

The Future & Conclusions

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Source of right-hand image above: Metropolia University of Applied Sciences, Helsinki, Finland.

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The Future – one possible version

Introduction

Within some of the preceding chapters, a view has been offered of what the future of motoring may bring. For example, the ever-increasing proportion of the car's value represented by electronics and software, the 'airless tyre', telematic services riding on the back of mandatory Emergency Call (E-call) functionality, widespread car-to-car communications and the prospect that the second half of the 21st century could herald the widespread adoption of hydrogen as the fuel of choice for our cars.



In terms of the car performance, the influence of Formula One Racing has been mentioned in the context of Energy Recovery Systems and their relevance to battery electric and hybrid car powertrain design. Formula One also has blazed a trail in terms of vehicle safety with the use of carbon fibre materials, lightweight for fuel efficiency and capable of withstanding impacts that would otherwise result in death or serious injury to the occupants.

As previously noted, land speed records have been held by both steam and battery powered cars prior to records set by internal combustion engine cars. More recent records have been established by jet and rocket powered cars and the next UK attempt on the record, with a target of 1000mph, is to be made with a car, [Bloodhound](#), powered by internal combustion (to



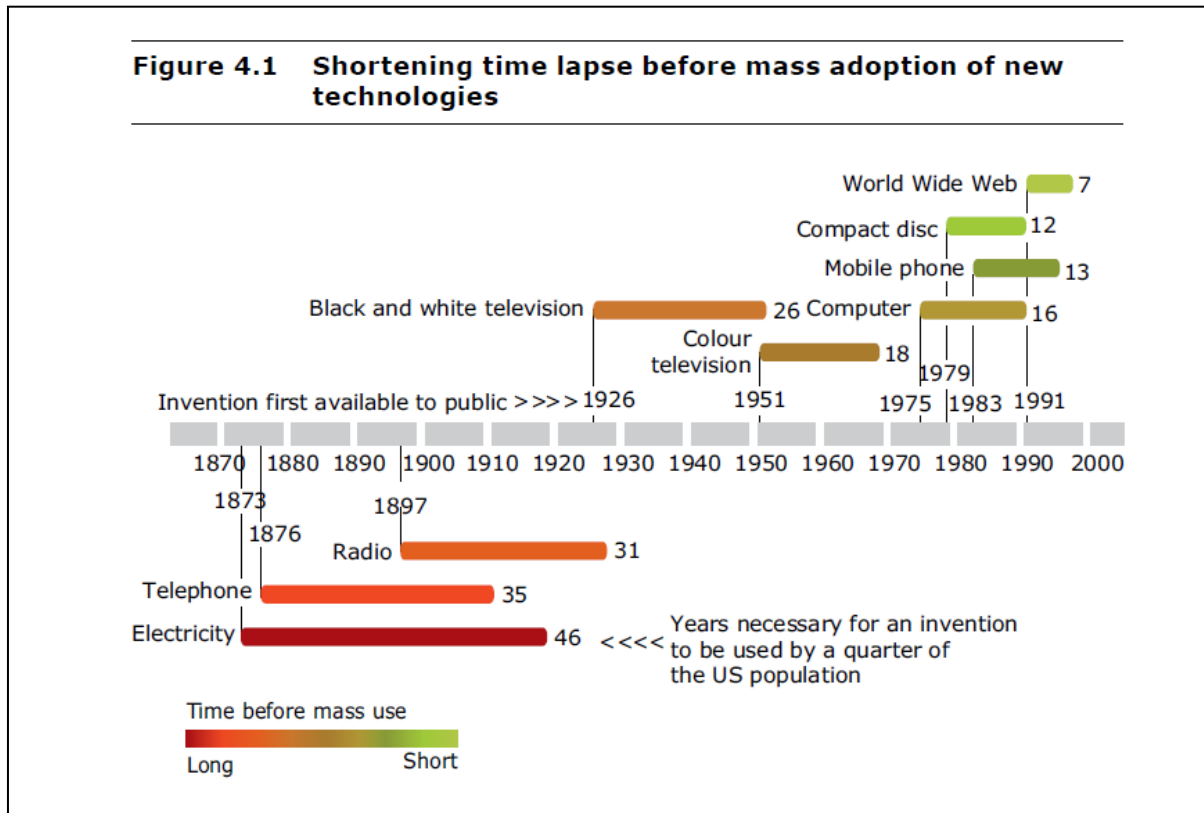
pump fuel), a jet engine and a rocket motor. Whilst the land speed record is one of the objectives of Bloodhound, the main objective is to encourage an enthusiasm for science, technology, engineering and maths amongst the current generation of schoolchildren. Without their skills, none of the possibilities presented in the

remainder of this concluding chapter will come to fruition.

Historically, there are occasions when the developed world has been saved from the folly of its own actions through a fortunate change in the direction of technology that conveniently removes a looming problem. It was argued in the chapter on the Internal Combustion Engine that its invention was an example of one such 'disruptive technology'. And the problem it avoided? In 1894, the Times of London estimated that every street in the city would be buried under [9ft of horse manure by 1950](#)! This was not as far-fetched as it may seem today. Urban populations were increasing, and rail transport exacerbated the problem as horses were used for the final leg of passenger and goods transport. (There is an uncanny modern day parallel here with internet and white-van deliveries adding to urban pollution of a different sort). The private car was hailed as an environmental saviour which, in less than two decades removed

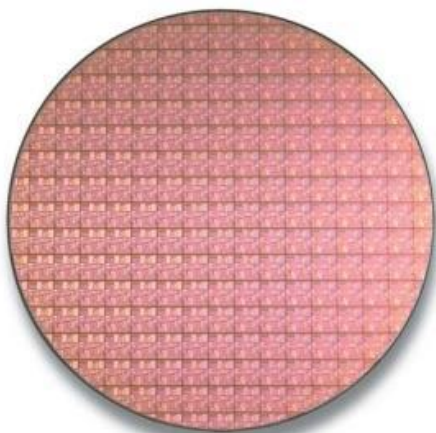
an urban planning nightmare that, to the majority of the population, had no foreseeable solution. Will hydrogen power be the next such technology? More shortly!

Before looking at specific topics, it is also instructive to look at the evidence that supports what many of us sense; namely that the *rate* of adoption of new technology is increasing. The figure below is based on the talk “[The Accelerating Power of Technology](#)” in which Ray Kurzweil suggests that technological advances proceed exponentially and not linearly. His figure below was reproduced in “The European Environment – State and Outlook 2010” and, as an historic view is as valid today as it was in 2010 and needs little additional explanation.



So, what else might be waiting around the next technological corner?

Back to basics



As already discussed in the chapter on the Electronic Control Unit, the value of electronics and software in the car is set to increase still further if the targets for net zero greenhouse gas emissions and ‘zero fatalities’ are to be met and the concept of the ‘connected car’ becomes reality. Fundamentally, the reason that electronics can be used to achieve these objectives is due to the ever-increasing packing density and power reduction of modern electronics.

In the mid-1980s the target, subsequently the state-of-the-art, lithography in semiconductor processing was to

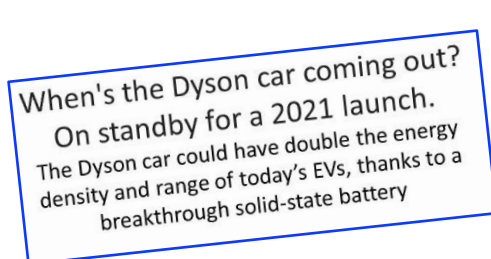
achieve a sub-micron - ie less than 1000 nanometres¹ (nm) - level of detail². This meant that semiconductor masks used in fabricating devices, for example a transistor, on a wafer of silicon would have sub-micron features and this in turn would determine the number of devices that could be grown on a wafer of typically 50mm diameter. The home PC and smartphone today are running processors with [sub-30nm geometry](#) produced on 200 or 300mm wafers.

At this level of detail, the features of the device are already shorter than the [wavelength of the light](#) used to illuminate the photosensitive resist that forms the etch mask overlaying the semiconductor material. Extreme ultraviolet illumination sources, with a wavelength of 193nm, may reduce device geometry by a further (small) factor, three dimensional structures may increase packing density and increased use of parallel processing will increase speed. High device density reduces power consumption, improving cooling, enables more powerful and faster processors, results in a high production yield on wafers of up to 300mm diameter and ultimately delivers lower unit cost. High conductivity interconnections – graphene is one possibility – will also help with thermal issues.

Minimising the power to switch the state of a transistor (between “0” and “1”) may be achieved through use of piezoelectric material, flipping electron spin state or controlled quantum tunnelling effects³. On the other hand, it is possible that the next breakthrough may be away from purely mineral-based electronics: germanium, silicon, gallium arsenide and indium phosphide. Biological-based electronics may provide that breakthrough. Bioelectronics as the basis of future computers was demonstrated when scientists at Stanford University published their results of a transistor based on DNA and RNA; dubbed a [‘transcriptor’](#).

Batteries

Researchers working on lithium air batteries have successfully used a [bio-engineered virus coating](#) to increase the electrode area of the battery with the potential for increasing capacity and hence the range of electric vehicles, with no associated weight increase. [Flow batteries](#), using an organic electrolyte, are one possible solution to smoothing the flow of renewable energy generators such as solar, wind and wave. With brine as the electrolyte, they may even have a role as a [future power source](#) for electric cars. Lithium batteries using solid-state electrolytes offer another route towards a step-change improvement in battery life.



Car Magazine [website](#)



The Verge [website](#)

¹ A nanometre is one millionth of a millimetre or 10⁻⁹m

² The image above is of a 25mm wafer of silicon with multiple semiconductor devices prior to being scribed into individual dice (c1980)

³ New Scientist, 21 February 2015

Artificial Intelligence

Innovation in how the computational hardware of the day is used is also likely to enhance future vehicle applications. [Artificial neural networks](#) have been around for many decades but their affordable implementation has had to await low cost, high-speed processors and vast, affordable memory. Neural networks are particularly good at analysing complex situations. In a facial recognition application, the 'system' is taught to recognise the face of the subject under different lighting, different profiles, with / without glasses, facial hair, headgear etc. When deployed to spot a face in the crowd, identification of the subject is based on the learned knowledge and the identification is typically expressed with an associated probability. Over [97% correct recognition rates](#) have been achieved; virtually equalling the performance of a human being set the same challenge.

In the automotive world, the role for artificial neural networks is as one input to an autonomous vehicle navigation application. The images captured from on-board sensors and cameras under different lighting and road conditions, different traffic densities, different lane markings and different weather conditions would all be built into the learning phase with the neural network 'decision' being one input to the autonomous navigation system.

In short, on-going developments in the world of electronic devices will enable ever more applications, which hitherto may have been unaffordable or impractical to implement, to find their way into the car of the future.

Vehicle trends

As outlined above and in the chapter on the Electronic Control Unit (ECU), electronic hardware and lines of programming code comprising the embedded software, dominate a modern vehicle. In the ever-increasing drive to reduce vehicle weight and hence improve fuel economy, this trend is sure to continue.

For most modern vehicles, depressing the right foot on the throttle pedal no longer moves a heavy metal Bowden cable that owes its origins to the world of early 20th century cycling. The action of depressing the throttle pedal moves the slider of the throttle potentiometer providing a variable voltage signal to the appropriate ECU(s). The actual throttle opening, controlling the amount of air admitted to the engine, is measured by the throttle position sensor, (another potentiometer) providing confirmation of the throttle opening to the ECU. Along with other sensor inputs, such as air temperature, engine coolant temperature, manifold vacuum, crankshaft position, vehicle speed and emissions related data (and, for an automatic gearbox, gear ratio) the amount of fuel injected into the cylinders is determined.

Continuing the trend, the abandonment of direct mechanical linkages to steering, brakes (including the parking brake / hand brake) and clutch, in the on-going quest to reduce vehicle weight, is simply a continuation of the 'drive-by-wire' theme. The [Infiniti Q50](#) was one of the first cars to adopt electronic steering (although the mechanical steering column remains in the event of an electronic failure). Electronics enable the steering ratio to be adjusted as the car's speed increases and allows feedback from the road surface to be varied to suit the driver's preference. Drive-by-wire is an essential, enabling technology if the process of driving is to become ever more efficient and automated.

Electronics, used in the aid of improved safety, take many forms. Included in the safety enhancement features are:

- the provision of information to make en-route decisions on congestion avoidance
- on-board cameras – potentially reducing ambiguity over insurance claims and maybe reducing premiums - as well as enhancing the drivers view in vehicle blind spots
- lane keeping alerts
- emergency brake assistance
- adaptive cruise control – responding to the speed of surrounding traffic – with or without the aid of car-to-car communications
- parking assistance

Technically, the feasibility of an autonomous vehicle has already been demonstrated under well controlled conditions: good visibility, clear lane markings and familiar routes - see the reference to the autonomous, battery electric Swiss bus in “Part 1 – Environmental”. Some of the earlier predictions for full autonomy were very optimistic and a couple of fatalities in the USA involving test vehicles have made the latest predictions more cautious. The UK government is envisaging the legislation and technology will be ready for trials on public roads by [2021](#) and most major vehicle manufacturers, along with partners representing end users (eg [Uber](#), [Addison Lee](#)) and software developers (eg [Oxbotica](#), [Nvidia](#)), have projects aimed at autonomy. Given the hundreds of millions of dollars being invested in the concept, there is little doubt that vehicle autonomy will become increasingly common within the next decade.

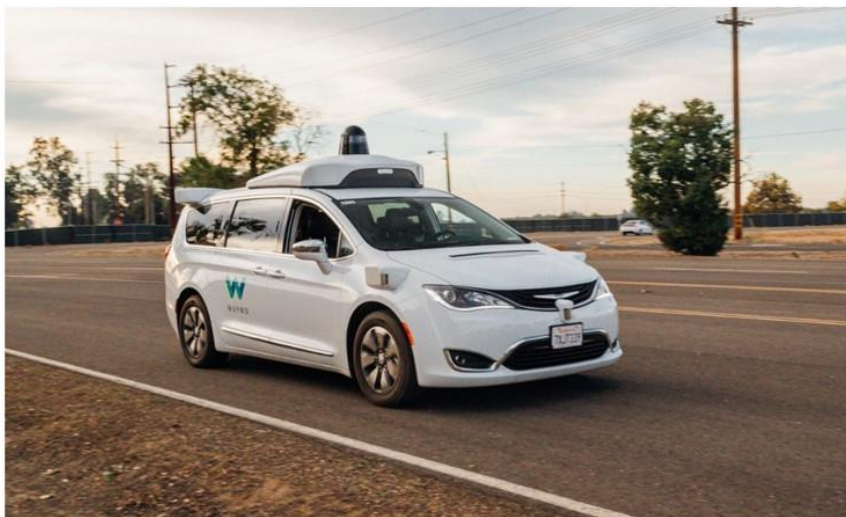
Albeit not from a traditional automotive background [Waymo](#), formerly the autonomous vehicle business of Google, has similar aims.

Waymo gets the green light to test fully driverless cars in California

Human-free driving in the Golden State

By Andrew J. Hawkins | [@andjayhawk](#) | Oct 30, 2018, 5:11pm EDT

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Whether known as ‘autonomous driving’ or, maybe less emotively ‘assisted driving’, the outcome from the investment and momentum of these projects seems certain to become ever more apparent in our daily driving lives. Increased mobility and independence for the elderly, as well as smoother traffic flow, with the associated environmental benefits, and a major step towards the ‘zero fatalities’ target are all potential benefits. Legislation and public acceptance may, however, have to catch up with the technical progress.

Motive Power

So, whether autonomous or not, what will be powering the cars of the future?

The adverse effects of vehicle exhaust on human health, including in the extreme, premature death, have already been quantified in “Part 1 – Environmental”. The corresponding financial cost has been addressed in a report from the Organisation for Economic Cooperation and Development (OECD). It estimates that, in the OECD countries plus the six BRIICS⁴ nations, air pollution cost [US\\$5.1 trillion in healthcare in 2015](#) with half of this attributable, in the EU and USA, to road transport. Since the most harmful emissions come from diesel vehicles, the OECD wants governments to remove incentives to buy them. Nitrogen dioxide (NO₂) levels in London’s Oxford Street, predominantly from diesel powered buses, cars and taxis, were recorded as exceeding the recommended average EU safe level for [80% of days](#) during the first half of 2018.

[New vehicle registrations](#) reflect the concern over NO₂ levels from diesel cars. Of the newly registered cars in GB in 2018, 1.5 million were petrol (a rise of 9% over 2017), 736,000 were diesel (a fall of 30%), 146,000 were alternative fuel (a rise of 22%) and, of these, 63,993 were ULEVs⁵ (a rise of 20%). A similar trend is apparent in the first half of 2019 with ULEVs representing [2.1% of all new registrations](#).

Table 5.4. Manufacturer commitments on electrification

Manufacturer	Timing	Commitment
Nissan	2025	BEVs 50% of sales in Japan and Europe
Mercedes	2025	BEVs 15 - 25% of sales
VW	2025	EVs 25% of sales
Porsche	2030	EVs 100% of sales
Toyota	2030	EVs and conventional hybrids 50% of sales
Volvo	2030	EVs and conventional hybrids 50% of sales
Honda	2030	BEVs, PHEVs and hydrogen 15% of sales

Source: Nissan (2018) *M.O.V.E. to 2022 Midterm Plan*; Daimler (2017) *CASE Strategy*; VW (2016) *TOGETHER - Strategy 2025*; Honda (2017) *2030 Vision*; Manufacturer announcements.

Within the next 5 years all major manufacturers will have a good choice of electric cars in their product range and it seems highly probable that battery electric vehicles (BEV) sales will continue to form an ever-increasing share of the UK market. The table to the left is from the [2018 report](#) to

parliament by the Committee on Climate Change.

⁴ Brazil, Russia, India, Indonesia, China and South Africa

⁵ Ultra Low Emission Vehicles (ULEVs) are vehicles that emit less than 75g of carbon dioxide from the tailpipe for every kilometre travelled. In practice, the term typically refers to battery electric, plug-in hybrid electric and fuel cell electric vehicles.

Restricting that rate of growth is the higher price of the BEV, higher depreciation and a fragmented charging infrastructure. All the while the market remains small and prices high, take-up is likely to remain in single percentage figures. The recommendations of the Committee on Climate change for “[40-70%](#) of new car sales to be electric by 2030 and up to [40% of vans](#) (LCVs)” may be hard to achieve.

Increasing gas production by fracking is reducing gas prices in those parts of the world where fracking is gaining ground: the USA and China for example. Powering commercial vehicles and possibly cars on liquefied natural gas (LNG) then becomes affordable but this is still releasing carbon from a trapped state to enter the atmosphere.

Hydrogen

The gas that holds the greatest hope for the future of low emission motoring is hydrogen. The potential for hydrogen and air used with a fuel cell to generate electricity to power the car has been discussed in the Electric Vehicle chapter. The challenges facing this potentially carbon-free motive power are associated with the production and distribution of hydrogen. Nonetheless, as a mid-21st century solution, this must be a strong contender as a replacement for fossil fuel derived motive power.

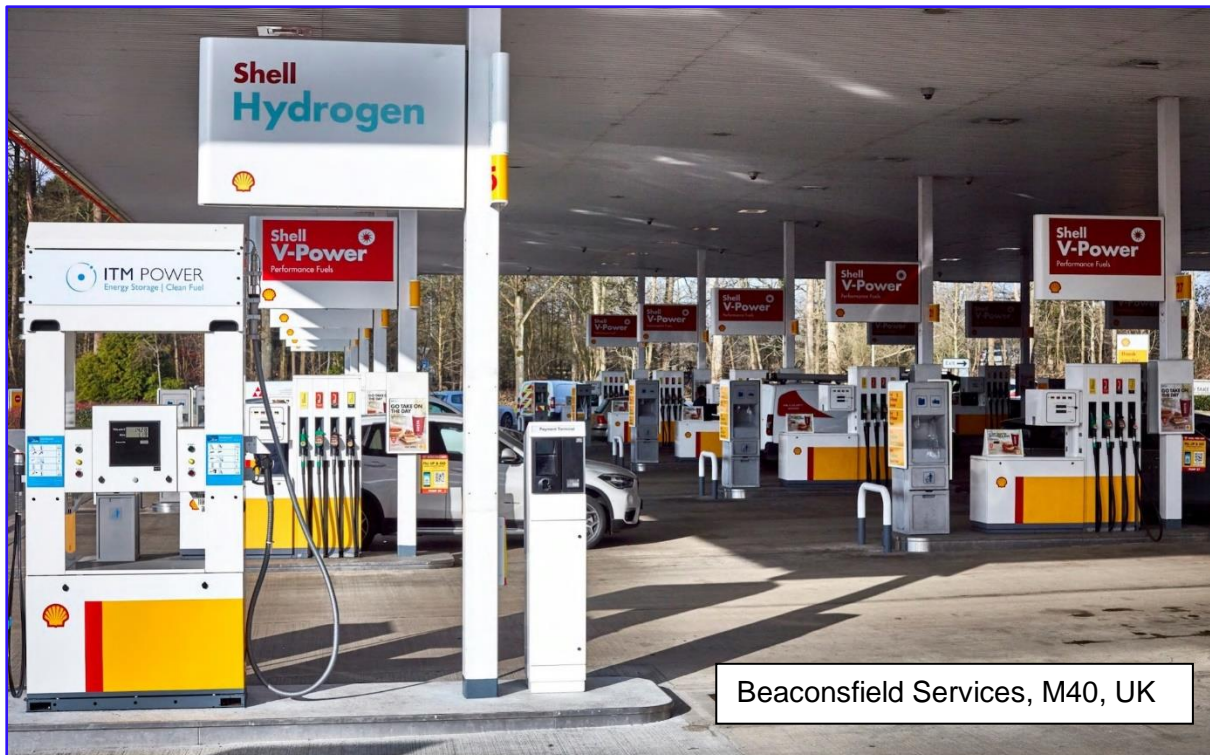
The success, or otherwise, of the fuel cell electric vehicle will depend heavily on the availability of a hydrogen infrastructure. The rollout of hydrogen refuelling in California was mentioned in “Part 3 – Technical” of this book. On a wider, global scale, Australia is planning to exploit its ideal climate for solar and wind energy production to become a hydrogen generator and exporter. Currently the country is economically heavily dependent on fossil fuel exports to South Asian countries. It recognises that the global move away from fossil fuels, in countries such as South Korea, China and Japan, where Australia has an existing customer base, offers an opportunity to become a supplier of hydrogen. In addition, it has the climate and the land area to become a major player in the hydrogen economy. Countries such as Qatar and Saudi Arabia have similar aspirations in the Japanese market.

A northern hemisphere country with access to abundant renewable energy is Norway where over 96% of domestic power is hydro generated. Production of liquid hydrogen from electrolysis of water or from natural gas (using carbon capture) is seen as a way of kick-starting the country’s hydrogen economy⁶. To hasten this process, the Norwegian government is withdrawing funding from firms solely involved in fossil fuel extraction and re-investing in renewables⁷.

Closer to home still, [a report from the Institution of Engineering and Technology](#) considers it feasible to “re-purpose” the UK natural gas system to handle hydrogen. This is seen as a key step in achieving the UK’s greenhouse gas target by 2050.

⁶ New Scientist, 8 June 2019

⁷ New Scientist, 22 June 2019



Social trends

Finally, in this brief look into the future, most of the preceding discussion has focused on the car; its technical development and motive power. Will any of this have a significant social effect? As with any significant disruption of established technology, associated social disruption seems likely.

The move away from the internal combustion engine as the primary source of motive power to battery electric power (or plug-in hybrid or fuel cell electric) is going to be accompanied by a major change in vehicle production and servicing techniques and skills. The component count of moving parts in the drive train of an electric vehicle is typically less than 20% of those in an equivalent petrol or diesel vehicle. Surplus manufacturing capacity seems likely to result in factory closures, retraining of staff and redundancies.

Well over a decade ago, industry watchers were predicting that within a decade or two there would be just a handful of global motor vehicle manufacturers: chiefly because of the enormous cost of developing a new vehicle. This would come about through alliances, mergers and acquisitions. The realisation of this prediction is becoming apparent today with two major global players, [VW and Ford](#), collaborating in the areas of electric vehicle production and autonomous vehicle technology.

What wasn't quite so widely predicted was the appearance of new players in the (electric) vehicle market who have no links to historical makers: the likes of Tesla, Google, Dyson and others. The social upheaval, as existing manufacturing plants close and new skills are required in the emerging vehicle market, could be almost as significant as those seen at the dawn of the motoring age.

Conclusions

Seeking international agreement to try to limit global warming to no more than 1.5°C by the end of the century is, by definition, a global endeavour. It requires sceptical nations such as Qatar, Russia, Saudi Arabia and the US (curiously those nations with a high vested interest in fossil fuel production!) to accept the [IPCC guidance](#). There are, however, still things that other blocks of nations (eg the EU) and individual countries can do to mitigate the risk and, ultimately, things that we, as individuals, can do.

Arguably, those long-established, developed nations, such as many Western European countries and the USA, pioneering nations in the industrial revolution, should be leading the way to a less environmentally harmful pattern of conducting our personal and professional lives.

For the last couple of decades, developing countries such as Brazil, Russia, India and China have aspired to catch up with the living standards of the developed world. Intensified global competition for natural resources has occurred and this trend is unlikely to reverse in the short term. Fossil fuel consumption and other [global megatrends are forecast to remain heading “the wrong way”](#) until at least 2030, with the use of [oil, gas and coal expected to grow](#) in volume over this period.

In motoring, as in the wider uses of energy, there are no easy answers but those actions that can be taken include:

- *Using less of the Earth’s raw materials.* Ultimately, if we are to keep the effect of manmade air and sea pollution to a level where we ensure future generations can enjoy the quality of life experienced in the developed world at the start of the 21st century, the energy use per head of population has to fall⁸.

Whether driven purely by environmental concerns or economic necessity, in the world of motoring there are encouraging signs. Average annual car mileage in the UK is falling, the number of cars on the road, whilst still rising, appears to be flattening and of those that are being purchased, [smaller, lower emission cars predominate](#). Amongst young people in the UK, Germany, the USA, Australia and Japan, those learning to drive are doing so [at a later age](#) and car ownership is seen as less important than ownership of a good, smartphone and reliable internet access. Increased urban living may also be a factor in this age group⁹.

- *Reusing more.* For more than a decade, EU directives have covered the end-of-life disposal of vehicles: they are now built to be recycled rather than sent to landfill. The average age of cars on the UK roads is at its highest for over 25 years but even so, the average life is still just [8.2 years](#). The CO₂ produced during manufacture and scappage can be a significant percentage of that emitted by a car during its lifetime: anything from 15% to 50%, depending on the age of the car and assumptions made in the calculation, so it makes sense to maximise the use of our cars. One trend that will

⁸ [David J C MacKay: “Sustainable Energy without the hot air”](#)

⁹ Eric Sanderson: “Terra Nova: The New World after Oil, Cars and Suburbs”

help is that away from personal ownership to membership of [instant sharing schemes](#): again, particularly relevant in urban areas. Technically, software upgrades to existing hardware are likely to extend the useful life of the ever-more connected car.

- *Innovating alternative solutions.* Europe is relatively resource poor, particularly in some of the materials required to support next-generation electronics and the rare earth minerals used for powerful electric motor magnets. It imports many of the resources it requires. With a dependence on non-European suppliers, some with associated political instabilities or ambitions that do not align with western democracy, there is every incentive to develop European solutions to energy generation; for domestic and industrial use, for transportation and for food production. Many areas of innovation in car transport have been covered in this book. One specifically on the mind of a major manufacturer and highlighted by [Bill Ford](#), Executive Chairman of the Ford Motor Company, is that of networked cars leading, by 2025, to autonomous cars bringing their benefits of lower emissions, less gridlock and lower casualty figures.

Perhaps the biggest challenge will be that of fuelling the car of the future whilst keeping the harmful emissions of the car, when in use and during manufacture, to levels that produce no further degradation to the planet's atmosphere. This surely, is the role in which hydrogen will be instrumental over the next 30 years as we approach the middle of the 21st century.

Finally, whilst trying to avoid producing proscriptive lists, a significant part of this book has focused on what the individual motorist can do to minimise his or her impact of motoring on our environment. A discussion on how we might better plan our journeys to avoid congestion, avoid becoming lost, select our new or used car and prolong the life of that car has been presented. It is encouraging that there must be a significant number of motorist who are already changing their habits (or not even going down the route of car ownership) since for reasons of cost, population growth - especially in our cities - or environmental concerns, there are trends that suggest the current "Direction of Travel" of motoring may yet be something that our planet will survive. But not without some significant change.

The Cotswold Motoring Museum and Toy Collection is not just about cars. Toys that our parents and grandparents played with as children, everyday artefacts from the Victorian and Edwardian era plus an insight into the social history of the village of Bourton-on-the-Water and much more can be found in the Old Mill, alongside the River Windrush.

