Getting Around: Future Transport to 2040

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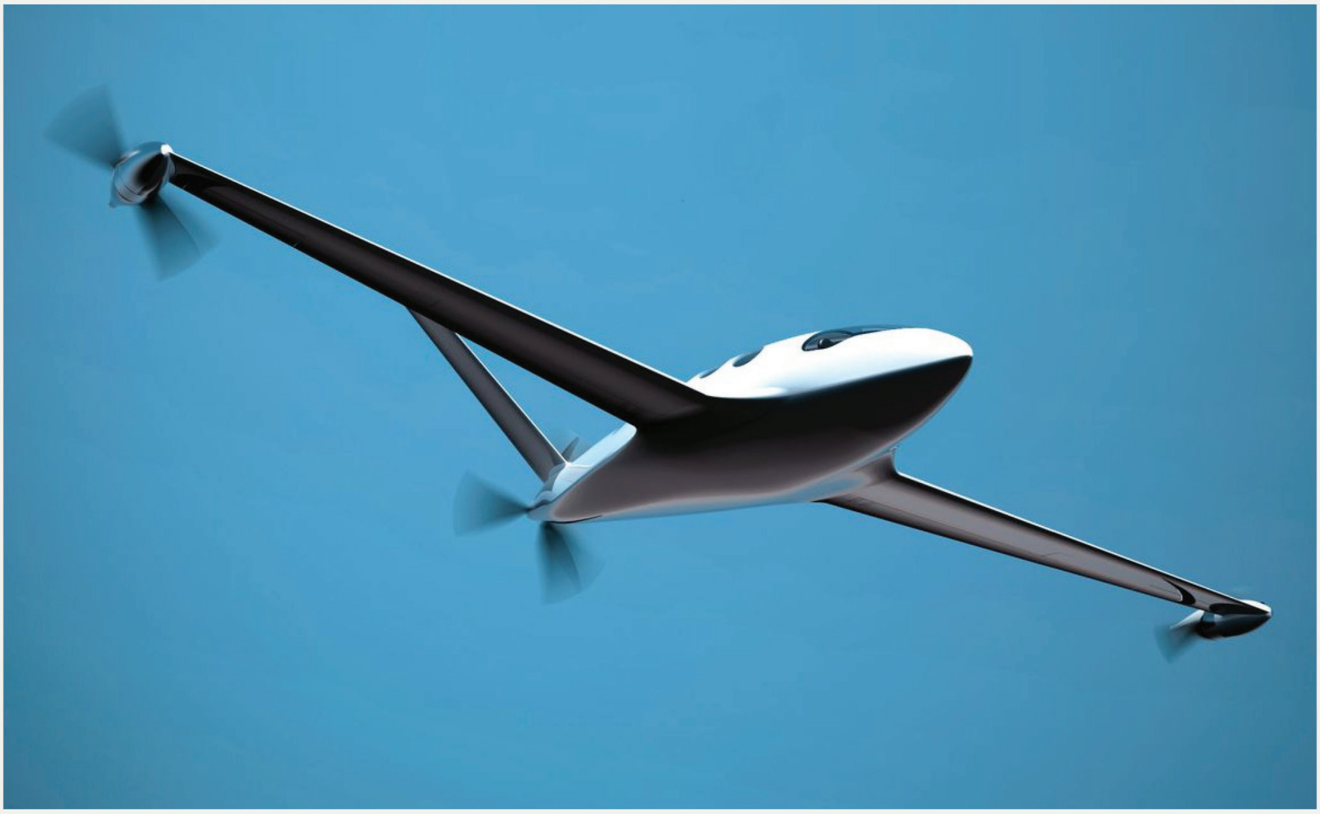
The shape of future transport is now emerging, incorporating exciting new technologies including electric vehicles, autonomous driving, ride-hailing, and more speculative possibilities such as hypersonic flight. Led by a mix of entrepreneurs and state enterprise, new transport is also driven by fuel efficiency standards, carbon pricing, bans on conventional vehicles and other environmental initiatives. Some transport transformation is over-hyped in the short term, but the longer-term impact is set to be enormous. What are the implications for fuel types, overall demand and required infrastructure, over what timescales and in which geographies? What market sectors will remain for hydrocarbons? And how can major oil and gas producers protect themselves – and even benefit from these changes?



Eviation's Alice electric commuter plane (Source: Computer rendering by Eviation)

Executive Summary

- The global transport industry is on the verge of massive changes, unprecedented for the last 70 or even 100 years.
- These changes include the rise of electric vehicles, autonomous (self-driving) vehicles, new business models (ride-hailing apps), and new fuels for ships and planes.
- Such transformational changes go alongside steady shifts in demographics (ageing Western populations, rising Asian travellers), new transport infrastructure, and improving vehicle efficiency.
- These changes are driven by the availability and improvement of new technologies, environmental pressures to reduce greenhouse gases and other pollution, economic drivers (primarily lower costs), and changing consumer tastes.
- Changes in transport have huge implications for the energy business: transport accounts for 21% of primary energy demand and 57% of oil demand[1].
- Transformation in transport will have wider knock-on effects for society and geopolitics, which themselves affect the broader energy industry.

Implications for leading oil and gas exporters

- The electrification of transport is expected to lead to a peak in oil transport use by the 2030s, itself driving a decline in oil consumption overall.
- This will also shift the mix of the barrel demanded, away from heavy fuel oil (for ships) and gasoline (cars), and relatively towards diesel, then jet fuel.
- Gas will pick up some of the transport market, particularly in liquefied natural gas (LNG) for shipping, though remaining much smaller than oil today.
- Increased electricity demand is positive for low-carbon generation, including gas with carbon capture and storage (CCS), renewables and nuclear. It also represents a major opportunity for electricity distribution and storage integration.
- Hydrogen is a potential fuel for heavy ground transport, ships and aeroplanes, but requires early policy support and corporate investment.
- Oil and gas producers can adapt by **defending** demand through improving the acceptability of hydrocarbons; **creating** demand through investing in new markets (geographical and sectoral) and new products (such as hydrogen); **hedging** (investing in non-hydrocarbon transport); and **diversification** (broadening their economies beyond energy).

Future transport will be determined by the interplay of four trends: technology, environment, economics and consumers

Previous fashions in transport have suggested significant changes that did not come to pass. In the 1980s, methanol (made from natural gas) was popularised as an alternative fuel; biofuels and hydrogen were supported by the George W. Bush administration in the early 2000s; the worldwide introduction of the Toyota Prius in 2000 led to expectations that most future vehicles would be hybrids; and in the 2010s, cheap natural gas has seen it touted as a fuel for heavy road transport in particular[2].

But this time, the confluence of four trends looks set to have a much stronger impact, leading to a transport sector in the 2030s that is radically different from today's.

Technology is evolving rapidly, in the areas of new motive power for traditional vehicles (electric cars, LNG ships), entirely new travel modes (such as drones, Hyperloops and hypersonic flight), and new models for transport use (ride-hailing and self-driving vehicles).

This technological growth is partly endogenous, partly driven by the high cost of oil in the 2000s, but particularly encouraged by **environmental** factors. European metropolises such as Paris and London, Asian megacities like Shenzhen, and busy shipping lanes, all seek to reduce air pollution. Even more importantly in the long term, now that progress is being made on low-carbon electricity, attention has turned to the next major sector emitting greenhouse gases.

Growth in the global **economy** influences the demand for travel: leisure, business, and goods transport. Income levels determine the type of vehicles that can be afforded, and the money available for research. The falling cost of new transport systems, and the rising cost of legacy ones once carbon, pollution and congestion costs are included, can drive rapid adoption once a tipping point is reached.

Consumers are both the most and least certain of the four factors. Reasonable projections can be made of the number, ages and incomes of consumers in the major transport markets. But the adoption of new transport systems depends on factors such as branding, customer convenience, social and cultural attitudes (varying between countries and regions), and environmental awareness.

Transport technology is in a phase of rapid development

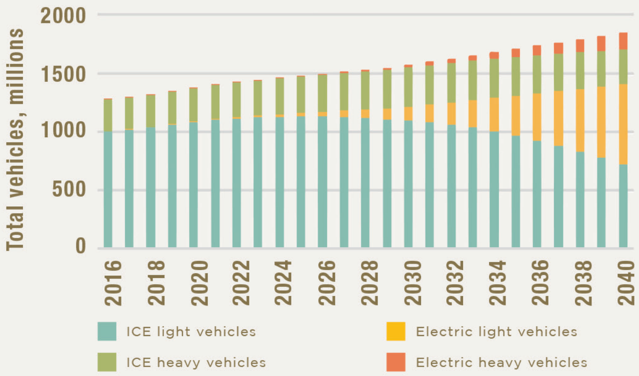
The current period is perhaps the most exciting for new vehicle technologies since the post-World War II expansion of personal motoring and mass air travel, or even the early 20th century changeover from horses, steamships and rail to the internal combustion engine (ICE) and pioneer flights.

Battery-electric drive, drones, autonomous vehicles, private and reusable rockets, and ride-hailing gather the most headlines. More speculative transformational technologies include electric ships and aeroplanes, cargo airships, hydrogen fuel cells, carbon-neutral synthetic fuels and advanced biofuels, auxiliary sails for ships, 'Hyperloops', the return of supersonic passenger travel, hypersonic flight and frequent space travel.

Electric vehicles (EVs) are particularly transformational because of their potential environmental and cost advantages, and their compatibility with ride automation and large-scale electricity storage.

FIGURE 1 shows how the total number of ICE vehicles worldwide could peak around 2025 (and their fuel consumption before that, because of improving efficiency). Electric vehicles take up the growth after that, but because of the high reliability of modern cars, the fleet is still more than half ICE by 2040, unless scrappage incentives are introduced. Meanwhile, the heavy vehicle (trucks, buses) fleet peaks in 2032, and battery vehicles are still a relatively small part of the fleet even by 2040.

FIGURE 01: **LIGHT AND HEAVY VEHICLE FLEET, INTERNAL COMBUSTION ENGINE (ICE) AND ELECTRIC VEHICLES**[3]



The more transformational technologies have hardly made an impact on global transport yet, except in a few niche markets such as electric cars in Norway, and electric bicycles. Online ride-hailing has already shaken up the taxi business worldwide, and online shopping has affected the retail business. Video calling (Skype and similar services), webinars, teleworking and virtual reality have been predicted to reduce transport demand, particularly for business. But so far, online communications seem mostly to have been additive, rather than replacing the requirement for in-person meetings.

Which of the new transport technologies advance to a dominant role, and how fast, is hard to predict and depends not just on technological progress, but also on social acceptance and regulatory frameworks.

Some of the most important changes are from less obvious and glamorous technologies. Improving vehicle efficiency has a larger impact on fuel demand than electrification, over the medium term. LNG is emerging as a fuel for ships to replace the traditional use of more expensive oil, and cut pollutants and carbon dioxide emissions. Artificial intelligence for logistical scheduling cuts costs for goods transport. Mass transit and high-speed rail are important for keeping dense cities liveable and linking urban centres. Electric bicycles, motorbikes and rickshaws could expand rapidly in crowded cities in the developing world.

In aviation, low-cost airlines flying to regional airports have been part of a trend away from the hub-and-spoke model, in favour of flying point-to-point, often in new, smaller and more efficient planes such as the Mitsubishi Regional Jet[4].

Many of these advances in technology and business models, particularly the incremental ones, are driven by competitive and regulatory pressure. Environmental policy is important in supporting the 'clean' options. Some of the more speculative possibilities are driven by individual entrepreneurs or start-up firms scenting an opportunity. And advances in batteries and electric vehicles are led by strategic goals, particularly China's goal to create a new world-leading industry and diminish its dependence on imported oil.

Environmental pressures will increasingly drive transport changes

Environmental policy in many countries seeks to reduce the greenhouse gas impact of transport, particularly by encouraging electric and other low-carbon movers; boosting public transport, cycling and walking; and improving vehicle energy efficiency.

High fuel taxes have long been usual in Europe and Japan, even if not explicitly targeted at carbon dioxide reductions. Transport has not yet been brought into carbon pricing or capping schemes, but this may happen with shipping and aviation. Most major economies, including China and the US, have light vehicle fuel economy standards, which the EU is now extending to trucking (see the Al-Attiyah Foundation Issue 16, December 2017).

Limits on sulphur and other pollutants in fuel have been steadily tightened, while the 'Dieselgate' scandal implicating Volkswagen in 2015 has dealt a severe blow to European plans to promote diesel as a relatively clean and efficient alternative to petrol (gasoline). The IMO2020 regulation limiting marine fuel to no more than 0.5% sulphur (from maximum 3.5% today), is starting to shake up the maritime sector, and limits on carbon dioxide are likely to come in the mid-2020s (see the Al-Attiyah Foundation Issue 18, February 2018).

A number of countries have now announced bans on sales of new ICE vehicles by a certain date: India, Netherlands, and Sweden by 2030; UK and France by 2040; and China (aspirational, but date not set). Cities intending to ban ICE vehicles include Amsterdam, London, Barcelona, Brussels, Hainan and Los Angeles, by 2030. These bans may well be delayed or scaled back, but give an increasingly strong signal to consumers and automakers.

However, some developments in transport are environmentally unfavourable, unless offset by other policies. Supersonic, hypersonic and space travel are particularly energy-hungry. Increased use of ride-hailing apps reduces public transport ridership: for every year after they enter a market, rail ridership drops by 1.3% and bus ridership 1.7%[5]. The greenhouse gas impact of this will be reduced if on-demand vehicles move to battery models, but there will still be a negative effect on congestion, and on usage of public transport which in turn worsens its economics and potentially leads to poorer service.

Autonomous vehicles would allow much longer and perhaps faster commutes, contributing to suburban sprawl, and so in turn to larger, more energy-demanding homes. They may also be larger and more luxurious (including, for instance, televisions, work stations, dining areas, bathrooms and beds), which would again increase their energy consumption.

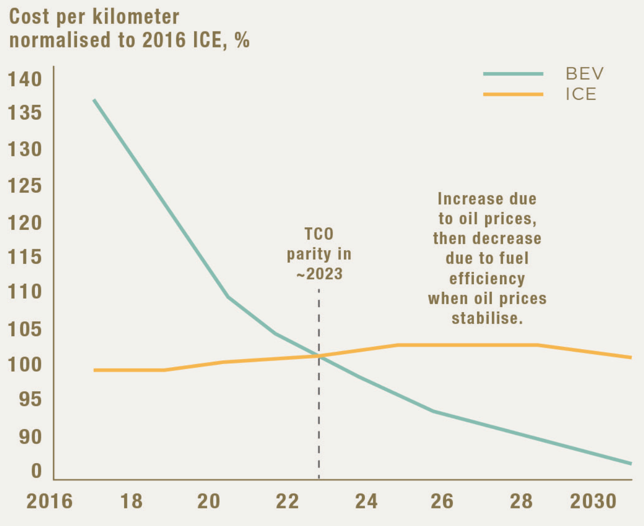
Economics can lead to tipping points, but completely new technologies have to cross a large hurdle

The growth of the Asian urban middle class, and of globalisation, has spurred transport growth. Africa may emerge too, but continuing strong growth in air and sea cargo could be more doubtful in a world of growing trade barriers. The economic drag of increasingly severe climate change is a further feedback loop.

The take-up of electric passenger vehicles is so far driven mainly by government policies, including fleet emissions standards, direct subsidies, tax credits, subsidised charging, and perks such as free parking, registration and use of express lanes.

But as the share of these vehicles expands, governments will have to reduce subsidies. For mass adoption, electric cars will have to reach cost-parity with ICE cars. They may sustain a moderate up-front premium in view of lower fuel and maintenance costs, but this cannot be too large. Battery packs, now costing below $250/kWh, will have to fall to $100/kWh to take off in markets without high fuel taxation, such as the US. This could be reached by the end of the 2020s. But in a highly-taxed market such as the EU, a medium-duty battery truck could reach cost parity with its ICE equivalent as soon as 2023 (FIGURE 2).

FIGURE 02: **TOTAL COST OF OWNERSHIP PER KM FOR EU MEDIUM-DUTY TRUCK, REGIONAL USE**[6]



If the use of ICE cars begins to decline, their value proposition will be worsened by losing economies of scale – as repair shops and petrol stations close down, and automakers devote less research and development funding to a 'sunset' technology.

The economics of other transport systems varies greatly case-by-case. The viability of public transport, for instance, depends among other factors on local geography, climate, existing infrastructure, customer tastes and fuel prices. Supersonic and hypersonic travel, by contrast, will probably be taken up by the military, wealthy early adopters and senior businesspeople, for whom price (within reason) is less important than speed and convenience.

In shipping, LNG vessels offer advantages in fuel cost over marine diesel or low-sulphur fuel oil, but significant up-front costs for construction, and loss of cargo space. Shipowners find it hard to make such investments at a time when the industry is struggling.

Some other technologies will require sizeable initial spending to bring them to maturity. For instance, several companies, including Lockheed Martin, are seeking to reintroduce commercial airships[7].

Consumer taste is the most unpredictable factor

Demographics present a reasonably clear picture of the future user base for transport, at least out to 2040: an ageing and stagnant or falling population in the West, Japan and China, versus continuing population growth but with smaller families in south Asia and Africa. Older people are generally expected to travel less. Congestion in megacities also presents an increasing barrier to individual car use.

Yet it is not straightforward to extrapolate from this to transport demand, and from that to what types of vehicle or mode will be preferred. As the popularity of single-occupant SUVs and pick-ups in the US shows, consumers do not necessarily adopt what seems to be the most cost-effective option. Individual tastes, fashions, the desire to show off status, cultural and social trends, environmental awareness, effective marketing, and factors of microeconomics and practicality not always visible to the analyst, all play a role.

For instance, Tesla's high-end positioning and effective marketing allowed it to capture early adopters, while giving political cover to support generous EV subsidies. This changed the image of EVs from the earlier view of them as underpowered and unglamorous.

Ride-hailing apps such as Uber, Lyft, Careem and Didi have not made profits but have achieved huge stock market valuations on the zeitgeist of 'disruption' of a traditional industry.

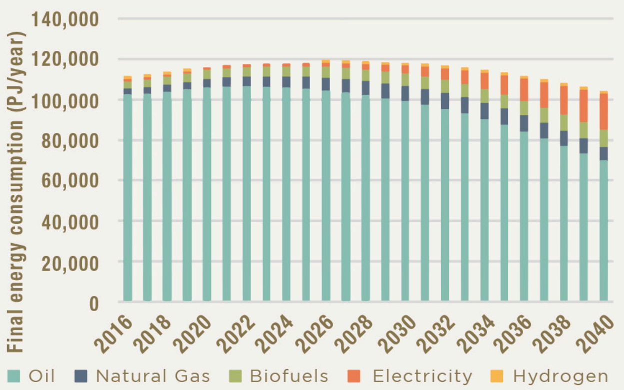
Younger people in Western countries have also shown less tendency to become car owners. This is often ascribed to environmental awareness, to a cultural shift or to the use of ride-hailing. But it could also represent the economic struggles of this cohort following the Great Recession of 2008-9.

The combined effect of these factors is a major, but slow-moving, shift in energy use

Final energy use in transport is set to peak, then gradually start falling in the 2020s, driven by the major increase in efficiency with electrification (FIGURE 3). Oil is the major loser; the minor use of coal (in rail) is eliminated entirely; gas gains, particularly in maritime; biofuels become important as a low-carbon choice in maritime and aviation; electricity gains significantly in road transport, and has a little take-up in aviation and shipping by 2040. In DNV's view, hydrogen has very little role throughout, although other pathways are possible.

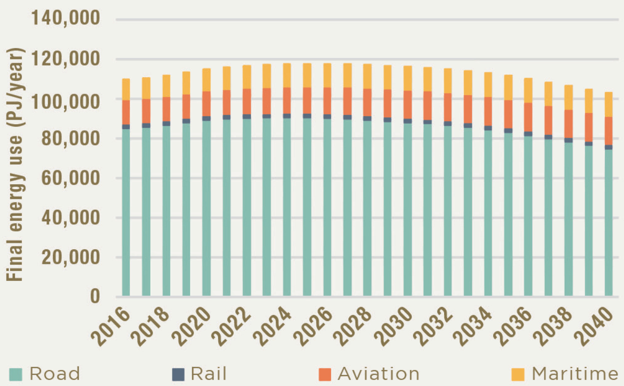
By 2040, oil use in transport is about 67% of the 2018 level. Gas, conversely, is almost three times as big as in 2018, though still minor compared to oil.

FIGURE 03: **FINAL ENERGY CONSUMPTION IN TRANSPORT, BY TYPE**[8]



Transport energy use remains concentrated in road transport, but electrification reduces its share of final energy. Road energy use falls about 0.7% annually from 2018-40, aviation grows 0.7% per year and maritime 0.4% (FIGURE 4).

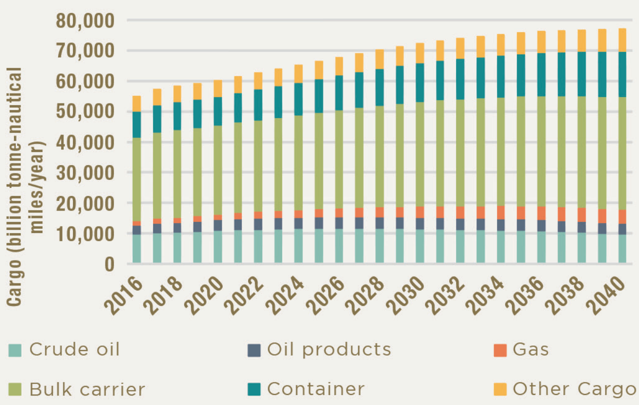
FIGURE 04: **FINAL ENERGY USE IN TRANSPORT, BY MODE**[9]



There will also be shifts within the barrel. Heavy fuel oil will be driven out by changes in shipping, including greater penetration of LNG. Gasoline will be replaced by electrification. Diesel passenger vehicles will lose out in Europe, but overall diesel demand should stay more robust until electricity, LNG or hydrogen begins to replace it in heavy vehicles. And kerosene for aviation will be in growing demand for longer, as electric or hydrogen aeroplanes will probably not be in widespread use until after 2040, although biofuels will have a growing share of the market in order to cut airlines' carbon footprint.

Changes in the energy mix will also influence changes in transport. For instance, in a world of declining coal and oil demand, tankers and bulk carriers will be less in demand, with oil tanker demand essentially flat from about 2025 and falling after 2030 (FIGURE 5). To some extent, shippers of LNG and hydrogen may pick up that demand, but overall shipping growth slows markedly after the early 2030s. Diesel for trucks and trains used to haul coal will also diminish, particularly in the US and China.

FIGURE 05: **SHIPPING DEMAND BY CARGO**[10]



The transport and energy sectors will become more closely linked

At the moment, the broader energy sector interacts with the transport sector relatively little. Energy is required, of course, to make vehicles, and to move energy materials (coal, oil, gas) around. But nearly all transport is driven by oil, and affects other energy uses mainly via price.

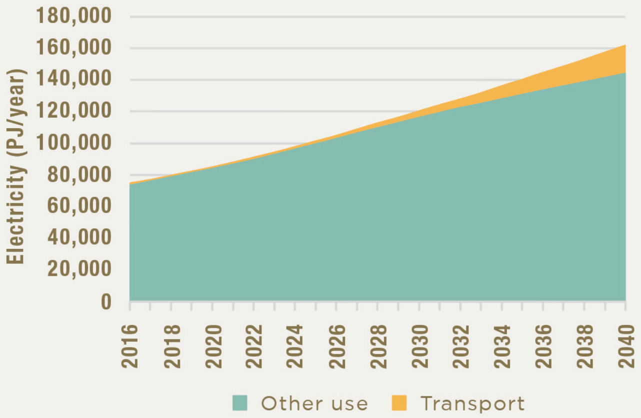
In the future, electrification, and perhaps the rise of hydrogen and carbon capture, will couple the sectors much more closely. In particular, electric vehicles may act as a collective giant battery, charging at times of surplus electricity (such as daytime in sunny places), and partly discharging at night to support the grid. Surplus renewable energy may be used to produce hydrogen or synthetic methane, which can then be stored for eventual use as a transport fuel.

Battery charging demand will alter daytime patterns of electricity demand to a degree, and in particular may require strengthening of distribution networks for high-demand concentrations of charging points, such as workplaces and malls.

Electricity demand for transport grows but remains a relatively modest part of overall electricity demand, about 11% by 2040 (FIGURE 6). Nevertheless, by that year, transport electricity is equivalent to 565 GW of generation running continuously, representing a large opportunity.

Falls in oil demand will lower its price, potentially increasing demand in other sectors. This dynamic is already playing out in a small way with the IMO regulations, where the price of high-sulphur fuel oil has dropped sharply ahead of the 2020 introduction of the regulations, to the point that it may outcompete gas or even coal in power and industry. This fall in oil price, if not offset by carbon pricing. also challenges alternative transport methods to continue improving their cost-competitiveness.

FIGURE 06: **ELECTRICITY DEMAND FOR TRANSPORT AS A SHARE OF THE TOTAL**[11]



The changing transport scene affects energy indirectly as well as directly

Changes in transport can have far-reaching and unpredictable social, economic and even geopolitical consequences.

For instance, autonomous vehicles could lead to safer, quicker, less congested and cheaper travel. They would have many fewer accidents, would drive more efficiently, and not waste time searching for parking. Being safer, they could also be lighter, reducing fuel consumption. Much higher daily mileage for on-demand autonomous vehicles would make highly-efficient, probably battery, drive the preferred choice.

Such improved transport would make travel more popular, improve access to remote communities, and allow new users (for instance the young and elderly).

While good things in themselves, this could encourage urban sprawl, reduce the demand for public transport, and cause widespread job losses among taxi drivers, chauffeurs, delivery drivers, truckers, sailors and pilots.

Electric vehicles require much less maintenance (having many fewer moving parts than an internal combustion engine), greatly reducing the market for repair. Manufacturing countries with a strong lead in internal combustion engines, notably Germany and Japan, could lose business to battery and autonomous innovators in China and the US. Demand for primary steel and aluminium may fall.

Fuel and vehicle taxes are an important part of government budgets, particularly in Europe and Japan. Electricity has been more lightly taxed, and charging for battery vehicles is often provided free. Some part of fuel taxation is supposedly justified to reduce oil dependency, and to internalise the negative effects of oil combustion. But a major shift to electric vehicles will require replacing this revenue base, whether by taxing electricity more, shifting to per-kilometre road pricing, or increasing other taxes.

New rail routes through Eurasia, part of China's Belt-and-Road Initiative, can be cheaper than air cargo and faster than sea, while Russia's Arctic 'Northern Sea Route' opens up a quicker way to Asia. These corridors bypass maritime chokepoints that could become the focus of conflict. Meanwhile the expansion of the Panama and Suez canals has assisted LNG trade, particularly from the US to Asia.

Transport transformation still faces numerous barriers

Transforming the transport sector, in particular electrifying vehicles, faces a number of challenges.

Consumers in most markets are still not entirely familiar with electric vehicles, and may be concerned about range, charging times, the availability of charging points, performance in extreme (hot or cold) temperatures, and the resale value of vehicles with old batteries. Typical electric vehicles today have a range of more than 320 km, with Tesla's Model 3 claiming 482 km, but ICE vehicles can travel more than 640 km, and then refuel much faster than an electric car – perhaps 5-10 minutes, versus at least 30 minutes for a partial charge on the fastest electric systems, and more than a day for a full charge on a home system.

Batteries and electric motors employ a range of special materials, particularly lithium, cobalt, graphite and rare earth elements (REEs). Most of these are not actually particularly rare, but reserves and production are often concentrated in a few countries, which may seek to be monopolists (China in REEs), or may be politically unstable (Congo in cobalt). New sources and alternative materials can be developed, but the long lag-time on mining projects can lead to a volatile boom-bust cycle of commodity prices.

New transport also needs new infrastructure. Electric vehicles require charging points, for which the ideal location and business model is not yet clear – it could be at homes, workplaces, malls, on the street, at traditional petrol stations, or even delivered wirelessly through the road.

LNG shipping needs the availability of bunkering, which is being introduced at most of the world's major ports. Public transport and high-speed rail involves megaprojects with consequent risks over land use conflicts and cost overruns. Hydrogen requires the creation of a whole new value chain like the LNG industry, from production (from natural gas and/or electrolysis of water) to transport, storage, delivery and use.

Such large-scale new infrastructure has typically, in the past, required government intervention, either direct spending or at least subsidies and regulatory support.

This means that intelligent government policies will be required to realise the benefits of new transport systems without suffering too many of the harms.

To reduce the environmental footprint of transport, and meet the goals of cutting greenhouse gases emissions, air pollution, noise and congestion, governments may employ a range of policies.

Carbon pricing and congestion pricing address the main externalities of transport use. The power grid will have to be coordinated with transport electrification to make use of the battery storage potential and avoid demand surges at popular charging times, such as the early evening.

An overall vision for transport within a city, country or region will be necessary to ensure that ride-hailing, autonomous vehicles, public transport and air travel interlace smoothly, and that remote or poorer communities are not underserved. For those put out of work by new transport systems, systems of social support and retraining will be necessary.

Major oil and gas exporters have options to respond to future transport shifts

The shift in future transport presents some opportunities, but more challenges, to major oil and gas exporters. The main issue is, of course, the expected reduction in oil demand and prices.

Possible responses can be divided into four main categories.

Demand defence: Maintain oil demand by improving vehicle efficiency, promoting cleaner engines, and encouraging economic development along with road, port and airport construction in lower-income countries, particularly in Africa and south Asia. Direct air capture (DAC) of carbon dioxide would help to offset transport emissions and so permit continuing expansion of air travel. Refiners will have to consider their shifting geography, with Europe and Japan likely to see declines in transport fuel demand first, while demand keeps rising in south and south-east Asia and Africa.

Demand creation: Create new markets for oil and, particularly, natural gas, by promoting LNG for trucks and ships; and hydrogen (made from natural gas) as a fuel for trucks, ships and potentially aircraft, as well as providing lift for airships. Natural gas, especially if fitted with carbon capture and storage (CCS), can be used to generate clean electricity to charge electric vehicles. Super/hypersonic planes, space travel and autonomous flying vehicles also create new markets for transport energy. Outside the transport sector, there is increasing effort by the major oil and gas producers to promote petrochemicals and non-metallic materials derived from hydrocarbons.

Hedging: Invest in non-oil/gas transport, such as electric vehicles, batteries and their required minerals, and in other new mobility, particularly autonomous vehicles, to provide an economic offset for falls in hydrocarbon demand. Some major oil companies, such as Shell, BP and Total, are already following this approach, including expanding into electricity retail and charging stations. BP operates the UK's largest electric car charging company, Chargemaster, while Middle East sovereign wealth funds have made investments in Uber and Tesla.

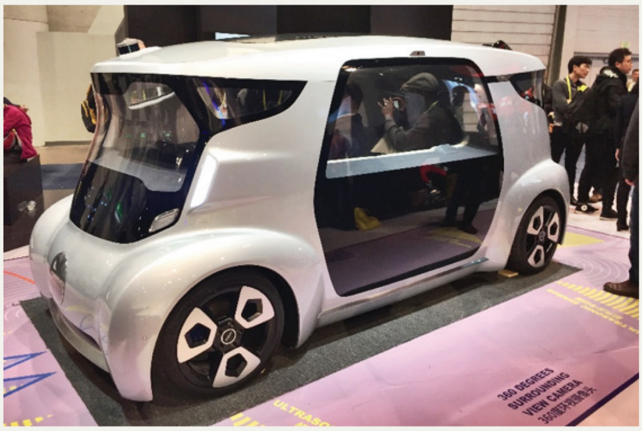
Diversification: Reduce exposure to oil and gas through wider economic activity, particularly beyond the energy sector – an aim for most hydrocarbon-exporting countries, but one that has generally proved hard to achieve.

Conclusions

These radical changes in transport are at their early stages. They may be easy to dismiss at the moment, with just 2.1% of new car sales in 2018 being electric. But leading oil and gas producers, companies and consumers have to watch out for signposts: the increasing competitiveness of electric vehicles on cost and performance, their growth in early-adopter markets such as Norway, and the increasing trend by governments to mandate their use. The same goes for other emerging technologies.

At the same time, not all possible technologies will take off, or at least will take time to do so. Barriers of infrastructure, regulation and consumer familiarity can hold them back even when they appear commercially mature. Some tasks, such as reaching full automation of driving, appear more challenging than first thought.

The implications of new transport reach well beyond the energy sphere, and will have widespread ramifications for industry, society, the environment and geopolitics. Major oil and gas exporters will have to watch developments carefully, invest at strategic points, and make their own economic decisions robust to new emergent transport paradigms.



Uisee autonomous car from China (Source: monsieur paradis https://www.flickr.com/photos/zacharyparadis/32009883161/)

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