ELECTRIFYING MOBILITY: REALISING A SUSTAINABLE FUTURE FOR THE CAR

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ELECTRIFYING MOBILITY: REALISING A SUSTAINABLE FUTURE FOR THE CAR

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CONTENTS

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PART 1

THE POLITICAL-ECONOMIC CONTEXT AND ENVIRONMENTAL IMPERATIVE

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CHAPTER 1

THE ELECTRIFICATION OF AUTOMOBILITY

Graham Parkhurst

ABSTRACT

Observations worldwide suggest that climate heating has moved from the stage of being a conceptual future threat to being widely recognisable as having a tangible and present impact in the 2020s. The promotion of the electric car, as a key feature of the wider electrification of mobility, is one of the key policy initiatives seeking to reduce climate change emissions from the transport sector, particularly in the wealthier, more car-dependent states globally. Such developments led the International Energy Agency to question, in 2020, whether we had entered the decade of "electric drive" (IEA, 2020). However, electric motive power is not new. Electric cars have been around for longer than the internal combustion engine (ICE). The century-long dominance of the latter is explained by a number of advantages and contextual factors. In the 2020s, whilst some of the barriers to EV adoption have reduced, others, notably battery energy density and cost to the consumer, remain. And the consequences of the transition to electric cars will be felt not solely in respect of greenhouse gas emissions, but will affect economic production, the relative demand for resources and human skills, social and technical practices, travel behaviour, and the extent to which all citizens are included in/excluded from mobility systems, and hence wider society.

The present chapter introduces the principal themes of the book, outlining the narrative through its 4 parts and 11 subsequent chapters. In doing so, it underlines the importance of the transition from the internal combustion engine

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to the electric motor as not simply a technical substitution, but a potential revolution that could radically change the economy, society, and hopefully the environment, for the better. Now is an important moment to be charting and examining the rise of the electric car and exploring whether it represents a step towards more sustainable mobility.

Keywords: Climate heating; electrification; sociotechnical transition; electric car; sustainable mobility; automobility

The final stages in the preparation of this book coincided with a context in which climate change was not only increasingly apparent but also had triggered a new level of alarm that its progress might soon be unstoppable. A key iteration in the series of annual summits of parties to the United Nations Framework Convention on Climate Change was held in Glasgow in November 2021. 'COP26' was presented by the host government as the 'last best chance' (UK Government, 2021, p. 6) for sufficient action to limit the worst implications of climate change for the viability of many species, including humans. The conference was seen as particularly crucial due to a series of climatic and climate-linked events in the previous months, leading to a new intensity in the global public discourse, tracked extensively in the media. Perhaps most salient amongst the high-temperature records broken by the several heatwaves felt in the Northern hemisphere summer was that at the village of Lytton in British Columbia, Canada. For three days in a row in late June, temperatures shattered the previous national record of 45 °C set in 1937 (Little, 2021), reaching 49.6 °C on 30 June 2021, exceeding the predictions of climate models (Watts, 2021a). Then, within a week, Lytton had been all but destroyed by one of many wildfires triggered by the 'heat dome' (Burston & Cecco, 2021). Across the Atlantic in mid-July, a rainstorm deposited two-months' rainfall on northwest Europe in 48-hours. The storm, variously described as a 'once-in-a-generation', '200-year', and 'millennial event', triggered extensive flooding resulting in the loss of over 150 lives (Oltermann, 2021). Also in July, over 300 people died in floods triggered by record extreme rains, a year's-worth of rainfall in three days, in Henan, China (Davidson, 2021).

Whilst excess rainfall troubled many countries, already by August, the year 2021 was declared the worst global wildfire season since satellite records began (Watts, 2021b). Fires were spreading out of control that month in both Greece and Turkey (Otte, 2021), whilst in July, the situation became so severe with the 'Bootleg' fire in Oregon, that commentators resorted to hoping the natural side effects of 'smoke-shading' from other fires would outweigh the wind and lightning strikes induced by Bootleg itself (The Guardian, 2021).

Beyond these relatively short-duration events, there was also growing concern about 'tipping points' leading to more fundamental and irreversible change, such as heightened concern that the Gulf Stream circulation current in the Atlantic, already at its slowest for 1,600 years might imminently halt (Carrington, 2021), causing radical changes to the geographies of temperature and rainfall, with disastrous consequences for human food production.

Growing beliefs that the opportunities for sufficient action were reaching end-game injected intensity into international and national debates around the acceptability of solutions which would require human behaviour change and have uncertain economic consequences (even if the implications of inaction were expected to be greater for both humans and the economy). These debates focussed a spotlight on electricity as a cross-sectoral vector for zero-carbon energy, due to its capability of being produced in a range of ways, and the existence of increasingly effective technologies which enable electrification as a process of substituting fossil fuels with electric power. In this context, the electric vehicle emerged as an attractive solution for the transport sector, promising significant increases in energy efficiency and reductions in greenhouse gas emissions, all, according to some visions, for relatively little behaviour change. The overarching aim of this book is to deconstruct and evaluate that composite claim.

Electric motive power is not new; indeed, it has been part of the transport system for some 170 years; rail, road, and water transport applications were amongst the pioneering implementations of the electric motor from the early nineteenth century. Nonetheless, the technology was immediately in competition with steam 'external' combustion engines, mainly fuelled by coal, and later the petroleum-fuelled ICE.

One key advantage of electric power across the decades has been relative simplicity. The invention of the rechargeable lead-acid battery by Gaston Planté in 1859 predated the internal combustion engine by two decades, and hence the first car was in fact electric, whilst an electric car was the first vehicle to exceed 100 km/h, and for the first 20 years or so of the automobile age, electric models were the most numerous and popular (Guarneri, 2012). A photograph of Thomas Parker's first electric car of 1884 shows a four-wheel 'horseless carriage' with three passengers aboard and an altogether more solid appearance than Benz's tricycle (Parkhurst, 2021). More fundamental advantages behind the initial attractiveness and popularity of EVs included cleanliness and quietness of operation: EVs were literally less likely to 'scare the horses' and promised to remove their 'noxious emissions', rather than replace manure with exhaust fumes. They were also far easier to operate than the alternatives, representing for a comparatively short period both the 'best available technology' and fashionable consumption. Indeed, for the first 20 years of the 'automobile', both ICE and electric vehicle (EV) technologies offered similar range (30–50 km) and speed (15–25 km/h). EVs provided taxi services in New York and postal deliveries in France (Guarneri, 2012, p. 6).

From this relatively strong competitive position, the relegation of the electric road vehicle during the 1920s alongside the increasing domination of the ICE vehicle (ICEV) offers some insights for the current aspirations for an electrification transition, as the key factors in the historic fate of EVs continue to feature strongly in modern debates.

Electric cars in the 1910s were costly, not only in absolute terms but also relatively so. The rise of mass 'Fordist' production, indeed pioneered in the auto-assembly industry, more than offset the simplicity advantage of the EV. In the United States, electric battery cars were up to five times more expensive than ICE cars and were therefore a luxurious, exclusive option (Guarneri, 2012).

Even today, EVs continue to bear a price premium, and models have been over-represented in the premium segments, suggesting production is less profitable (at least to-date) for utility models. Moreover, for many private purchasers, the used car market remains the key one, and EVs have hitherto been a niche option in that domain, and subject to concerns about battery longevity.

And once an ICEV had been purchased, it was affordable to use due to petrol or 'gas' being a plentiful commodity which could be refined in large volumes at low cost and sold into a market at a price which did not reflect the long-term environmental and health costs of the emissions. This latter point is critical, as the efficiency of EVs is only attractive to the consumer where the cost of fuel is a salient decision-making factor. In some jurisdictions, notably in Europe, duties and taxation maintain a significant price differential between liquid road fuels and electric recharging, with electric vehicles usually being *substantially* cheaper to refuel. This is not the case globally, and so in some places such savings are a weak motivation.

ICE technology continued to be developed and refined, leading to more comfortable, reliable, and easier to use vehicles and, in particular, range grew. In this context, the parallel enhancement in road infrastructure enabled the ICE car to become a long-range transport mode, rivalling the monopoly provider of such services, the railways. Whilst a local service domain suited the EV, which could be charged overnight sufficiently for a relatively short, moderate-speed daily use pattern, the energy intensity necessary to support higher speed and distance was not available from the battery technology at the time. However, limited range and associated 'range anxiety' continue to be a constraint on the attractiveness of EVs to consumers, who tend to buy for the longest potential journey not the typical daily trip, with greater range tending to come only with significantly higher purchase cost.

The importance of the ICEV production industry has developed a particular economic role and geographical pattern, producing important concentrations of employment with a range of skill levels and associated political importance in terms of economic activity. The significant investment in plants capable of producing particular kinds of vehicles and motors adds financial inertia to political inertia. Electrification demands significant changes in the business practices of the established auto manufacturers, and over a comparatively short period of time, at a high short-run cost of restructuring and re-equipping factories and supply chains, as well as managing other barriers to transition such as winners and losers amongst groups of workers with specialist skills in the labour market.

The rise of the ICE has changed society in terms of particular behaviours and practices. In response to the availability of affordable, fast, private transport by vehicles that can provide daily mobility in exchange for being refuelled once a week or so, and in a matter of minutes, urban form has evolved in most places to become less dense and less constrained by alignment with public transport service corridors. Such a system has created a particular culture of automobility (Urry, 2004) and dependence on the car (Mattioli et al., 2020). The place for EVs in this spatial-socioeconomic nexus after 1950 was limited and specific, where stringent noise or gaseous emissions requirements were prioritised, such as industrial applications within closed environments, or the British tradition of before-dawn, daily deliveries of milk to households.

Hence, the electrification of the mobility sector seeks to overturn a deeply entrenched system built on plentiful, available, easily-distributed, and stored fossil-fuel power. EVs are attempting to emerge from niche applications to become the primary motive force, requiring that specific ownership, usage, and maintenance practices associated with ICEVs are challenged. The scale and difficulty of the project should not be underestimated. Whilst the electric motor has always been a competitive technology, and the powertrain efficiency has been enhanced through developments in power electronics, the limited energy density and recharging time of batteries for motive power – the original Achilles heel of the electric vehicle – remains a significant technical and consumer barrier, even if significant resources are being directed towards removing it.

The electrification of mobility consists of a number of technologies applied across both traditional and novel forms of transport (Parkhurst, 2021). In the case of rail, it merely implies the diffusion of mostly well-established technologies across networks, many of which already exhibit a high reliance on electric traction. For entirely new modes, such as the small personal mobility modes of e-scooters and e-bikes, an entirely new support infrastructure and user-culture must be created, but the technical constraints are largely solved by solutions such as detachable, low-capacity batteries which can be recharged off the vehicle. Major problems remain for the long-distance, energy intensive modes of aviation and shipping, where it is not yet clear whether purely electric solutions are feasible. Even amongst the traditional road vehicles, the opportunities for electrification show variability: long-distance road freight haulage might need solutions such as overhead pantograph infrastructure for a purely electric energy solution to be sufficient, whereas battery storage is a far more reasonable prospect for urban buses following predictable duty cycles and covering modest daily distances.

However, the mode of transport in focus for the present book is the passenger car, as it dominates the road networks of the industrialised states by its physical presence, and, in most of these states, is the leading means of passenger transport by number of trips, and even more obviously by annual distance travelled, for example, accounting for more than two-thirds of passenger-km in the European Union in 2017 (European Environment Agency, 2019). And for the passenger car, and hence this book, the clear leader technology in the 2020s is the battery-electric vehicle (BEV).

A potential contributor technology for electrification is the hydrogen fuel cell (FC), producing electricity on-board by electrolysis, and requiring refuelling with hydrogen gas under pressure. However, although as a technology FCs have a long heritage, application to road transport is relatively recent; mainly since 2000. There have been few production FC cars reach the market and these have sometimes been limited offers under special lease arrangements. At the time of writing, only two major manufacturers (Toyota, Hyundai) had models available in the United Kingdom. The longest-running model, the Toyota Mirai, had achieved sales of approaching 10,000 units globally 2014–2022. From the consumer perspective, a FC Vehicle (FCV) potentially replicates ICEV refuelling practices, but if the BEV charging network is limited, that for FCVs is almost absent, and considerable environmental and technical challenges remain around sourcing and

supplying sufficient hydrogen. FCs remain a potential future option particularly for large vehicles operating from depots with their own refuelling infrastructure, but the BEV is currently the only commercialised and attractive option for most light road vehicle applications.

FCVs are in fact just one example of a hybrid technology combining a power generator with a battery for its energy needs. Most hybrid EVs (HEVs) combine batteries with an ICE; the two either acting in concert or as alternates. Toyota launched the first mass-produced ICE-BEV hybrid, the Prius, in 1997. By 2020, most hybrids had batteries which could be pre-charged from the electric grid as well as the capability to operate solely on the battery for medium speed and distance trips. However, whilst hybridisation has been a useful transitional technology, it comes with the higher cost and vehicle weight of duplicating the powertrain, and increases complexity over the ICE, rather than reducing it as a pure EV does. ICE-BEV hybrid dependence on fossil fuels is likely to remain, limiting the extent to which a sustainable future for the car is possible. Hence, HEVs are considered where essential in this book to understanding the evolution of the BEV car, but are not a central focus. Otherwise, hydrogen FCs, battery-swap technologies, and advances in battery storage may reduce the barriers to electrification in the future, and the interrogation of these more futuristic vehicles is on the horizon of the scope of this volume, but it nonetheless emphasises current evidence and experiences in understanding at what point we have reached in the transition to the electric car, the wider societal and economic changes which are underway, and whether the transition will bring wider sustainability benefits.

The book takes a multidisciplinary approach drawing on sociology, social and environmental psychology, business studies, political studies, sociotechnical transition studies and environmental science, as well as transport planning and geography. Analytical approaches include systematic literature review, multi-criteria analysis, analysis of financial flows, quantitative travel data analysis, digital ethnography and discourse analysis, whilst theoretical perspectives draw upon social practice theory, theories of technology adoption, political-economic theory, psychological theories of personality, self-presentation, and social norms, and space–time geography.

Part 1 considers the 'contexts and imperatives' of transitioning to electric cars. In the first chapter, Roberts explores the interrelationships between society, the economy, and the built environment that have coevolved over the last century to become a specific set of technologies and practices, picking up the debate on how far electric cars can represent a 'drop-in' technological substitution, or will be embroiled in political struggles between interests seeking to protect the value of capital, livelihoods, and even current parking practices.

Even if electric cars do achieve wide levels of acceptance and adoption, a more fundamental question about the transition is whether it does indeed provide the technological basis to radically reduce the negative environmental consequences of both car ownership and car use. Over recent decades, the transport of people and goods has been responsible for a growing share of global energy consumption and greenhouse gas emissions. In the EU in 2016, road transport was responsible for 72% of transport sector carbon dioxide emissions, and car use 60% of these