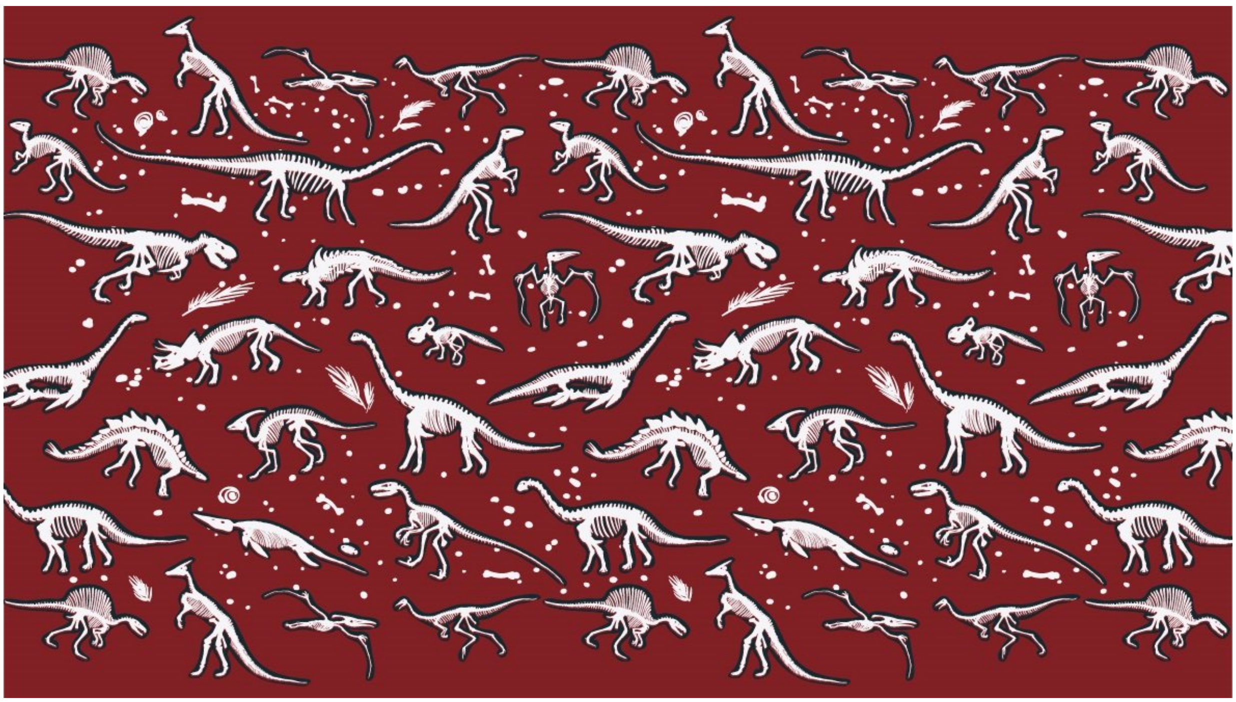
Leaving fossils behind for the future of transport

March 21 2018, by Chris Brace



Credit: University of Bath

One of the key challenges we face as a species in the 21st century is how to co-exist with nature in a sustainable manner whilst maintaining our way of life and extending these benefits across the developing world. This basic tension affects every area of our modern way of life, but none more so than transport. We live in a time of unprecedented technological progress, with colossal investment in clean transport technologies – but there is a significant risk that in a rush towards technological change we neglect the big picture. To fully understand the scale and importance of the challenge that confronts us we need to consider the profound impact that transport has already had on our way of life.

In the developed world we have had the benefit of affordable transport for several hundred years, and for the last hundred years this has been enabled by the internal combustion engine. This is the prime mover that provided the affordable power that shaped the 20th century. The most obvious examples of this can be seen in motor cars, goods vehicles, construction machinery and agricultural machinery. Because the arrival of affordable power predates most of us it is hard to understand just how profound the societal changes that were set in motion by this revolution have been.

Today, every aspect of our way of life is enabled or shaped by the ease in which we can travel between towns and cities, carrying our families and possessions with us. This has enabled a fundamental shift in the way we live, building new houses in suburbs and rural communities while working, learning and engaging in recreation in towns and cities that would have been largely inaccessible only a century before. Our food is grown on an industrial scale and transported along with manufactured goods across trans-continental distances by road to our shops. The houses we live in, the offices we work in and the transport network that links them was constructed using the power of the diesel engine.

Today we can see more clearly the negative impacts of this rush to mobility and policymakers face a huge challenge in implementing effective regulation to mitigate the effects on global warming, local air quality, use of scarce resources, congestion and many more. Even so, it remains the case that the fundamental shift in living standards and quality of life afforded by affordable transport are profound and these benefits must be retained even as we modernise our technology.

Furthermore, these benefits are needed by developing societies across the world as they struggle to access the standard of living that we take for granted. Gaining access to affordable transport transforms the life chances of people living in poverty across the world, raising their earning potential by an order of magnitude as well as enabling access to health care, education and even leisure activities.

To resolve these conflicting needs fully we must consider every part of the problem – power generation, storage, and distribution as well as end use in the vehicle. The manufacture and recycling of the vehicles we use must also be considered as an integral part of the problem. The way we use the vehicles is also a critical aspect that we cannot neglect if we want efficient, safe and effective transport networks. In addition we must never lose sight of the need to do all of this in a manner which is commercially achievable; companies that develop and build cars, trucks and machines must be able to sell them at a sustainable price. The ownership and use of these products must also be affordable in the context of the benefits that they provide. The power generation and distribution infrastructure must be delivered within a realistic time frame with manageable levels of public investment. The power that we produce must be affordable to the end user. To meet the global need these tests must be met in the emerging economies as well as the developed world. Otherwise the developing world will continue to increase their use of affordable but unsustainable technologies that we in Europe have benefited from so strongly.

The real challenge we face as engineers and scientists is not to develop transport technologies that are clean. This is a key step along the route, but it is not the whole problem. Our real task is to develop truly sustainable, clean and affordable transport technologies that are scalable and appropriate across the globe. This is a task that is immeasurably more challenging than simply making clean vehicles, and will necessitate effective policy to encourage research and development and to influence behaviour. It will also call for an acceptance of technologies that offer opportunities to improve in the future, as well as those that help us meet goals today.

Diesel

As Ben Marlow points out in a recent article in The Telegraph, the UK government's approach to preserving air quality has been inconsistent. In the Autumn Budget 2017, Chancellor Philip Hammond announced increased Vehicle Exercise Duty for diesel cars, effective from April 2018.This is leading to the bizarre situation in which the purchase of new, clean diesel vehicles is subject to disincentives while the use of older and less clean vehicles is prolonged. This is a problem for us all, not just the manufacturers. The problem has two main aspects, local air quality and global CO_2 emissions. Firstly, new, cleaner diesel vehicles can be expected to displace older diesel vehicles from fleets and so help to improve city air quality. On the second point, buyers who have turned away from diesel have in the main bought petrol powered vehicles; this has resulted in the first rise in fleet CO_2 emissions after two decades of hard-won improvement.

Diesel engines remain an essential element in the struggle to reduce CO_2 emissions from transport. We all need diesel to continue to be a viable technology; the industry have worked very hard to develop these technologies, it would have been much easier to keep building the old and thirsty petrol engines of thirty years ago. The fundamentally different combustion regime used in diesel engines makes them more efficient in real world usage but also makes effective aftertreatment of the pollutants more difficult than in petrol engines – but great progress has been achieved, to the point where the air quality gap between petrol and diesel is disappearing fast. New RDE-compliant diesels are over 10 times better for NO_x and PM emissions than even 8-10 year old diesel vehicles on the road today, and they're better in the real world as well as on the test cycle. The real world emissions limits that apply to these vehicles are the same as those applied to petrol cars. In addition, and crucially, they are around 20% better on CO2 emissions than equivalent petrol cars.

Many commentators suggest that buyers should simply switch from diesel to alternatives like electric vehicles, hybrids and plug-in hybrids. Indeed, it is encouraging to see sales of these vehicles rising to their highest-ever level – but sales are not rising fast enough to offset the increased uptake of petrol vehicles. Sales of these alternatively powered vehicles needs to rise much further before they can offer a credible mitigation to reduced diesel sales. Electric and hybrid sales are improving as the technology progresses, but high vehicle purchase costs and (as yet) inadequate charging and renewable electricity generation infrastructure mean that they aren't ready to be the complete answer yet. It is expected to be at least a decade before these new vehicle types achieve significant market adoption, and in the meantime we need to keep CO2 reducing year on year – or, if anything, accelerate our progress on CO2 significantly. Moving away from diesel has demonstrably had the opposite effect.

Manufacturers continue to improve alternatively powered vehicles along with conventional petrol and diesel vehicles. Even by 2040 our research, and the automotive industry technology roadmaps, anticipate that the internal combustion engine (including diesel engines) will still be essential in many vehicle types. These will be advanced designs, usually as part of a hybridised powertrain – but internal combustion engines nonetheless. We can speculate as to what fuel blend these engines might burn, but the benefits of high energy density fuels are key to many vehicles. All of these vehicle types are essential for the foreseeable future, but this advanced technology is of reduced benefit if we keep older vehicles on the road too long. At this point we all need clarity from government that they value the contribution that new clean vehicles (including diesel) can make to both city air quality and CO_2 reduction.

Sustainable liquid fuels

But, if hybrids and electric cars are not a complete solution, what does the future look like? People often (mistakenly) think that engines have to run on fossil fuels – so, by that logic, we have to stop everything that we've been doing to date, which in turn means switching from internal combustion engines to electric vehicles or hydrogen fuel cells. But these are presently unaffordable – even with subsidies, which governments cannot and do not want to keep handing out for ever. Viewed in these terms we have a major problem if personal transportation is to continue to be as affordable as it has been to date, while also meeting goals for sustainability and air quality. How can this conundrum be solved?

One promising answer is the production of sustainable liquid fuels that would allow us to continue using internal combustion engines sustainably but with no loss in efficiency. The technology to recycle captured CO_2 into methanol with the input of hydrogen already exists – it's used on submarines to recycle waste CO_2 without producing bubbles of gas that might reveal the craft's position. One could consider it a man-made version of photo-synthesis, but because all the processes are chemical and not biological the rate can be much faster. The challenge for scientists is just to make it affordable – and many are working on this.

Part of that challenge would lie in sourcing the energy required to perpetuate this fuel cycle – but because the fuel could be produced anywhere and exported easily, and would privilege otherwise unusable land such as deserts, there are opportunities here too. Put an electrofuel plant where there is an abundance of renewable energy that is difficult to extract within a nation's borders (whether that's the Sahara or the Orkneys) and all of a sudden a different dynamic is possible: because, for any country which annually transfers a large amount of its GDP out of its economy to pay for transport fuel, even keeping a small annual proportion of it internally compounds the benefit year-on-year.

Also, where biofuels are subject to limits on how much can be made, the sustainable methanol cycle suffers no such disadvantage: the feedstocks – air, water, and renewable energy – are effectively not subject to limitations by man, and from these free feedstocks (given one has invested in the equipment to obtain them) fuel with a high value is made, for which there is a validated and immediate demand.

If this is not convincing enough, consider this: while policymakers can imagine nothing but electric and hydrogen vehicles on the road, there is effectively no other way to decarbonize aviation than to create a carbon-neutral kerosene. It has to be done there, and now the EU is funding the Sun-to-Liquid project to accelerate the solar-driven synthesis of jet fuel from solar energy, CO2 and water. When this is proven, the technology can be fed back to fuels for road transportation and shipping.

There is another intriguing possibility with the cycle. Methanol can be a feedstock for the petrochemical industry, which also uses fossil oil. If plastics, paints, solvents etc. were made from methanol using direct air capture CO2, then the process effectively goes carbon-negative because the carbon is sequestered in solid form. You can't do that using electricity or hydrogen as an energy vector for transportation.

So, here's an unfashionable view from a pragmatist: keep engines, which are eminently affordable for the most important stakeholder (the end customer), but eliminate the culprit – fossil carbon. Use taxation to penalise fossil carbon fuels and promote carbon-neutral electrofuels. As soon as any such fuel is put into the pool then all of the vehicles start to be decarbonised: one doesn't have to wait for unproven new technology which may or may not be affordable. The existing fuel distribution infrastructure can be used, too. And remember that, while I personally think that strategies can be put in place to make electrofuels as cheap as the fossil alternatives, in reality they are not competing with fossil fuel but with electricity and hydrogen – they just need to be cheaper than those to be the most attractive alternative. Electrofuels would be truly disruptive to EVs and fuel cell vehicles because of the known affordability of what they go into. It's also worth noting that fuel is a grudge purchase; it's made because the buyer needs it to travel. Buying a more efficient vehicle, on the other hand, can nearly always be delayed – and for this reason decarbonising the energy source will always give quicker results than building a more efficient vehicle.

We could even co-evolve advanced internal combustion engines and electrofuels for greater system efficiency and provide cleaner air. There is also the potential to go carbon-negative, without upsetting the economic model of transport and keeping taxation constant. The affordability of the internal combustion engine can get us out of the situation we now find ourselves in. It is, after all, newer technology than either the battery or the fuel cell.

Finding a future

Policymakers must move beyond the current paradigm of policy for sustainability in transport, and start looking at the bigger picture. Real, long-term impacts on the key priorities of air quality and carbon emissions will only be achieved by an approach that clearly and consistently supports new technologies offering a strict benefit over current models. Any attempt to pick pre-supposed winners, particularly by closing off promising avenues of research, should be avoided; the stakes are too high, and the risk to society too great.

For the UK government, the context of Brexit adds an additional layer of urgency to this demand; on leaving the EU, Britain will almost certainly retain its commitments to the Union's vehicle standards, and a clear, consistent, communicative approach on the government side will be crucial to the future success of the industry.

Effective regulation can (and should) be a powerful driver of research and development in the automotive industry – but only when it's technologically agnostic and goal-driven.

Provided by University of Bath

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