been recognized. The United Nations Environment Program (UNEP) publishes periodic 'emissions gap' reports. Its recent 10-year summary report notes emissions grew at an average 1.6% per year 2008 to 2017 and 'show no signs of peaking' (Christensen and Olhoff, 2019, p. 3). In 2018, the 9th Report stated that annual emissions in 2017 stood at a record of 53.5 Gigatonnes of $C0_2$ and equivalents ($GtC0_{2e}$) (UNEP, 2018, p. xv). This compares to less than 25 $GtC0_2$ in 2000 and far exceeds on a global basis the level in the Kyoto Protocol benchmark year of 1990. According to the 9th Emissions Gap Report 184 parties to the Paris Agreement had so far provided NDCs. If these NDCs are achieved annual emissions in 2030 are projected to still be 53 $GtC0_{2e}$. However, if the current 'implementation deficit' continues global annual emissions could increase by about 10% to 59 $GtC0_{2e}$. This is because current emissions policy is not sufficient to offset the 'key drivers' of 'economic growth and population growth' (Christensen and Olhoff, 2019a, p. 3). By sharp contrast the IPCC *Global Warming of 1.5⁰C* report states annual global emissions must fall by 45% from the 2017 figure by 2030 and become net zero by mid-century in order to achieve the Paris target (IPCC, 2018). According to the subsequent 10th Emissions Gap Report, emissions increased yet again to 55.3 $GtC0_{2e}$ in 2018 and, as a result of this adverse trend, emissions need to fall by 7.6% per year 2020 to 2030 to achieve the IPCC goal, and this contrasts with less than 4% had reductions begun in 2010 and 15% if they are delayed until 2025 (UNEP 2019a). Current emissions trends mean we will achieve an additional 500 $GtC0_2$ quickly and imply an average warming of 3 to 4^0C over the rest of the century and into the next. We are thus on track for the 'dangerous anthropogenic interference with the climate system' that the COP process is intended to prevent (UNFCCC, 1992, p. 4). According to the 10th Emissions Gap Report, 78% of all emissions derive from the G-20 nations and whilst many countries had recognized the need for net zero only 5 of the G-20 had committed to this and none had yet submitted formal strategies. COP 25, December 2019, meanwhile, resulted in no overall progress other than on measurement and finance (for detailed analysis see Newell and Taylor, 2020). As such, the situation is urgent and becoming more so.

Problems, moreover, have already begun to manifest (IPCC 2019; UNEP 2012, 2019). Climate change does not respect borders, some countries may be more adversely affected sooner than others, but there is no reason to assume that cumulative effects will be localised. Moreover, there is no reason to assume they will be manageable based on our current designs for life. In November 2019, several prominent systems and climate scientists published a survey essay in *Nature* highlighting 9 critical climate tipping points that we are either imminently approaching or may have already exceeded (Lenton et al, 2018). In that same month, more than 11,250 scientists from 153 countries (the Alliance of World Scientists) signed a letter published in *BioScience* concurring that we now face a genuine existential 'Climate Emergency' and warning of 'ecocide' if 'major transformations' are not forthcoming (Ripple et al, 2019). We live in incredibly complex interconnected societies based on long supply chains and just in time delivery – few of us (including nations) are self-sufficient. Global human civilization is extremely vulnerable and the carbon emission problem is only one of several conjoint problems created by our expansionary industrialised-consumption system. Appropriate and timely policy solutions are, therefore, imperative. Cambridge now has a Centre for the Study of Existential Risk and Oxford a Future of Humanity Institute (see also Servigne and Stevens, 2015). This is serious research, not millenarian cultishness. The Covid-19 outbreak only serves to underscore the fragility of our systems. As Michael Marmot, Professor of epidemiology has commented, the outbreak reveals both how political decisions can make systems more vulnerable, but also how governments can, when sufficiently motivated, take immediate and radical action (Harvey, 2020). To reiterate, however, according to both the IPCC and UNEP, emissions *must* fall drastically.[7]

[7] The UNEP 9th Report calls for a 55% reduction by 2030.

Policy design and implementation are mainly national (domestic). As such, an initial focus on the UK provides a useful point of departure to contextualize what the transition to BEVs might be expected to achieve.

The Problem of Unmaking

The UK is a Kyoto and Paris signatory. It is a member of the European Emissions Trading Scheme (ETS). The UK Climate Change Act 2008 was the world's first long term legally binding national framework for targeted statutory reductions in emissions. The Act required the UK to reduce its emissions by at least 80% by 2050 (below the 1990 baseline; and this has been broadly in line with subsequent EU policy on the subject).[8] The Act put in place a system of five yearly 'carbon budgets' to keep the UK on an emissions reduction pathway to 2050. The subsequent carbon budgets have been produced with input from the Committee on Climate Change (CCC), an independent body created by the 2008 Act to advise the government. In November 2015, the CCC recommended a target of 57% below 1990 levels by the early 2030s (the fifth carbon budget).[9] Following the Paris Agreement's new target of 1.5^0C and the IPCC and UNEP reports late 2018, the CCC published the report *Net Zero: The UK's contribution to stopping global warming* (CCC, 2019).[10] The CCC report recognizes that Paris creates additional responsibility for the UK to augment and accelerate its targets within the new bottom-up Paris NDC procedure. The CCC recommended an enhanced UK net zero GHG emissions target (formally defined in terms of long term and short term GHGs) by 2050. This included emissions from aviation and shipping and with no use of strategies that offset or swap real emissions. In June 2019, Theresa May, then UK Prime Minister, committed to adopt the recommendation using secondary legislation (absorbed into the 2008 Act – but *without* the offset commitment). So, the UK is one of the few G-20 countries to, so far, provide a formal commitment on net zero, though as the UNEP notes, a commitment is not itself necessarily indicative of a realisable strategy. The CCC responded to the government announcement:

> This is just the first step. The target must now be reinforced by credible UK policies, across government, inspiring a strong response from business, industry and society as a whole. The government has not yet moved formally to include international aviation and shipping within the target, but they have acknowledged that these sectors must be part of the whole economy strategy for net zero. We will assist by providing further analysis of how emissions reductions can be delivered in these sectors through domestic and international frameworks.[11]

The development of policy is currently in flux during the Covid-19 lockdown and whilst Brexit reaches some kind of resolution. As noted in the introduction, however, May's replacement, Boris Johnson has signalled his government's commitment to achieving its statutory commitments. However, this has been met with some scepticism, not least because it has not been clear what new powers administrative bodies would have and over and above this many of the Cabinet are from the far right of the Conservative Party, and are on record as climate change sceptics or have a voting record of opposing environmentally-focused investment, taxes, subsidies and prohibitions (including the new Environment Secretary, George Eustice, formerly of UKIP). Policy may and hopefully will change, becoming more concrete, but it is still instructive to assess context and general trends.

The UK has one of the best records in the world on reducing emissions. However, given full context, this is not necessarily a cause for congratulation or confidence. It would be a mistake to think that emissions reduction exhibits a *definite rate* that can be projected from the past into the future.[12] This applies both

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[8] The initial rationale in 2008 was that to achieve a maximum limit of 2°C warming global emissions needed to fall from the levels at that time to 20-24 $GtC0_2e$ with an implied average of 2.1-2.6 t $C0_2$ per capita on a global basis in 2050. This translated to a 50-60% reduction to the then global total. Since UK emissions were above average per capita, the UK reduction required was estimated at about 80%. Given that emissions then increased and atmospheric ppm has risen the original calculations are now mainly redundant.

[9] For the work of the CCC see: https://www.theccc.org.uk/about/

[10] The report also provides useful context regarding the UN SDGs (CCC, 2019: p. 66) and CCC thinking on growth and economics (CCC, 2019: pp. 46-47)

[11] https://www.theccc.org.uk/2019/06/11/response-to-government-plan-to-legislate-for-net-zero-emissions-target/

[12] And further methodological issues apply in economics (see Morgan, 2019a; Nasir and Morgan, 2018; Morgan and Patomäki, 2017).

nationally and globally. Some sources of relative reduction that are local or national have different significance on a global basis (they are partial transfers) and overall the closer one approaches net zero the more resistant or difficult it is likely to become to achieve reductions. The CCC has already begun to signal that the UK is now failing to meet its existent budgets. This follows periods of successive emissions reductions. According to the CCC, the UK has reduced its GHG emissions by approximately one third since 1990. 'Per capita emissions are now close to the global average at 7-8 $tC0_2e$/person, having been over 50% above in 2008' (CCC, 2019, p. 46). Other analyses are even more positive. According to Carbon Brief, emissions have fallen in seven consecutive years 2013-2019 and by 40% compared to the 1990 benchmark. Carbon Brief claim that since 2010 the UK has the fastest rate of emissions reduction of any major economy. However, it concurs with the CCC that future likely reductions are less than the UK's carbon budgets and the new net zero commitment requires: amounting to only an additional 10% reduction over the next decade to 2030.[13]

Moreover, all analyses agree that the reduction has mainly been achieved by reducing coal output for use in electricity generation (switching to natural gas) and by relative deindustrialization as the UK economy has continued to grow – manufacturing is a smaller part of a larger service based economy.[14] *And*, the data is based on a *production focused* accounting system. The accounting system does not include all emissions sources. It does not include those that the UK 'imports' based on consumption. UK consumption based emissions per year are estimated to be about 70% greater than the production measure (for different methods see DECC, 2015).[15] If consumption is included, the main estimates for falling emissions change to around a 10% reduction since 1990. Moreover, much of this has been achieved by relatively invisible historic transitions as the economy has evolved in lock-step with globalization. That is, reductions have been ones that did not require the population to confront behaviours as they have developed. No onerous interventions have been imposed, *as yet*.[16] However, it does not follow that this can continue, since future reductions are likely to be more challenging. The UK cannot deindustrialize again (nor can the global economy, as is, simply deindustrialize in aggregate if final consumption remains the primary goal), and the UK has already mainly switched from coal energy production. Emissions from electricity generation may fall but it also matters what the electricity is being used to power. In any case, future emissions reductions, in general, require more effective changes in other sectors, *and* this necessarily seems to require everyone to question their socio-economic practices. Transport is a key issue.

As a 'satellite' of its National Accounts, the UK Office for National Statistics (ONS) publishes Environmental Accounts and this data is used to measure progress. Much of the data refers to the prior year or earlier. In 2017 UK GHG emissions were reported to be 566 million tonnes $C0_2e$ (2% less than 2016 and, as already noted about one third of the 1990 level; ONS, 2019). The headline accounts break this down into four categories (for which further subdivisions are produced by various sources) and we can usefully contrast 1990 and recent data (ONS, 2019: 4):

Top 4 Sectors for GHG emissions UK	1990 $MtC0_2e$	2017 $MtC0_2e$
Electricity supply	217	100

[13] For full analysis see: https://www.carbonbrief.org/analysis-uks-co2-emissions-have-fallen-29-per-cent-over-the-past-decade The Carbon Brief analysis omits shipping and aviation. As the campaign group Transport and Environment notes UK shipping was responsible for 14.4 $MtC0_2$, which is the third highest in Europe (after Netherlands and Spain) and shipping is exempt from tax on fossil fuels under EU law. See p. 20: https://www.transportenvironment.org/sites/te/files/publications/Study-EU_shippings_climate_record_20191209_final.pdf

[14] UK coal use for energy supply reduced by approximately 90% 1990 to 2017 and in 2019 amounted to just 2% of the energy mix and in 2019 the UK went two weeks without using any coal at all for power production (the first time since 1882); 1990 to 2010 natural gas use steadily increased from a near zero base but has declined since 2010 as use of renewables has grown. Coal use in manufacturing has decreased 75% 1990 to 2017 (ONS, 2019). As noted some assessments place the reduction in total emissions at around 40% based on other metrics and the tabulated figures I provide indicate yet another percentage – *all* however are trend decreases indicative of a general direction of travel.

[15] 'Embedded emissions' or the UK carbon footprint is addressed by the UK Department for Environment Food and Rural Affairs (Defra). To be clear, there is a whole set of further issues that one might address in regard of measurement of emissions – how they are attributed and what this means (where created, where induced through demand, which state, what corporation, and so different 'Cartesian' claims regarding the significance of location are possible, and this is indicative of the conflict over representation and partition of responsibility (so whilst the climate does not care about borders, they have infected measurement and policy). There is no scientifically neutral way to achieve this, merely different sets of criteria with different consequences (I thank an anonymous referee for extended comment on this, see also Taylor, 2015; who argues that adaptation politics produces a focus on governance within existing political and economic structures based on borders etc.).

[16] Congestion charges in London or a plastic bag tax do not meet this threshold.

Manufacturing	180	86
Household	142	144
Transport & storage	66	83
Total for all sectors	794	566

The Environmental Accounts' figures indicate some shifting in the relative sources of emissions over the last thirty years. As we have intimated, electricity generation and manufacturing have experienced reduced emissions, though they are far from zero; household and transport, meanwhile have remained stubbornly high. Moreover, the accounts are also slightly misleading for the uninitiated, since transport refers to the industry and not all transport. Domestic car ownership and use is part of the household sector and it is the continued dependence on car ownership that provides, along with heating and insulation issues, one of the major sources of the persistently high level of household emissions. The UK Department for Business, Energy and Industrial Strategy (DBEIS) provides differently organized statistics and attributes cars to its transport category and uses a subsequent residential category rather than household category. The Department's statistical release in 2018 thus attributes a higher 140 $MtC0_2e$ to transport for 2016, whilst the residential category is a correspondingly lower figure of approximately 106 $MtC0_2e$. The 140 $MtC0_2e$ is just slightly less than the equivalent figure for 1990; although transport achieved a peak of about 156 $MtC0_2e$ in 2005 (DBEIS, 2018: 8-9). As of 2016, transport becomes the largest source of emissions based on DBEIS data (exceeding energy supply) whilst households become the largest in the Environmental Accounts. In any case, looking across both sets of accounts, the important point here is that since 1990 transport as a source of emissions has remained stubbornly high. Transport emissions have been rising as an industrial sector in the Environmental Accounts or relatively consistent and recently rising in its total contribution in the DBEIS data. The CCC *Net Zero* report draws particular attention to this. Drawing on the DBEIS data it states that 'Transport is now the largest source of UK GHG emissions (23% of the total) and saw emissions rise from 2013 to 2017' (CCC, 2019, p. 48). More generally the report states that despite some progress in terms of the UK carbon budgets, 'policy success and progress in reducing emissions has been far from universal' (CCC, 2019, p. 48). The report recommends (2019, pp. 23-26, 34):

- A fourfold increase by 2050 in low carbon (renewables) electricity
- Developing energy storage (to enhance use of renewables such as wind)
- Energy efficient buildings and a shift from gas central heating and cooking
- Halting the accumulation of biodegradable waste in landfills
- Developing carbon capture technology
- Reducing agricultural emissions (mainly dairy but also fertilizer use)
- Encouraging low or no meat diets
- Land management to increase carbon retention/absorption
- Rapid transition to electric vehicles and public transport

As we noted in the introduction, the UK Department for Transport *Road To Zero* document stated a goal of ending the sale of conventional diesel and petrol powered ICE vehicles by 2040. The CCC suggested improving on this:

> **Electric vehicles.** By 2035 at the latest all new cars and vans should be electric (or use a low-carbon alternative such as hydrogen). If possible, an earlier switchover (e.g. 2030) would be desirable, reducing costs for motorists and improving air quality. This could help position the UK to take advantage of shifts in global markets. The Government must continue to support strengthening of the charging infrastructure, including for drivers without access to off-street parking. (CCC, 2019, p. 34)

The UK government's response to these and other similar suggestions has been to bring the target date forward to 2035 and to propose that the prohibition will also apply to hybrids. However, the whole is set to go out to consultation and no detail has so far (early 2020) been forthcoming. In its March 11th 2020 Budget the government also committed £1 billion to 'green transport solutions', including £500 million to support rollout of the electric vehicle charging infrastructure, whilst extending the current grant/subsidy scheme for new electric vehicles (albeit at a reduced rate of £3000 from £3500 per new registration). It has also signalled that it may tighten the timeline for sales prohibition further to 2030.[17] As policy, much of this is, ostensibly at least, positive, but there are a range of issues that need to be considered regarding what is being achieved. The context of transition matters and this may transcend the specifics of current policy.

BEV transition: life cycles?

The CCC is confident that a transition to electric vehicles can be a constructive contribution to achieving net zero emissions by mid-century. However, the point is not unequivocal. The previously quoted CCC communique following the UK government's commitment to implement *Net Zero* uses the phrase 'credible UK policies, across government, inspiring a strong response from business, industry and society as a whole', and the CCC report places an emphasis on BEVs *and* a transition to public transport. The relative dependence between these two matters (and see conclusion). BEVs are potentially (almost) zero emissions in use. But they are not zero emission in practice. Given this, then the substitution of BEVs for current carbon powered ICEs is potentially problematic, depending on trends in ownership of and use of powered vehicles (private transportation). These points will become clearer as we proceed.

BEVs are not zero emission in context and based on life cycle. This is for two basic reasons. First, a BEV is a powered vehicle and so the source of power can be from carbon based energy supply sources (and this varies with the 'energy mix' of electricity production in different countries. IEA, 2019, p. p. 8). Second, each new vehicle is a material product. Each vehicle is made of metals, plastics, rubber and so forth. Just the cabling in a car can be 60kg of metals. All the materials must be mined and processed, or synthesized, the parts must be manufactured, transported and assembled, transported again for sale and then delivered. For example, according to the SMMT in 2016 only 12% of cars sold in the UK were built in the UK and 80% of those built in the UK were exported in that year. Some components (such as a steering column) enter and exit the UK multiple times whilst being built and modified and before final assembly. Vehicle manufacture is a global business in terms of procuring materials and a mainly regional (in the international sense) business in terms of component manufacture for assembly and final sales. Power is used throughout this process and many miles are travelled. Moreover, *each* vehicle must be maintained and serviced thereafter, which compounds this utilisation of resources. BEVs are a subcategory of vehicles and production locations are currently more concentrated than for vehicles in general (Tesla being the extreme).[18] In any case, producing a BEV is an economic activity and it is not environmentally costless. As Georgescu-Roegen (1971) noted long ago and ecologically-minded economists continue to highlight (see Spash, 2017; Holt et al, 2009), production cannot evade thermodynamic consequences. In terms of BEVs, the primary focus of analysis in this second sense of manufacturing as a source of contributory emissions has been the carbon emissions resulting from battery production. Based on current technology, batteries are heavy (a significant proportion of the weight of the final vehicle) and energy intensive to produce.

Comparative estimates regarding the relative life cycle emissions of BEVs with equivalent fossil fuel powered vehicles are not new.[19] Over the last decade the number of life cycle studies has steadily risen as the interest in and uptake of BEVs has increased. Clearly, there is great scope for variation in findings, since the energy mix for electricity supply varies by country and the assumptions applied to manufacturing can vary between studies. At the same time, the general trend over the last decade has been for the energy mix in many countries to include more renewables and for manufacturing to become more energy efficient This is partly reflected in metrics based on emissions per $GDP, which in conjunction with relative

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[17] This is supported, for example, by The Climate Group's EV100 initiative: a voluntary scheme where corporations commit to making electric the 'new normal' of their vehicle fleets by 2030 (recognizing that over half of annual new registrations are owned by businesses) https://www.theclimategroup.org/project/ev100

[18] Until recently Tesla had one main production centre in California. However, it now also has a $5 billion factory in Shanghai and plans for a factory in Berlin. Tesla is currently the world's largest producer of BEVs (368,000 units in 2019), followed by the Chinese company BYD Auto (195,000 units in 2019). Tesla was founded July 2003 by Martin Eberhard and Mark Tarpenning in response to General Motors scrapping its EV programme (as unprofitable). Elon Musk joined as a HNWI first-round investor February 2004 (he put in $6.5m of the total $7.5m and became chairman of the Tesla board); Eberhard was initially CEO, but was removed and replaced by Musk in 2007 and Tarpenning left 2008. Tesla floated on the Nasdaq June 2010 at $17 per share and exceeded $500 per share for the first time January 2020. Tesla is the US's most valuable car manufacturer by market capitalisation (worth more than Ford and GM combined).

[19] The European Commission's collaborative research forum JEC has been producing 'well-to-wheels' analyses of energy efficiency of different engine technologies since the beginning of the century. The US periodically publishes the findings of its GREET model (the Greenhouse gases Regulated Emissions and Energy use in Transportation model). See https://greet.es.anl.gov

expansion in service sectors are used to establish ‘relative decoupling’. So, given that both the energy mix of power production and the emissions derived from production can improve, then one might expect a general trend of improved emissions claims for BEVs in recent years and this seems to be the case.

For example, if we go back to 2010 the UK Royal Academy of Engineering found that technology would likely favour PHEVs over BEVs in the near future because the current energy mix and state of battery technology indicated emissions deriving from charging were typically higher for BEVs than an average ordinary car’s fuel consumption – providing a reason to persist with ICE vehicles or, more responsibly, choose hybrids over pure electric (Royal Academy of Engineering, 2010). Using data up to 2013, but drawing on the previous decade, Holtsmark and Skonhoft (2014) come to similar conclusions based on the most advanced BEV market – Norway. Focusing mainly on energy mix (with acknowledgement that a full life cycle needs to be assessed) they are deeply sceptical that BEVs are a significant net reduction in carbon emissions (Holtsmark and Skonhoft, 2014, p. 161, 164). Neither the Academy nor Holtsmark and Skonhoft are merely sceptical. The overall point of the latter was that more needed to be done to accelerate use of low or no carbon renewables for power infrastructure (a point the CCC continues to make). This, of course, *has* happened in many places, including the UK. That is, acceleration of use of renewables, though it is by no means the case government can take direct credit for this in the UK (and there is also evidence on a global level that a transition to clean energy from fossil fuel forms is much slower than some data sources indicate; see Smil, 2017a, 2017b).[20] In terms of BEVs, however, recent analyses are considerably more optimistic regarding emissions potential *per BEV* (for example, Hoekstra, 2019; Regett et al, 2019). Research by Staffell et al (2019) at Imperial for the power corporation, Drax, provides some interesting insights and contemporary metrics.

Staffell et al split BEVs into three categories based on conjoint battery and vehicle size. A 30-45 kWh battery car, equivalent to a mid-range or standard car. A heavier, longer-range, 90-100 kWh battery car, equivalent to a luxury or SUV model, and a 30-40 kWh battery light van. They observe that a 40-litre tank of petrol releases 90-100 $kgC0_2$ when burnt and the ‘embodied’ emissions represented by the manufacture of a standard lithium-ion battery are estimated at 75-125 $kgC0_2$ per kWh. They infer that every kWh of power embodied in the manufacture of a battery is, therefore, approximately equivalent to using a full tank of petrol. For example, a 30 kWh battery embodies 30 40-litre petrol tank’s worth of emissions. The BEV’s are also a source of emissions based on the energy mix used to charge the battery for use. The in-use emissions for the BEV are a consequence of the energy consumed per km and this depends on weight of car and efficiency of battery.[21] They estimate 33 $gC0_2$ per km for standard BEVs, 44-54 $gC0_2$ for luxury and SUVs and 40 $gC0_2$ for vans. In all cases this is significantly less than an equivalent fossil-fuel vehicle.

The insight the estimates and comparisons are leading towards is that the battery embodies an upfront carbon cost’ which can be gradually ‘repaid’ by the saving on emissions represented by driving a BEV compared to driving an equivalent fossil-fuel powered vehicle. That is, the environmental value of opting for BEVs increase over time. Moreover, if the energy mix is gradually becoming less carbon based this effect is likely to improve further. Based on these considerations, Staffell et al estimate that it may take 2-4 years to repay the embodied emissions in the battery for a standard BEV and 5 to 6 for the luxury or SUV models. Fundamentally, assuming 15 years to be typical for on-the-road life expectancy of a vehicle, they find lifetime emissions for each BEV category are *lower* than equivalent fossil-fuel vehicles.

Still, the implication is that BEVs are *not* zero emission. Moreover, the degree to which this is so is likely to be significantly greater than a focus on the battery alone indicates. Romare and Dahlöff (2017), assess the life-cycle of battery production (not use), and in regard of the stages of battery production find that the manufacturing stages account for about 50% of the emissions and the mining and processing stages about the same. They infer that there is significant scope for further emissions reductions as manufacturing processes improve and the Drax study seems to confirm this. However, whilst the battery may be the major component, as we have already noted, vehicle manufacture is a major process in terms of all components and in terms of distance travelled in production and distribution. It is also worth noting that the weight of batteries creates strong incentives to opt for lighter materials for other parts of the vehicle. Most current

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[20] For example, since 1985 according to Carbon Brief global coal use in power production measured in terawatt hours only reduced in 2009 and 2015 (though it seems likely to do so in 2019); China notably continues to build coal-fired power plants though the rate of growth of use has slowed. (According to the IEA Coal report, 2019, China consumed 3,756 million tonnes of coal in 2018 (a 1% increase) and India 986 million tonnes (a 5% increase). Renewables are a growing part of an *expanding* global energy system.
https://www.carbonbrief.org/analysis-global-coal-power-set-for-record-fall-in-2019

[21] Staffell et al observe that the British electricity grid produces an average 204 $gC0_2$ per kWh in 2019 and a standard petrol car emits 120-160 $gC0_2$ per km.

vehicles are steel based. An aluminium vehicle is lighter, but the production of aluminium is more carbon intensive than steel, so there are also further hidden trade-offs that the positive narrative for BEVs must consider.[22]

The general point worth emphasising here is that there is basic uncertainty built into the complex evolving process of transition and change. There is a basic ontology issue here familiar in economic critique: there is no simple way to model the changes with confidence, and in broader context confidence in modelling may itself be a problem here when translated into policy, since it invites complacency.[23] That said, the likely direction of travel is towards further improvements in the energy mix and improvements in battery technology. Both these may be incremental or transformational depending on future technologies (fusion for energy mix and organics and solid state technologies for batteries perhaps).[24] But one must still consider time frames and ultimate context.[25] The context is a carbon budget and the need for radical reductions in emissions by 2030 and net zero by mid-century. Consider: if just the battery of a car requires four years to be paid back then there is no significant difference in the contribution to emissions from the vehicle into the mid 2020s. For larger vehicles, this becomes the later 2020s, and each year of delay in transition for the individual owner is another year closer to 2030. Since transport is (stubbornly) the major source of emissions in the UK and a major source in the world, this is not irrelevant. BEVs can readily be a successful failure in Paris terms. This brings us to the issue of trends in vehicle ownership and substitutions. This also matters for what we mean by transition.

Substitutions and transformations: successful failure?

There are many ways to consider the problem of transition. Consider the 'Precautionary Principle'. This is Principle 15 of the 1992 Rio Declaration: 'In order to protect the environment, the precautionary principle shall be widely applied by the States [UN members] according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation' (UNCED). Assuming we can simply depend on unrealised technology potentially violates the Principle. Why is this so? If BEVs are a source of net emissions, then each new vehicle continues to contribute to overall emissions. The current number of vehicles to be replaced, therefore, is a serious consideration, as is any growth trend. Here, social redesign rather than merely adopting new technology is surely more in accordance with the Precautionary Principle. BEVs may be sources of lower emissions than fossil fuel powered vehicles, but it does not follow that we are constrained to choose between just these two options or that it makes sense to do so in aggregate, given

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22 This is a point made by Richard Smith. There are, of course, alternatives to aluminium. One should also note that manufacturers are responding to consumer preference by increasing the average size of models and this is increasing weight and resource use. In February 2020, for example *Which* Magazine analysed 292 popular car models and found that they were on average 3.4% or 67kg heavier than older models and this was offsetting some of the efficiency gains for emissions.

23 And the argument this is leading to is that it makes far greater sense to default to greater dependence on prudential social redesign, rather than optimistic technocentrism, behind which is techno-politics.

24 For discussion of battery technology and scope for improvement see Manzetti and Mariasiu (2015) and Faraday Institution (2019). Currently, most BEVs use lithium-ion phosphate, nickel-manganese cobalt oxide or aluminium oxide batteries. Liquid electrolyte constituents require containment and shielding. Specifically, a battery creates a flow of electrons from the positive electrode (the cathode made of a lithium metal oxide etc from the previous list) through a conducting electrolyte medium (lithium salt in an organic solution) to a negative electrode (the anode made typically of carbon, since early experiment with metals tended to produce excess heating and fire). This creates a current. Charging flows to the anode and discharge oxidises the anode which must then be recharged. The batteries are relatively low 'energy density' and can be a fire hazard when they heat. Given the chemical constituents, battery disposal is also a significant environmental hazard (see IEA, 2019: pp. 8, 22-23). A 'solid-state' battery uses a specially designed (possibly glass or ceramic) solid medium that allows ions to travel through from one electrode to another. The solid-state technology is in principle higher energy density, much lighter, and more durable. The implication is higher kWh batteries with greater range, charging capacity and durability and efficiency. Jeremy Dyson has reportedly invested heavily in solid state technology and though his proposed own brand BEV is not now going ahead, reports indicate the battery technology investment will continue.

25 One might also consider hydrogen battery technology. Hydrogen fuel cell technology for vehicles is different than BEV. The vehicle has a tank in the rear for compressed cooled gas, which supplies the cell at the front of the car whilst driving. Refuelling is a rapid pumping process rather than a long wait. The gas has two possible origins: natural gas conversion where 'steam methane reformation' separates methane into hydrogen and $C0_2$ or water electrolysis, where grid AC electricity is converted to DC, which is applied to water and using a membrane splits it into hydrogen and waste oxygen. Currently over 95% of hydrogen is from the former. Major investors in hydrogen technology are Shell (for natural gas conversion), IMT Power (in partnership with Shell) for water conversion, and Toyota whose Mirai model is hydrogen powered.

the objective of radical and rapid reduction in emissions. If time is short and numbers of vehicles are large and growing then the implication is that substitution of BEVs should (from a precautionary point of view) occur in a context that is oppositional to this growing trend. That is, the goal should be one of *reducing* private car ownership and use, and increasing the availability, pervasiveness and use of public transport (and alternatives to private vehicle ownership). This is an issue compounded by the finding that there is an upfront carbon cost from BEVs. Some consideration of current vehicle numbers and trends in the UK and globally serve to reinforce the point.

The UK Department for Transport publishes annual statistics for vehicle licensing. According to the 2019 statistical release for 2018 data there were 38.2 million licensed vehicles in Britain and 39.4 million including Northern Ireland (Department for Transport, 2019). Vehicles are categorised into cars, light goods vehicles, heavy goods vehicles, motorcycles and buses and coaches. Cars comprised 31.5 million of the total (82%) and the total represented a 1.2% increase on 2017. There is, furthermore, a long-term year-on-year trend *increase* in vehicles since World War II and over the last 20 years that growth (the net change as new vehicles are licensed and old vehicles taken off the road) has averaged 630,000 vehicles per year (Department for Transport, 2019, p. 7). This is partly accounted for by population growth, and business growth, but also by an increase in the number of vehicles per household. According to the statistical release, 2.9 million new vehicles were registered in 2018, and though this was about 5% fewer than 2017 the figure remained broadly consistent with long term trends in numbers and still represented growth (contributing to the stated 1.2% increase).[26] Of the total new registrations in 2018, 2.3 million were cars and 360,000 were light goods vehicles. Around 2 million has been typical for cars.

The point to take from these metrics is that numbers are large and context matters. Cars represent 31.5 million emission sources and there are 39.4 million vehicles in the UK. Replacing these 1:1 reproduces an emissions problem. Replacing them in conjunction with an ownership growth trend exacerbates the emissions problem that then has to be resolved. If around 2 million new cars are registered per year then the point at which the BEVs amongst these new registrations can be assumed to begin payback for embodied emissions *prior* to the point at which they become net sources of reduced (and not *zero*) emissions is staggered over future years based on the rate of switching. There are then also net new vehicles. Given there are 31.5 million cars to be replaced over time (plus net growth) there is a high likelihood of significant transport emissions up to and beyond 2030. The problem, of course, is implicit in the Department for Transport policy commitment to end sales of petrol and diesel vehicles by 2035 and ensure all vehicles are zero-emission in use by 2050. Knowingly committing to this *ingrained* emission problem, given we have already recognized the urgency and challenge of the carbon budget and the 'stubbornness' of transport emissions, is not prudent, *if alternatives exist*. It is producing a problem that need not exist purely because enabling car ownership and use is a line of least resistance in policy terms (it requires least change in behaviour and thus provokes limited opposition). It is also worth noting that the UK, like most countries, has an 'integrated' transport policy. However, the phrasing disguises the relative levels of investment between different modes of transport. Austerity politics may have resulted in declining road quality in the UK but in general terms the UK is still committed to heavy investment in and expansion of its road system.[27] This infrastructure investment seems 'economically rational, but it is also a matter of relative emphasis and 'lock-in'. Future policy is predicated on the dominance of road use and thus vehicle use.

The crux of the matter here is how we view political expedience. Surely this hinges on the consequences of policy failure. That is, the failure to implement an effective policy given the genuine problem expressed in the goal of 1.5^{0}C or 2^{0}C. 'Alternatives' may seem unrealistic, but this is a matter of will and policy – of rational social design rather than impossibility. The IPCC and other sources suggest that achieving the Paris goals requires mobilization of a kind not previously seen outside of wartime. Policy can pivot on this quite quickly, even if perhaps this can seem unlikely in 2020. Climate events may make this *necessary* and popular pressure and opinion may be transformed. This is currently uncertain. Positions on this may yet move quite quickly.

Lock-in also implies an underlying sociological issue. This is important to consider regarding simply opting for substitution without greater emphasis on reduction. Even if substitution occurs smoothly,

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[26] Though fewer new cars were registered than in previous years this significant metric for total number of vehicles is the cumulative number of registrations (taking into account cars no longer registered). There are, however some underlying issues: uncertainty regarding the status of diesel cars and problems of availability, cost and trust in BEVs seems to be causing many people in the UK to delay buying a new car; the expansion of Uber meanwhile has had a generational and urban effect, reducing car ownership as an aspiration amongst the young.

[27] And re aviation, a new runway at Heathrow between 2026 and 2050.

it places greater pressure on areas of reduction over which we have less control as societies and involves an orientation that has further potential policy consequences that cannot be readily quantified and which increase overall uncertainty regarding NDCs. As any modern historian, urban geographer or sociologist will attest, car ownership has been imbricate with the development and design –the configuration - of modern societies, and it has been deeply integrated into identity. Cars are *social* technologies and philosophers also have much to say about this sociality in general (for example, Faulkner and Runde, 2013; Lawson, 2017). Cars are more than merely convenient; they are sources of autonomy and status (for example John Urry explored the sociology of 'automobility'; see, Dennis and Urry, 2009). As such, the more that environmental and transport policy validate the car, then the more that the car is *normalized* through socialization for the citizen, perhaps leading to citizens being more prepared to countenance locked-in harms (congestion etc.) prior to change, in turn, making it less likely (sub)urban spaces are redesigned in ways predicated on the absence of (or severe limits to) private transport. The trend in many countries over the car era has been that building roads leads to more car use, which leads to congestion, which leads to more roads (especially in concentrated zones around (sub)urban spaces).

According to the UK Ordinance Survey, Britain has increased its total road surface by 132 square miles over the decade since 2010 (a 9% increase). According to the UK Department for Transport, vehicle traffic increased by 0.8% in 2019 (September to September) to 330.1 billion miles travelled and car travel, as a subset, increased to 258 billion miles (a 1.5% increase).[28] The March 11th 2020 Budget seems to confirm the trend. Whilst it commits around £1 billion to 'green transport solutions', this is in the context of a £27 billion announced investment in roads, including upgrading and a proposed 4,000 miles of new road. As the Green Party MP, Caroline Lucas, noted there is a basic disconnect here, since this seems set to increase the UK's dependence on private transport, when it makes more sense to begin to curtail that dependence, given how significant the UK's transport emissions are.[29] So, within the various tensions in policy there seems to be a tendency to facilitate techno-political lock-in or path-dependence on private transportation. As Mattioli et al (2020) argue, the multiple strands of policy and practice that maintain car dependence contribute to 'carbon lock-in'. The systemic consequences matter both for the perpetuation of fossil fuel vehicle use in the short term and, given they are not net zero for emissions, powered vehicles in the longer term. Not only does this matter in the UK, it matters globally. All the issues stated are reproduced globally. Moreover, in some ways they are compounded for countries where widespread car ownership is relatively new.

The fallacy of composition, problems that need not exist and resource risk

Estimates vary for the global total number of vehicles. According to Wards Intelligence, the global total was 1.32 billion in 2016 (Petit, 2017). Extrapolated estimations imply that the total likely increased to more than 1.5 billion in 2019. In 1976 the figure was 342 million and in 1996 670 million, so the trend implies an approximate doubling every twenty years, which if it continued would imply a figure approaching 3 billion by end of the 2030s. Clearly, it is problematic to simply extrapolate a linear trend, but it is not unreasonable to assume a general trend of growth. Observed experience is that many 'developed' country middle-class households have accommodated more than one car per household. This is classically the case in the USA. In 2017, the USA, with a population of 325.7 million in that year, reported a total of 272.5 million registered vehicles compared to 193 million in 1990 (Statista, 2019). In any case, the world population is still growing, incomes are growing and many countries are far from a position of 1 car per household. China with a population of 1.3 billion overtook the USA in total number of registered vehicles around 2016 to 2017, with 300.3 million registered vehicles in March of 2017 (Zheng, 2017). Growth is rapid and the China Traffic Bureau of the Ministry of Public Security reported a total of 325 million registered vehicles, December 2018, an increase of 15.56 million in the year (*China Daily*, 2018). The People's Republic is now the world's largest car market and the number of registered cars increased to 240 million in 2018 (Statista, 2019b). India too has rapidly growing car ownership and on a lesser scale this is replicated across the developing world.

For our purposes, two well-known concepts and a further resource dependence risk seem to apply here. First, there is patently a 'fallacy of composition' issue. That is, the assumption that many can do what few previously did without changing the conditions or producing different (adverse) consequences than arose when only a few adopted that behaviour or activity. Those consequences are climatological and ecological.

[28] See: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/852708/provisional-road-traffic-estimates-gb-october-2018-to-september-2019.pdf

[29] See: https://greenworld.org.uk/article/budget-deeply-disappointing-says-caroline-lucas

It remains the case that we are socialised to desire and appreciate cars and it remains a fact that private transport can be extremely convenient. It can also, given the commentary above, appear hypocritical to be suggesting shifting to a far greater reliance on public transport, since this implicitly involves denying to developing country citizens a facet of modernity enjoyed previously by developed country citizens. But this is distraction from the underlying *collective* interest in reduced car ownership and use. It denies the basic premise that a Precautionary Principle applies to all and that societies that are not yet car dependent have the opportunity to avoid a problem, rather than have to manage it via either moving straight to private transport BEVs or a transition from fossil fuel powered ICEs to BEVs with all that entails in terms of ingrained emissions. Policy may be mainly domestic, but climate change is global and aggregate effects do not respect borders, which brings us to a second concept or risk that may be exacerbated.

Second, a 'quasi-Jevons' effect' may apply. Growth of vehicle use is a problem of resource use and this is a thermodynamic and emissions problem. However, it is, as we have noted, also the case that battery technology and energy mix for BEVs are improving. So, this *may* involve significant declines in relative cost, which in turn may create a tendency for BEV ownership to accelerate which could exacerbate net growth in numbers of vehicles. Net growth could ironically be to the detriment of emissions savings. Whether this is so, depends, in part, on what kind of overall transport policy countries adopt and whether consumers, corporations and markets are allowed to be the arbiter of which area of transport dominates. It also depends, in part, on what materials are required for future batteries. Current technology implies massive increases in costs based on securing sources of lithium and cobalt as battery demand rises. So even if a Jevons' effect is avoided, a different issue may apply. Resource procurement is a Precautionary Principle issue since effective BEVs at the kind of numbers necessary to substitute for *all* vehicles seems to require technological transformation – without it multiple problems apply whilst emissions remain ingrained.

For example, when the UK CCC announced its 2035 recommendation to accelerate the BEV transition, members of the Security of Supply of Mineral Resources (SSMR) project wrote a research note to the CCC (Webster, 2019). They pointed out that current *total* European demand for cobalt is 19,800 tonnes and that producing the batteries to replace 2.3 million cars in the UK (in accordance with contemporary statistics for new registrations) would require 15,600 tonnes. The UK would also need 20,000 tonnes of lithium, which is 45% of current total European demand. If we replicate this ramping up of demand across Europe and the globe for vehicles, recognizing that there are other growing demands for the minerals and metals (including batteries for other purposes) then it seems unlikely that supply can respond, unless dependence on lithium and cobalt (and other constituents) falls sharply as technology changes. Clearly, the problem is also contingent on uptake of BEVs. Over recent years there has in fact been oversupply of the main materials for battery production because several of the main mining corporations anticipated that battery demand would take off faster than it actually has. For example, global prices of cobalt, nickel and lithium carbonate have increased significantly over the last decade but have fallen 2018 to end of 2019. However, industry analysis indicates that current annual global production is the equivalent of about 10 million standard BEVs based on current technology, and as the previous statistics on global vehicle numbers (see also next section) indicate, this is far less than transition via substitution would seem to require in the next decade.[30]

Shortages and price rises, therefore, are if not inevitable, at least likely. Currently, about 60% of the cost of a BEV is the battery and 80% of that 60% (about 50% of the vehicle) is the cost of battery materials. It is, therefore, important to achieve secure supply and stable costs. The further context here is the issue of UK domestic battery capacity. In 2013, the government created the Advanced Propulsion Centre (APC) with a ten year £500 million investment commitment matched by industry. The APC's remit is to address supply chain issues for electric vehicles. Not unexpectedly, the APC quickly identified lack of domestic battery production capacity as a major impediment. In response in 2016 another government initiative, Innovate UK set up the Faraday Battery Challenge to encourage domestic capacity and innovation. The Battery Industrialisation Centre was then set up in Coventry, to attract manufacturers in the supply chain for BEVs to locate there, focused around a centre of research excellence. However, the APC has no control over global supply and prices of battery materials, the investment and location decisions of battery manufacturers, or the necessary infrastructure for BEVs to be a feasible technology.[31] For example, according to the APC, if

[30] For example, global production of cobalt in 2018 was 120,000 tonnes, and production of about 2 million BEVs currently requires around 25,000 tonnes, so 10 million BEVs would require all of current output. Cobalt traded at more than US$90,000 per ton 2018 but had fallen to around US$30,000 end of 2019.

[31] In the UK, current daily consumption of petrol and diesel for road transport is about 125 million litres or about 45 billion litres per year. So, BEVs are essentially substituting for this scale of energy use, shifting demand to electricity generation.

domestic BEV demand were 500,00 per year by 2025, then the UK would need 3 'gigafactories'. Battery manufacture is currently dominated by LG Chem and Samsung in South Korea, CATL in China and Panasonic in Japan. None of these have current plans to build a gigafactory in the UK. In any case, there is a further problem here which raises a whole set of environmental and ethical issues explored in ecological circles under the general heading 'extractivism' (see for example Dunlap, 2019). As time goes by, the UK and the world may become dependent on high price supplies of materials drawn from unstable or hostile regimes (Democratic Republic of Congo etc.), which is a risk in many ways (and a likely source of Dutch disease – the 'resource curse' - for unstable regimes). So, *not* placing a relative emphasis on substituting BEVs for ICEs and not endorsing the current vehicle growth trend (which is different as a suggestion than rejecting BEVs entirely) avoids multiple problems and risks.

It is also worth noting that simple market decisions can have a further collective adverse consequence based on individual consumer preference and reasoning, which may also affect BEVs in the short term. Many *current* BEVs have smaller or low efficiency batteries and thus short ranges. These favour urban use for short journeys, but most people own cars with a view also to range further afield. As such, it seems likely that until the technology is *all* long range (and the charging infrastructure is pervasive) many consumers, *if the choice exists* and income allows, will own BEVs as an additional vehicle not a replacement vehicle.[32] This may be a short-term issue, given the regulatory changes focused on 2030 to 2040 in many countries. But, again, from a Paris point of view, taking the IPCC 1.5°C and UNEP *Emissions Gap* reports into consideration, this matters. This brings us to a final issue. What is the actual take-up of BEVs (and ULEVs)? How rapid is the transition? In the introduction, I suggested the UK had reached a tipping point and that this mirrored a general trend globally. This, however, needs context.

How many EVs?

The data emerging in recent years and stated in the introduction is a step-change, but as a possible tipping point *it begins from a low base* and BEVs (the least emitting of the low emission vehicles) are a subset, albeit a rapidly expanding one, of ULEVs. According to the UK Department for Transport statistical release for 2018, there were 200,000 ULEVs registered in total, of which 63,992 ULEVs were newly registered in that year (Department for Transport, 2019, p. 4). 93% of the total registrations were cars and the total constitutes a 39% increase on the 2017 total and a 20% increase in the rate of registration – there were just 9,500 ULEVs at the beginning of 2010 (so, about twenty times greater in a decade). However, the 2018 data means that ULEVs accounted for just 0.5% of all licensed vehicles and were still only 2.1% of all new registrations in that year. Preliminary data available early 2020 indicates continued growth with almost 38,000 new BEV registrations in 2019, a 144% year-on-year increase. As a recent UK House of Commons Briefing Paper notes, however, the government prefers to emphasise the percentage changes in take-up rather than the percentages of the absolute numbers or the absolute numbers themselves (Hirst, 2019). The International Energy Agency (IEA) places the UK in its leading countries list by ULEV and BEV market share (measured by percentage of total annual registration): Norway dominates, followed by Iceland, Sweden, the Netherlands and then a significant drop-off to a trailing group including China, the USA, Germany, the UK, Japan, France, Canada and South Korea. However, market share in this trailing group is less than 5% in every case (see appended Figure 1). China, given its size (and because of the urgency of its urban air quality problems and its capacity for authoritarian implementation) dominates the raw numbers in terms of total ULEVs and BEVs. All this notwithstanding, the IEA confirms the general point that up-take is accelerating, but the base is low and so achieving total ULEV or BEV coverage is some way off:

> The global electric car fleet exceeded 5.1 million in 2018, up by 2 million since 2017, almost doubling the unprecedented amount of new registrations in 2017. The People's Republic of China… remained the world's largest electric car market with nearly 1.1 million electric cars sold in 2018

National Grid attempted to model this in 2017. Their forecast (highly contingent obviously) suggests that if all cars sold by 2040 were BEVs and thus the car market was dominated by BEVs by 2050 and if most vehicles were charged at peak times in 2050 then an additional 30 gigawatts of electricity would be required. This is about 50% greater than current peak winter demand in 2017. This was widely reported in the press. This best/worst case, of course, does not allow for innovative solutions such as off-peak home charging pioneered by Ovo and other niche suppliers. However, even with such solutions there will still be a net increase in required capacity from the system. This has been estimated at about 10 new Hinckley power stations.

[32] One possible long term solution currently in development is toughened solar panel devices that can be laid as road or car park surfaces, enabling contact recharging of the vehicle (in motion or otherwise). There are, however, multiple problems with the technology so far.

> and, with 2.3 million units, it accounted for almost half of the global electric car stock. Europe followed with 1.2 million electric cars and the United States with 1.1 million on the road by the end of 2018 and market growth of 385000 and 361000 electric cars from the previous year. Norway remained the global leader in terms of electric car market share at 46% of its new electric car sales in 2018, more than double the second-largest market share in Iceland at 17% and six-times higher than the third-highest Sweden at 8%. In 2018, electric buses continued to witness dynamic developments, with more than 460000 vehicles on the world's road, almost 100000 more than in 2017…In freight transport, electric vehicles (EVs) were mostly deployed as light-commercial vehicles (LCVs), which reached 250000 units in 2018, up 80000 from 2017. Medium truck sales were in the range of 1000-2000 in 2018, mostly concentrated in China. (IEA,2019: p. 9)

Over the next few years it seems likely we will see rapid changes in these metrics. There is a great deal of discussion in policy analysis regarding bottlenecks and impediments and these, of course, are also important (consumer uncertainty, 'range anxiety', availability of sufficient infrastructure for charging and so on).[33] However, as everything argued so far indicates regarding transition and trends, underlying the whole is the conditionality of success and the potential for failure, involving avoidable ingrained emission and risks. There is a basic difference between a superior technology and a superior choice since the latter is a socio-economic matter of context: of rates of change scales and substitutions. Ultimately, this creates deep concerns in terms of achieving the Paris goals. The IEA explores two forecast scenarios for up-take of ULEVs. Both involve a projection of annual ULEV sales and total stock to 2030 (IEA, 2019). First a 'New Policies' Scenario. This takes current policy commitments of individual countries and extrapolates. By 2030 the scenario projects global ULEV sales at 23 million in that year and a total stock of 130 million. This is considerably less than 30% of all vehicles now and in 2030. Second, a EV30@30 Scenario. This assumes an accelerated commitment that adopts the @30 goals (notably 30% annual sales share for BEVs by 2030; IEA, 2019, pp. 29-30). By 2030 the scenario projects global ULEV sales at 43 million in that year and a total stock of 250 million. Again, this is less than 30% of all vehicles now and in 2030.

The figures, of course, are highly conditional, but the point is clear, even the best-case scenario currently being anticipated has ULEVs and BEVs as a *minority* of all vehicles in 2030 – and 2030 is a key year for achieving Paris, according to the October 2018 IPCC 1.5^{0}C report. Moreover, it is notable that the projections assume continuous growth in the number of vehicles (and so continuous growth in ICE vehicles) *and* the major areas of numerical growth in BEVs continues to be China, so some significant part of the anticipated total will be new *ingrained* emissions that arguably did not need to exist.[34] Again, this is highly conditional but it at least creates questions regarding what is being 'saved' when the IEA claims that the New Policies Scenario results in 2.5 million barrels a day less demand for oil in 2030 and the EV30@30 Scenario 4.3 million barrels a day (IEA, 2019, p. 7).[35] Less of more is not a saving in an objective sense, if this is a preventable future, and it is not a rational way to set about 'saving' the planet. It remains the case, of course, that this is better than nothing, but it is deeply questionable whether in policy terms any of this is the 'best that can be done'. As stated in the introduction, technocentrism distracts from appropriate recognition of this. At its worse, technocentrism fails to address and so works to reproduce a counter-

[33] For example, analysis from Capital Economics suggests a 3-way charging split is likely to develop: home recharging is likely to dominate, followed by an on-route charging model (substituting for current petrol forecourts at roadside) and destination recharging (given charging is slower than filling a fuel tank it makes sense to transform car parks at destinations into charging centres – supermarkets etc.). They estimate UK demand at 25 million BEV chargers by 2050 of which all but 2.6 million will be home charging. As of early 2020 there were 8,400 filling stations which might be fully converted. Tesco has a reported commitment to install 2,400 charging points. These are issues frequently reported in the press.

[34] This point can also be made in other ways. Not only does the emissions saving relate to net new sources of cars, but the contrast is in terms of trend changes in size of vehicle. According to the recent IEA *World Energy Outlook* report (IEA, 2019a) the number of SUVs is increasing and these consume around 25% more fuel than a mid-range car. If current growth trends continue (SUVs are 42% of new sales in China, 30% in India and about 50% in the USA) the IEA projects that the take-up of ICE SUVs will more than offset any marginal gains in emissions from the transition to BEVs.

[35] It is also the case that the projected 'savings' from ULEVs are likely inaccurate. Following the EU, most countries adopted (and manufacturers report using) the Worldwide Harmonised Light Vehicle Test Procedure (WLTP). This became mandatory in the UK from September 2018. The WLTP is the new laboratory defined test for car distance-energy metrics. Vehicles are tested at 23^{0}C, but without associated use of A/C or heating. Though claimed to as realistic than its predecessors, it is still basically unrealistic. Temperature range for ULEVs has significant consequences for battery performance and for use of on-board services, so real distance travelled per unit of energy is liable to be less. For similar reasons, ICEs will also travel less distance per litre of fuel so this is not a comparative gain for ICEs, it is likely a comparative loss to all of us if we rely on the figures.

productive ecological modernization: the technological focus facilitates socio-economic trends, which are part of the broader problem rather than solutions to it. The important inference is that there are multiple reasons to think that a greater emphasis on social redesign and *less* private transport avoids successful failure and is more in accordance with the Precautionary Principle.

Conclusion: Unmaking and is Paris possible?

I ended the introduction to this essay by stating that we would be exploring the foregrounding question: What kind of solution are BEVs to what kind of problem? It should be clearer now what was meant by this. Ultimately, the balance between private and public transport matters if the Paris goals are to be achieved. Equally clearly, this is not news to the UK CCC or to any serious analyst of electric vehicles and the transport issue for our climatological and ecological future (again, e.g. Chapman, 2007; Bailey and Wilson, 2009; Williamson et al., 2018; Mattioli, 2020). At the same time, the context and issues are not widely understood and the problems are often understated, at least in so far as, discursively, most weight is placed on stating progress in achieving a transition to ULEVs and BEVs. This is technocentric. Despite its general concerns and careful critical stance, the CCC is also partly guilty of this. For example, Ewa Kmietowicz, Transport Team Leader of the CCC Secretariat, refers to the UK *Road to Zero* strategy as a 'lost opportunity', and the CCC identifies a number of shortfalls in the strategy.[36] However, the general thrust of the CCC position is to focus on rapid transition to BEVs and to overcoming bottlenecks.[37] Broader feasibility is subsumed under general assumptions about continued economic expansion and expansion of the transport system. So, there is more of a situation of complementarity (with caveats) between public and private transport, and the whole becomes an exercise in types of investment within expansionary trends, rather than a more radical recognition of the fundamental problems that we ought to think about avoiding. It is also worth noting that many of the major advocates of BEVs are industry organizations. The UK Society of Motor Manufacturers and Traders, for example, are not unconcerned but they are not impartial either; they have a vested interest in the vehicle *industry* and its growth. For industry, ULEVs and BEVs are an opportunity before they are a solution to a problem. There are, however, recognitions that a rethink is required. These range from direct activism, such as 'Rocks in the Gearbox' (along the lines of Extinction Rebellion), to analysis from establishment think tanks, such as the World Economic Forum[38], and statements from government oversight committees. For example, the UK Commons Science and Technology Committee (CSTC) endorses the CCC 2035 accelerated BEV target but also states more explicitly:

> In the long-term, widespread personal vehicle ownership does not appear to be compatible with significant decarbonisation. The Government should not aim to achieve emissions reductions simply by replacing existing vehicles with lower-emissions versions. Alongside the Government's existing targets and policies, it must develop a strategy to stimulate a low-emissions transport system, with the metrics and targets to match. This should aim to reduce the number of vehicles required, for example by: promoting and improving public transport; reducing its cost relative to private transport; encouraging vehicle usership in place of ownership; and encouraging and supporting increased levels of walking and cycling. (CSTC, 2019)

This, as Caroline Lucas suggests, speaks to the need to coordinate public and private transport policy more effectively and clearly, there is a need for broader informed debate here. In political ecological circles, for example, there is a growing critique of the tensions encapsulated in the concept of an 'environmental state' (see Koch, 2019). That is, the coordination and coherence of environmental imperatives with other policy concerns. State-rescaling and degrowth and postgrowth work highlights the profound problems that are now starting to emerge as states come to terms with the basic mechanisms that have been built into our economies and societies (see also Newell, 2019; Newell and Mulvaney, 2013).[39] New thinking is required and this extends to the social ontology and theory we use to conceptualise economies (see Spash and Ryan, 2012; Lawson, 2019) and political formations (see Bacevic, 2019; Patomäki, 2019. Covid-19 does not change this (Gills, 2020).

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[36] See https://www.theccc.org.uk/2018/07/10/road-to-zero-a-missed-opportunity/

[37] See https://www.theccc.org.uk/2018/07/10/governments-road-to-zero-strategy-falls-short-ccc-says/

[38] See https://www.weforum.org/agenda/2019/08/shared-avs-could-save-the-world-private-avs-could-ruin-it/

[39] For practical network initiatives see, for example https://climatestrategies.org

In transport terms, there are many specific issues to consider. Some solutions are simple but overlooked because we are always thinking in terms of sophisticated innovations and inventions. However, we do not need to conform to the logics of 'technological fixes', that we somehow think will enable the impossible, to perhaps see some scope in 'fourth industrial revolution' transformations (Morgan, 2019b; Center for Global Policy Solutions, 2017). For example, public transport may also extend to a future where no individual owns a range extensive powered vehicle (perhaps just local scooters for the young and mobility scooters for the infirm) and instead a system operates of autonomous fleet vehicles that are coordinated by artificial intelligence with logistics implemented through Smartphone calendar access booking systems – and coordination functions could maximise sharing, where vehicles could also be (given no drivers are involved) adaptable connective pods that chain together to minimise congestion and energy use. This seems like science fiction now, and perhaps a little ridiculous, but a few years ago so did the Smartphone. And the technology already exists in infancy. Such a system could be either state-funded and run or private partnership and franchise, but in either case it radically redraws the transport environment whilst working in conformity with the geography of living spaces we have already developed. Will is what is required and if the outcome of COP24 (UNFCCC, 2018) and COP25 (Newell and Taylor, 2020), with limited progress towards the Paris goals persists, then it seems likely that emissions will accumulate rapidly in the near future and the likelihood of a serious climate event with socio-economic consequences rises. At that stage, more invasive statutory and regulatory intervention may start to occur as the carbon budget becomes a more urgent target. Prohibitions, transport rationing and various other possibilities may then be on the agenda if we are to unmake the future we are currently writing and, to mix metaphors, avoid a road to nowhere.

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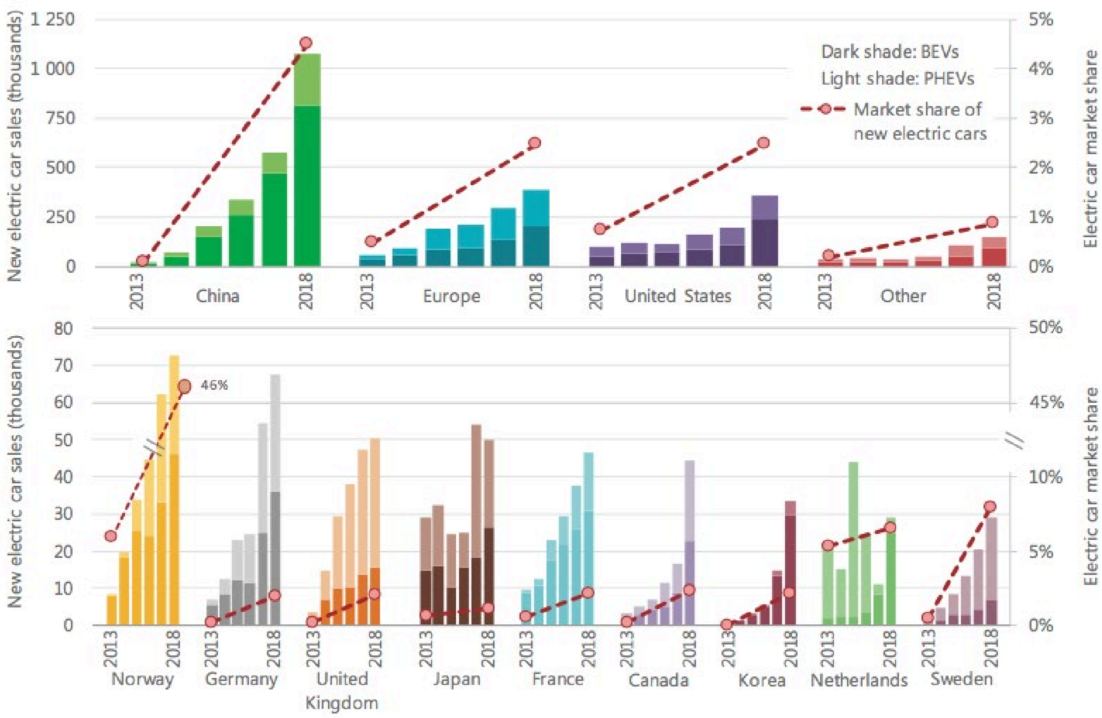
Appendix

Figure 1. Global electric car sales and market share, 2013-18



Source: IEA, 2019: p. 10