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Repowering Transport

Project White Paper

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The views expressed herein represent a collation of various viewpoints emerging from a series of discussions amongst the task force and project board participants from the Automotive, Aviation, Chemicals, Energy, Investors, and Logistics Industries. Although the observations and proposals in this document enjoy broad support, they do not necessarily reflect the views of every individual participant nor do they necessarily reflect the individual institutional viewpoints of any of the companies or institutions that took part, or of the World Economic Forum.

Executive Summary

Global transportation and fossil fuels are inextricably linked. More than 60% of the 87 million barrels of oil consumed every day powers the world's transportation system and liquid fossil fuels account for more than 96% of the current energy supply to the transport sector. Even in optimistic scenarios, fossil fuels will remain the primary source of energy in the transport sector for at least the next two decades.

Energy usage in the transport sector is expected to grow significantly in the years ahead – the "business as usual" scenario examined in this report suggests that the global transport sector will consume roughly 40% more energy in 2030 than it uses today. Given concerns regarding energy security, CO_2 emissions and local air quality, such a trajectory is clearly neither desirable nor socially, economically or environmentally sustainable.

Energy usage growth and oil consumption growth can be significantly reduced through an accelerated drive to adopt energy efficiency technologies that are commercially available today. However, foundations must be prepared now to accelerate the electrification of transportation and deployment of alternative fuels. To achieve further energy and oil consumption reductions by 2030 will require rapid uptake of PHEV/EV and alternative fuels, in addition to rapid adoption of energy efficiency technologies – including the deployment of energy efficiency technologies that are not yet fully commercial.

This report concludes that widespread deployment of a full suite of technologies is required to achieve further diversification of the energy base in the transport sector and to promote efficiency in energy use – there is no single technological "silver bullet". This report provides a framework of key enablers – partnerships, policies and financing mechanisms – that are critical to accelerate the development and deployment of these technologies. No single enabler or type of enabler is sufficient – policies need to be adapted to different modes and local situations, the appropriate partnerships differ by stage of technology development and many of the financing issues to be addressed are mode/ technology specific.

Policy

The debate should move beyond which policies are best. In practice, different types of policies address different challenges – all of which need to be addressed to effect the rapid deployment of a broad portfolio of technologies. The real challenge is to develop the best integrated set of policies – across modes, jurisdictions and technologies – and allocate funds and resources as efficiently as possible between the various policies.

We recommend a two-pronged approach:

Technology-independent policies are the most economically efficient since they create incentives or mandate goals but allow market forces to select the best technology solutions. Fuel taxes or carbon pricing mechanisms and performance standards such as CAFE standards and EU CO_2 standards are common examples. However, these policies are typically not sufficiently stringent to create rapid development on their own. Moreover, they only support R&D and infrastructure developments indirectly.

Technology-specific policies may be required in addition to ensure rapid progress. These policies are effective since they concentrate resources and provide a clear signal to industry, as well as addressing challenges, particularly financing challenges that technology independent policies cannot address. The challenge lies in achieving economic efficiency.

Partnerships

The number of non-traditional, multistakeholder partnerships in this space is proliferating rapidly. A range of partnership types are required for rapid technology deployment.

- Partnerships with relatively few players are effective at research, development and pilot-scale trials. For example, the Schaeffler-led partnership which developed modelling software for wind turbine power trains.
- Narrow-based, high investment partnerships are effective at developing infrastructure and bringing technologies to the market. For example, the partnership of the Swedish Energy R&D board, the European Investment Bank and VantagePoint Venture Partners investment in the 40-million gallon per year capacity Chemrec BioDME plant in Sweden.
- Broad-based partnerships have a role throughout the technology lifecycle – starting with conducting feasibility studies, policy lobbying and developing standards, and moving to address market failures caused by lack of information. For example, the US SmartWay programme which built an accreditation scheme to reduce fuel consumption in the road freight industry.

Financing

The incremental amount of capital required to diversify the energy source is estimated to be between US$ 4-8 trillion over the next 20 years. While this capital requirement is available, it is spread across a large number of financing sources (e.g. governments, manufacturers, service providers, individual consumers, etc.). The amount is in fact small in relation to industry turnover (US$ 4,500 billion) and comparable investments in other sectors, as well as compared to the US$ 700 billion global annual oil subsidies[1] (IMF).

In addition, transportation technology financing issues are quite distinct to the technology under consideration:

Energy Efficiency – the biggest issue is lack of information for the customer. Models similar to energy service companies (ESCOs – who are paid on the basis of energy savings) in other sectors can address some of these challenges.

Electric Vehicles – battery leasing models will be an important enabler for achieving substantial market share. However, the challenge lies in setting a residual value for batteries and developing the secondary market for batteries. Commercial infrastructure will need a rapid reduction in the cost of charging stations, new business models or government support to be viable.

Biofuels – Projects with a good business case are receiving funding, typically first generation. Second-generation plants have both technological and demand-side risks driven by uncertain, ineffective and conflicting policies. The high risk of investing in unproven technology requires governments to support the financing for these projects. Once the first few commercial-scale plants have been built and policy clarified, the market has enough information to evaluate risk satisfactorily and private capital flows efficiently.

Overall, private sector investors will invest in the transport sector, if they can assess the risks involved with reasonable confidence. It is, however, extremely difficult to secure private sector financing for high-risk projects with long payback periods. This is characteristic of technology development projects so governments will need to be involved at this stage.

Implications

Governments need to strengthen policies: existing technology-independent policies should be made more outcome-focused and perverse incentives should be removed. In parallel, governments should identify where their country (or region) has a competitive advantage to deploy technology-specific policies. Where subsidies are required, feebate structures should be investigated as a means to making these more affordable and hence credible.

Companies, governments and NGOs should consider the types of partnerships that could help accelerate their goals – looking for precedents from both within and outside their industry – and take the lead in initiating these.

In financing, the biofuels industry should work with governments to establish the most efficient ways for government to support technology development and commercialization, for example: grants, low-interest loans, loan guarantees and performance guarantees. To accelerate the adoption of energy efficiency technologies in the marine and heavy duty road transport sector, the industry should investigate models similar to ESCOs and identify a practical way to compile and evaluate data from various technologies to allow risk to be measured accurately enough for investment decisions. For electric vehicles, the challenge is less one of financing and more one of continuing to establish a business model (or set of business models) which will make electric vehicles (EVs) more attractive to both consumers and investors.

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[1] IMF, 2010 - Petroleum Product Subsidies: Costly, Inequitable, and Rising

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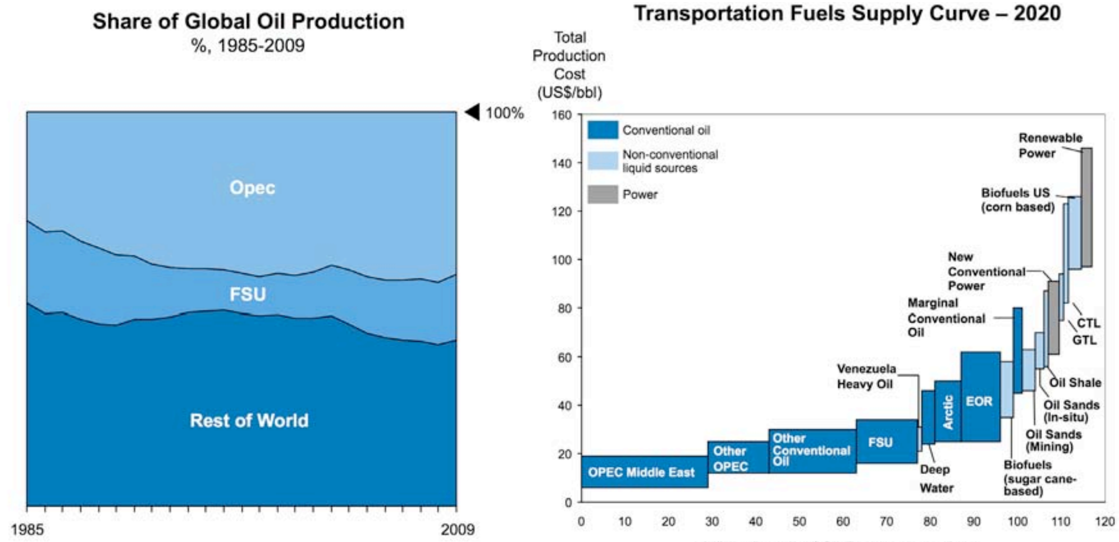
Introduction

Transportation and fossil fuels are currently inextricably linked; more than 60% of the 84 million barrels of oil consumed every day powers the world's cars, trucks, planes and other modes of transportation[1,2] and more than 96% of current energy supply to the transport sector is from liquid fossil fuels Many studies of energy usage in the transport sector show significant growth in demand in the years ahead.

The ramifications of this dependency are becoming more transparent every year. The increasing concentration of conventional oil production in fewer geographies and the increasing cost of new liquid fuels have combined to generate significant unease at the global and national levels regarding the security of supply (see Exhibit 1). Indeed, many countries rely on imported crude oil and refined oil products to fuel their transport sectors, and that dependence will only grow more severe in the coming decade. US crude oil imports are projected by the International Energy Agency (IEA) to account for 80% of the total consumed by 2020, up from 65% in 2008; China's reliance on imports will increase to 68% from 49% over this same time period.

Recent increases in the price of oil and persistent volatility in energy prices have exacerbated these concerns, and most forecasts point to even higher energy costs in the years to come (see Exhibit 2).

Exhibit 1: The End of Easy Oil?



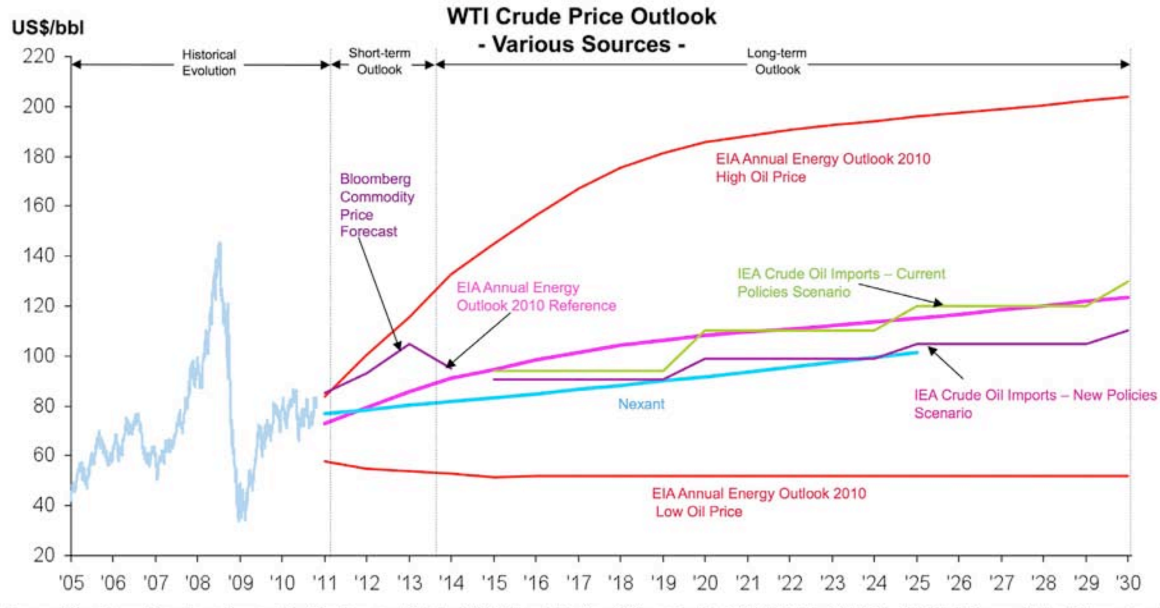
Share of Global Oil Production
%, 1985-2009

Transportation Fuels Supply Curve – 2020

Note: FSU – Former Soviet Union
Source: BP Statistical Review of World Energy 2010

Note: EOR – Enhanced Oil Recovery
Source: Booz & Company analysis

Exhibit 2: Long-term Upward Pressure on Crude Prices



WTI Crude Price Outlook
- Various Sources -

Source: Bloomberg; Bloomberg Commodity Price Forecast October 2010; Nexant Medium Oil Scenario July 2010; EIA July 27th 2010; IEA World Energy Outlook November 2010 (Real terms) Booz & Company research

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[1] IEA World Energy Outlook 2009

[2] BP Statistical Review of World Energy 2010

In addition, rising concerns about the role of fossil fuels in global **CO_2 emissions** are prompting national governments, especially in Europe, to develop technologies that encourage energy efficiency and generate more power from low-carbon renewable energy sources. At the local level, emissions-related policies are increasingly focused on **air quality**, with an emphasis on reducing pollutants such as SO_X, NO_X and PM_{10}.

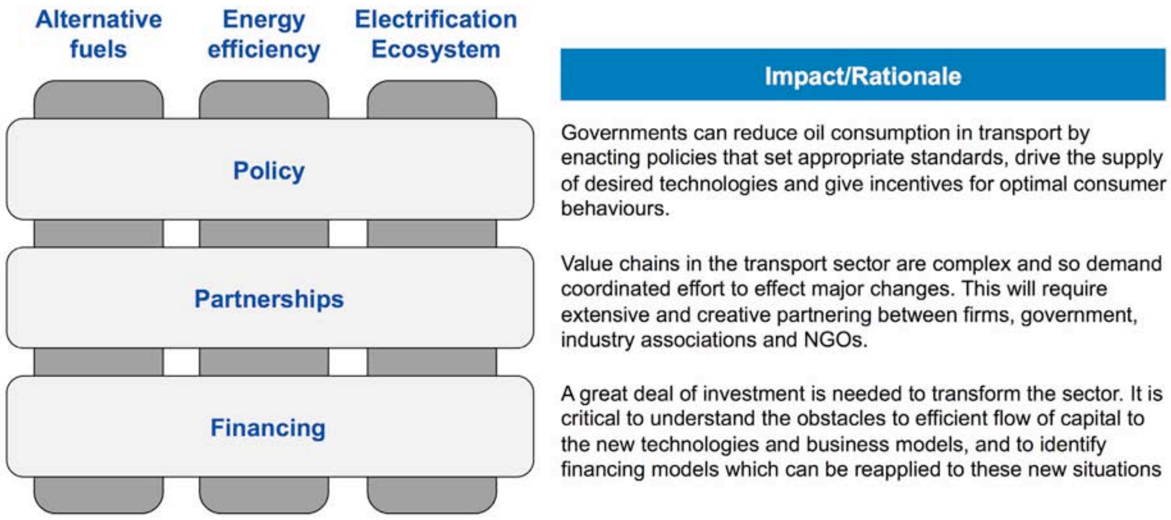
The transport sector is responding to these concerns, but the difference in structures of each mode of transport and the need to address multiple objectives makes coordinating those responses highly complex. Aviation and marine are inherently global in nature and have focused on global CO_2 reduction opportunities. For example, through the Air Transport Action Group (an independent coalition of member organizations and companies throughout the global air transport industry, including airports, airlines, manufacturers and air navigation services providers) the aviation industry made a commitment to stop the growth of CO_2 emissions by 2020, and halve net emissions (including offsets) by 2050, relative to the 2005 level. In October 2010, ICAO (International Civil Aviation Organization)[3] proposed a global framework for managing aviation CO_2 emissions which set targets of 2% improvement in fuel efficiency per year until 2020 and aspirational targets of 2% improvement in fuel efficiency per year from 2021-2050 as well as carbon neutral growth from 2020. The maritime industry is having similar global emissions-related discussions, with the IMO's Marine Environment Protection Commitee (MEPC) met in September 2010 with the goal of outlining a cap on global emissions from the shipping industry, although no final agreement was reached. In contrast, since the road and rail sectors are regionally or nationally managed, priorities are set at that level and hence energy security concerns become more relevant.

There are also differences in priorities by region. Many energy policies in the US and China are motivated by concerns regarding security of oil supply, whereas governments in the EU tend to be more concerned with controlling and reducing CO_2 emissions.

Project Objectives

This study attempts to go beyond the discussion on the types of technologies needed to tackle the energy security, air quality and carbon emissions challenges by examining three enablers necessary to accelerate their adoption. It provides a framework for analysing the impact of policy and regulation, partnership agreements and financing mechanisms on technology deployment in three major fields: energy efficiency, electric vehicles and alternative fuels (see Exhibit 3).

Exhibit 3: Framework for the Project Scope



Governments can reduce oil consumption in transport by enacting policies that set appropriate standards, drive the supply of desired technologies and give incentives for optimal consumer behaviours.

Value chains in the transport sector are complex and so demand coordinated effort to effect major changes. This will require extensive and creative partnering between firms, government, industry associations and NGOs.

A great deal of investment is needed to transform the sector. It is critical to understand the obstacles to efficient flow of capital to the new technologies and business models, and to identify financing models which can be reapplied to these new situations

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[3] The International Civil Aviation Organization (ICAO) is a special UN body. It is a global forum for cooperation among its Member States and with the world aviation community.

This project provides the analytical basis for ongoing debate, discussion and action in this field, and offers the World Economic Forum platform to bring together all the relevant stakeholders. Specifically, the project:

1. Provides a baseline for current energy demand in the transport sector (across all modes), along with future scenarios for the evolution of transportation energy demand under different conditions, in an attempt to bound this broad-ranging issue
2. Includes a brief summary of the various technologies under consideration for deployment in the transport sector to help frame our recommendations in the final section
3. Outlines some of the key challenges in deploying these technologies in the transport sector
4. Analyses the state of current policies, partnerships and financing mechanisms, and rates each of these enablers for its potential to address deployment challenges in the transport sector and to achieve the stated objectives of diversifying the energy mix and reducing energy usage

Approach

This report has been assembled from a wide range of sources, including published studies; input from executives participating in the World Economic Forum's Industry Partnership programmes in mobility (automotive, aviation, and logistics); energy (oil and gas, utilities, alternatives); chemicals and investors; and feedback from the Global Growth Company and Technology Pioneer communities (a full list of the contributing executives and companies is included on the cover page).

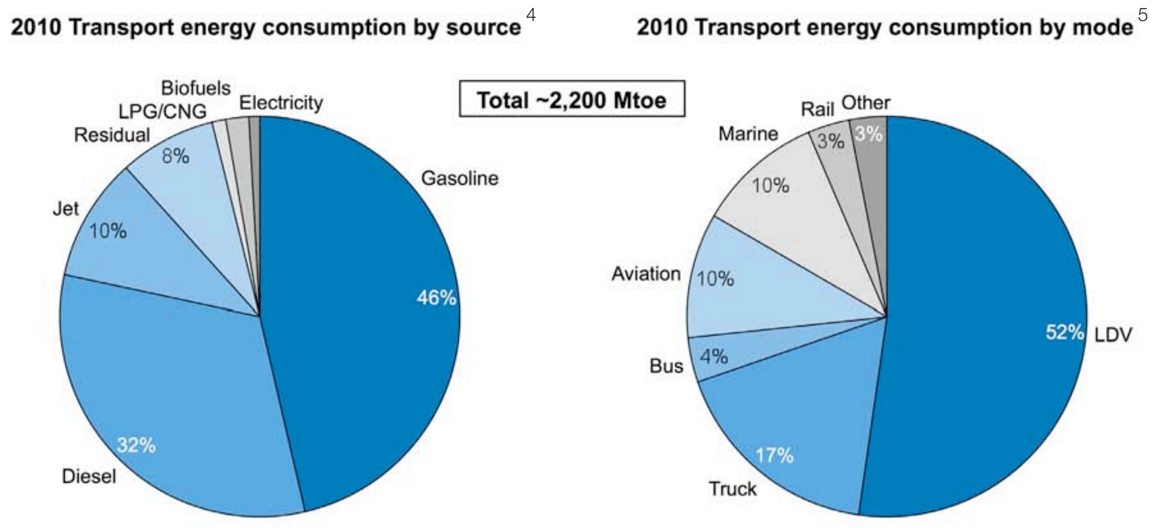
Energy consumption in the transport sector

Main Findings

- Under a "business as usual" scenario for growth in energy demand, the global transport sector will consume roughly 40% more energy in 2030 than it uses today.
- By just about any measure – oil supplies, energy security, CO_2 or other emissions – such growth in energy demand threatens the sustainability of the sector.
- The global transport sector has the potential to hold oil consumption levels in 2030 at the same level as today if readily available energy-efficient technologies are adopted at greater scale.
- Oil use and transport-related emissions could both be reduced by 2030 under a more aggressive scenario, where accelerated investments in electric vehicles and advanced biofuels yield technology solutions that are market-ready by 2020.
- Achieving significant energy diversity and efficiency improvement therefore requires deployment of a wide range of technologies – there is no single technological answer to this issue.

The global transport sector consumes about 2,200 million tonnes of oil equivalent (Mtoe) of energy each year. Of this, more than 96% comes from oil, comprising over 60% of the world's total oil production (see Exhibit 4). Road transport accounts for the majority of this energy consumption, with light duty vehicles (LDVs) accounting for about 52% of the total, while buses and trucks combined represent a 21% share. While air and marine transport each account for roughly 10% of global transport energy consumption, aviation is by far the fastest-growing sector, with a forecast increase in revenue-tonne-kilometres of ~5.1% per year to 2030. The rail sector accounts for roughly 3% of total transport-related energy consumption.

Exhibit 4: A Snapshot of Global Transport Energy Consumption



2010 Transport energy consumption by source[4]

2010 Transport energy consumption by mode[5]

Source: IEA / SMP, IMO, IATA, Carbon Neutral Skies team analysis, Repowering Transport team analysis

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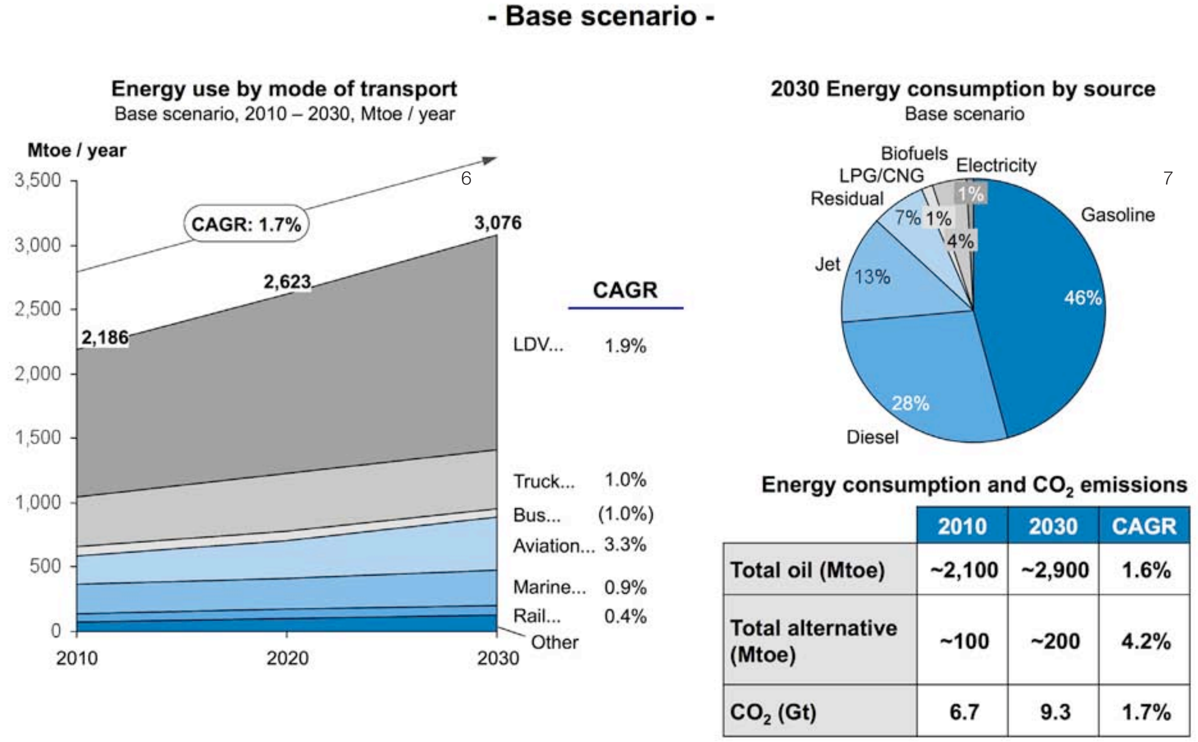
[4] LPG is Liquid Petroleum Gas; CNG is compressed natural gas.

[5] Light Duty Vehicles (LDV) includes passenger cars, light trucks, light commercial vehicles and minibuses; "Truck" category include medium and heavy duty trucks; "Bus" category includes only full-sized buses; "Other" category includes two and three wheelers.

If energy consumption grows in line with forecasts by the International Energy Agency (IEA) and many others – about 1.7% per year until 2030 – **the world will consume about 40% more energy than it uses today**, with little change to the mix of energy sources and both biofuels use and energy efficiency investments continuing at their current pace (see Exhibit 5). By just about any measure – oil supplies, energy security, CO_2 or other emissions – **such growth in energy demand threatens the sustainability of the sector**. In this **baseline case**, energy security risks – already perceived to be significant – would increase substantially. And since the energy source mix would remain broadly the same, CO_2 and local emissions would rise in step with energy consumption.

Exhibit 5: Establishing a Baseline for 2030 Energy Demand



	2010	2030	CAGR
Total oil (Mtoe)	~2,100	~2,900	1.6%
Total alternative (Mtoe)	~100	~200	4.2%
CO_2 (Gt)	6.7	9.3	1.7%

To understand the potential for energy usage reduction, energy diversification and CO_2 emissions reduction achievable by deploying the technologies identified earlier, two alternative scenarios were also investigated. These scenarios are not intended as forecasts, rather as a way to bound the situation and inform the level of policy intervention, partnership development and financial support required to drive technology deployment.

Foundation-building scenario

As discussed in greater detail later in the report, there are many energy-efficient technologies and process improvements available today that, if adopted, have the potential to dramatically reduce fuel consumption and change the trajectory of both energy demand and emissions in all modes of transport. In the first alternate scenario, these technologies are implemented at low-to-negative net present value (significant capital may be required but is offset by fuel savings), and little is required of either new infrastructure or behavioural change on the part of consumers.

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[6] CAGR – Compound Annual Growth Rate

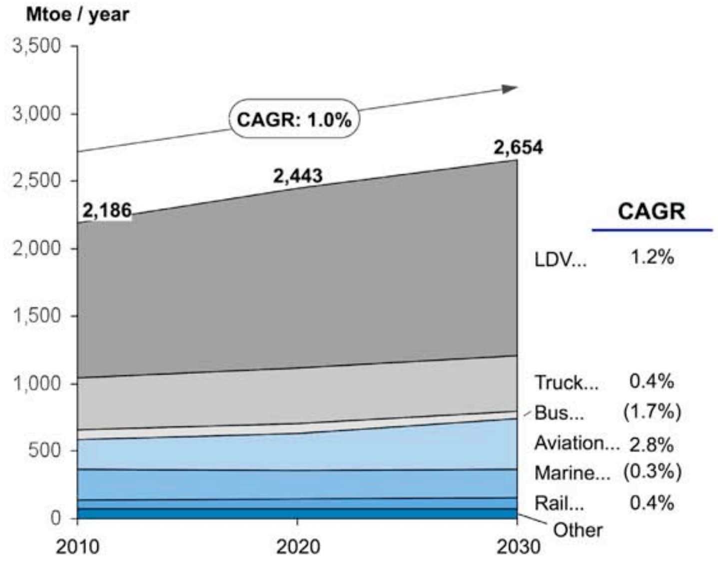
[7] Electricity kg CO2 per kWh assumed to be 0.52 in 2010 decreasing to 0.40 in 2030 (source: IEA World Energy Outlook 2010)
First-generation biofuels assumed to emit 65% of gasoline emissions per kWh and second generation 20%

In this scenario, advances in biofuels, electric vehicles and other breakthrough technologies are relatively modest; emphasis is on laying the foundations for their future growth through R&D programmes and infrastructure investment.

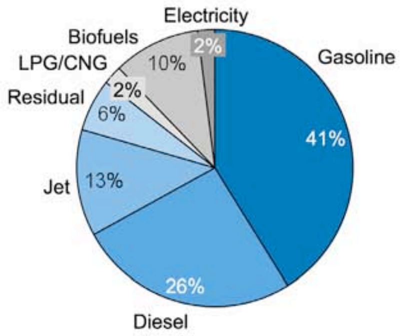
The ultimate outcome of the foundation building scenario is a transport sector that consumes roughly as much oil in 2030 as it does today while energy consumption rises slightly (see Exhibit 6), a result that is consistent with other experts' thinking: the "New Policies Scenario" published in the IEA's 2010 World Energy Outlook forecasts oil consumption growth of 0.5% per year from 2008 to 2035.

Exhibit 6: The Future of Energy Demand in the Foundation Building Scenario

Energy use by mode of transport
Foundation building scenario, 2010 – 2030, Mtoe / year



2030 Energy consumption by source [9]
Foundation building scenario



Energy consumption and CO_2 emissions

	2010	2030	CAGR
Total oil (Mtoe)	~2,100	~2,300	0.4%
Total alternative (Mtoe)	~100	~400	7.3%
CO_2 (Gt)	6.7	7.7	0.7%

While the foundation-building scenario would effectively level the growth of oil consumption, most nations' energy security concerns will likely only be alleviated once transport-related oil demand begins to decline, not just hold the line. In addition, the energy mix in 2030 would not be very different in this scenario than in the base case, leaving economies prone to fluctuations in the price of primary energy sources.

Furthermore, simply keeping oil consumption constant would fail to limit the concentration of greenhouse gases in the atmosphere to 450 parts per million of CO_2 equivalent – the measure at which most climate scientists believe is necessary to keep average global temperatures from rising by more than 2°C above pre-industrial levels. Local communities would likely also brand such an outcome "not enough" given that many urban areas already suffer from emissions-related public health problems[8], to which transport emissions contribute.

Rapid deployment scenario

In a more aggressive "rapid deployment" scenario, end-users adopt readily available energy-efficient technologies on an even greater scale. The biggest difference, though, lies in the treatment of breakthrough technologies – notably second-generation biofuels and electric vehicles – which are deployed much more rapidly, resulting in a significant shift in the energy source mix. As a result of these advances, **total energy use in the rapid deployment scenario rises slowly at 0.5% per year, while oil consumption actually *decreases* by 0.6% per year to 2030** (see Exhibit 7).

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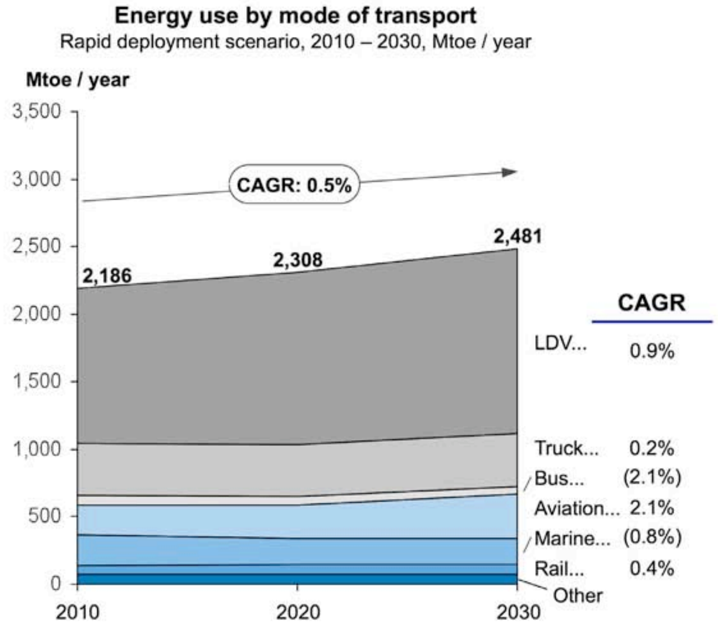
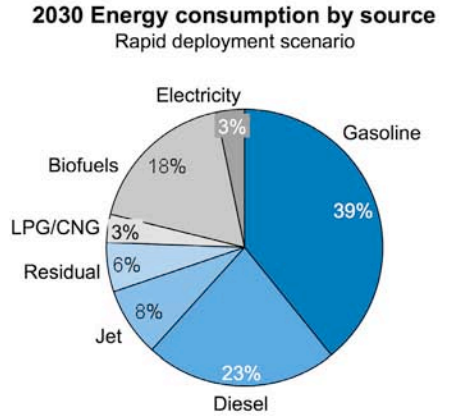
[8] OECD, 2008, Environmental Outlook to 2030

[9] The contribution of electricity to the energy consumption mix may appear surprisingly low. This reflects two factors: first, the low fleet turnover rate (LDVs last on average ~15 years) limits the share of on-the-road fleet despite a high share of sales; second, EVs use only ~25% of the energy that gasoline-fueled cars use on a tank-to-wheels basis.

Exhibit 7: The Future of Energy Demand in the Rapid Deployment Scenario





Energy consumption and CO_2 emissions

	2010	2030	CAGR
Total oil (Mtoe)	~2,100	~1,900	(0.5%)
Total alternative (Mtoe)	~100	~600	9.1%
CO_2 (Gt)	6.7	6.8	0.1%

These figures are consistent with a ~50% reduction in CO_2 emissions worldwide, across all industries. Two issues are important to note here. First, because of the long average lifetime of vehicles and hence slow fleet turnover, the most significant reductions will not occur until after 2030. Second, since other sectors such as utilities will have greater opportunities to profit from efforts to reduce CO_2 emissions, they will contribute a disproportionate share of emissions reductions. This is consistent with the views expressed in the IEA's World Energy Outlook 2010.

Nonetheless, **both scenarios illustrate that incremental energy efficiency measures and existing alternative fuels can have a significant impact in the short and intermediate term.** A great deal of the opportunity lies in simply getting more end-users to invest in existing technologies. Combustion technologies will ultimately reach thermodynamic constraints and the law of diminishing returns will take hold, but we are far from that point. In the marine and truck sectors, and to a lesser extent in aviation, there is a great deal of potential in using retrofit technologies and operational improvements to improve fuel efficiency.

Looking further out, **it is critical that public and private entities continue to support investment in electric vehicles, advanced biofuels and other breakthrough technologies so they can contribute a greater share of energy use and emissions reductions after 2020**. Incremental improvements from existing energy efficient technologies and first-generation biofuels will be harder to achieve by that time, meaning new innovations will need to assume a leadership role by then.

Technology overview

There is a great deal of scope for energy efficiency improvements in the road transport and marine sectors and some scope in aviation. Electrification is possible in the road and rail sectors only (although diesel-electric systems are used in some marine applications, these systems do not draw power from the grid). There is limited scope for electrification in heavy duty road transport – buses and other vehicles with stop-start duty cycles being the exception. The take-up rate of electric vehicles will likely be impacted by the challenges of enhancing electrical infrastructure to charge vehicles, overcoming cost barriers and changing consumer perceptions. The range of forecasts for vehicle take-up is large; more pessimistic commentators point to the many challenges to be addressed, while the more optimistic to the fact that the first mainstream electric vehicles are already being launched. Alternative fuels are relevant to all modes of transport but will be particularly important in the aviation and marine sectors since electrification is not possible.

Note: Fuel efficiency vs fuel consumption

Fuel efficiency and fuel consumption are closely related and often confused.
Fuel efficiency is measured as *distance* per *unit of consumption*; the most common measure is MPG (miles per gallon).
Fuel consumption is measured as *unit of consumption* per *distance*; the most common measure is litres/100km.

$$\text{Fuel efficiency (MPG*)} = \frac{235}{\text{Fuel consumption (litres / 100km)}}$$

** US gallon basis*

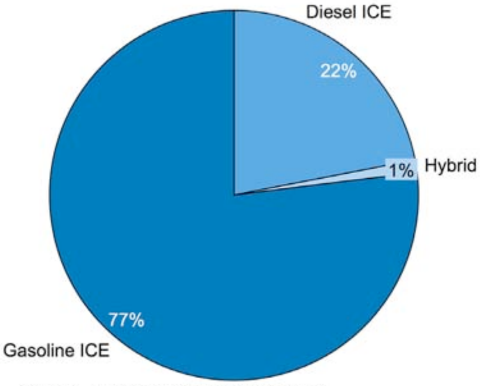
Fuel efficiency gain	Fuel consumption reduction
5%	~5%
10%	~9%
15%	~13%
20%	~17%
~43%	30%
100%	50%

Road transport

Light duty vehicles (LDVs[10])

Diesel- and gasoline-based internal combustion engine (ICE) power trains currently comprise roughly 99% of the global LDV fleet (see Exhibit 8). Because of the long lifetime of existing vehicles – the average vehicle stays in the fleet about 15 years – ICE power trains will continue to dominate the mix in 2030, even in the rapid adoption scenario. As a result, energy efficiency technologies will be extremely important to reduce energy consumption in the near to intermediate term.

Exhibit 8: Power train type mix in LDVs, 2010



Sources: IHS Global Insight; PWC Autofacts

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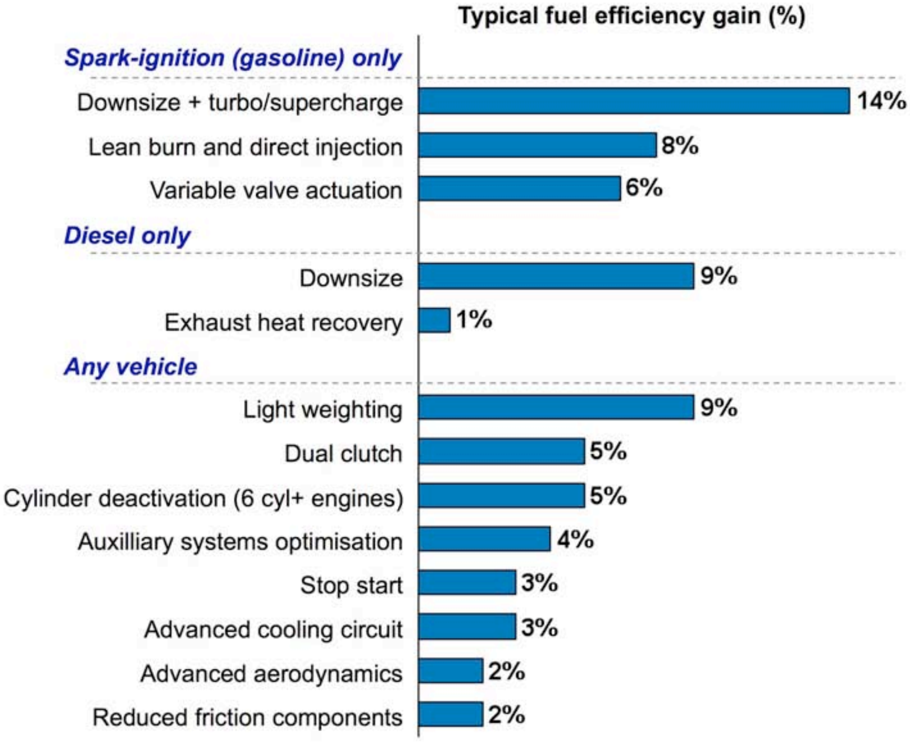
[10] LDVs include passenger cars, SUVs, pickups, minibuses and light commercial vehicles (under 8 tonne gross vehicle weight)

Energy efficiency in light duty vehicles has improved steadily over the last decade; today, there is a wide range of technologies that can yield substantial efficiency gains (see Exhibit 9). In fact, a number of studies have concluded there is significant potential for such technologies to improve fuel efficiency in the LDV fleet:

- The King Review estimated that a fuel efficiency gain of >40% (equivalent to >30% fuel consumption reduction) could be achieved by adopting a subset of energy efficiency technologies available today (not including hybrids).
- The MIT "Factor of Two" report outlined paths to achieving 100% efficiency improvement for new vehicles by 2035, predominantly using technologies available today.
- The 2008 IEA Energy Technology Perspectives study identified a similar range of technologies available today with potential fuel efficiency gains of 39-82% (equivalent to 28-45% fuel consumption reduction).

Exhibit 9: Technologies for increasing fuel efficiency of LDVs[11]



The greatest potential for exceeding the fuel efficiency gains listed in Exhibit 9 lies in making LDVs lighter. Compiled data show that light weighting generates a 9% increase in fuel efficiency (based on an 11% weight reduction), yet evidence supports the potential to go far beyond this amount of savings through the use of new materials, component integration and advanced joining methods. Lotus Engineering, for instance, concluded in a recent study[12] that the weight of a mainstream vehicle – in this case the Toyota Venza – could be reduced by 38% with only a 3% increase in cost by the year 2020. A weight reduction of this magnitude could improve fuel efficiency by 33%, though this weight reduction has to be balanced with vehicle safety performance, recycling regulations and vehicle cost. Advanced materials are a critical enabler for these types of savings, including the use of aluminium, magnesium, high-strength steel, composites and increased use of plastic.

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[11] Data reconciled from numerous sources: HM Treasury, 2007 – The King Review of low-carbon cars; National Research Council, 2008 – Assessment of technologies for improving light duty vehicle economy: letter report; MIT, 2007 – Factor of two: Halving the fuel consumption of new US autos by 2035; MIT, 2008 – On the road in 2035; TNO, 2006 – Review and analysis of the reduction potential and costs of technological and other measures to reduce CO2 emissions from passenger cars

[12] Lotus Engineering, An Assessment of mass reduction opportunities for a 2017 - 2020 model year vehicle program, available online at: http://www.theicct.org/pubs/Mass_reduction_final_2010.pdf

Carbon fibre composites in particular have great potential to reduce vehicle weights. Carbon fibre parts can be made up to 75% lighter than steel parts of the same strength, although weight savings of 50% are more common for cheaper forms of carbon fibre. Carbon fibre has been used in military applications for over 40 years and in race cars for more than 20 years. In the last decade, carbon has been used in limited applications in mass production cars and has been used extensively in high-end sports cars. For example, the Nissan 350Z and Mazda RX-8 (both selling over 30,000 cars/year) both used carbon drive shafts, and the Mercedes SLR and Porsche Carrera GT both have body panels and main structure made from carbon fibre.

Driver training can have a significant impact on fuel consumption, with studies showing a benefit of 5-10%[13]. However, these benefits are greatest on manual vehicles and require expensive on-the-road training to achieve. Moreover, it has been found that drivers tend to lapse after the training without ongoing monitoring, making this better suited to commercial drivers. There is potential for manufacturers to design cars that promote fuel-efficient driving, for example indicators on the dashboard which suggest when to change gears and “scoring” systems to show how fuel efficiently the driver is driving.

Hybrid power trains, which use two or more distinct power sources, can also generate substantial gains in fuel efficiency. There are a range of hybrid configurations that differ by cost and potential for fuel savings. These broadly fall into the following categories:

- **Mild hybrids**: These vehicles include a small electric motor and larger battery than is used in a regular vehicle. They can allow the ICE to be turned off when coasting or stationary, but cannot drive under electric power alone. The motor can provide extra power during acceleration and draw energy from regenerative braking.
- **Full, parallel hybrids**: The battery and motor in these vehicles are larger than in mild hybrids, allowing the vehicle to be driven for short (typically <2 miles) distances using electric power alone.
- **Full, series hybrids**: In a series hybrid, the ICE does not directly power the wheels. Rather, it connects to a generator that charges the battery, while a large electric motor powers the wheels. These vehicles can also be driven with electric power alone.
- **Plug-in hybrids (PHEVs)**: These vehicles are similar to full hybrids but their larger batteries allow them to drive under electric power alone for substantial distances (often ~40 miles). For this report, we classify PHEVs as electric vehicles rather than ICE-powered vehicles because under normal conditions they are designed to run on energy from the grid. These vehicles can use either a parallel or series configuration, though the latter is more common.

Efficiency gains for all hybrids depend heavily on the duty cycle. For in-town driving, which includes a lot of stops and starts, hybrids can deliver the biggest savings. The efficiency gains on highways are much lower. Depending on the battery size and vehicle type, mild hybrids can achieve up to 20% efficiency gains. Full hybrids (series or parallel) can deliver efficiency increases in excess of 50% under ideal conditions, though 30% gains are more typical.

The majority of energy efficient technologies for light duty vehicles are not suitable for retrofitting as most require a fundamental redesign of the engine or extensive bodywork. Although full hybrid technology is not suitable for retrofitting, it is possible to retrofit a vehicle with mild hybrid technology.

The cost and efficiency gains achievable are highly dependent on the duty cycle, vehicle type and how complex they are to integrate. A partnership formed between KPIT Cummins and Bharat Forge was able to generate fuel savings in excess of 40% during road tests of a retrofit kit for small cars in the Indian market.[12] The kit, which is expected to cost around US$ 1,500 - US$ 3,000 fully fitted, pairs a small motor (<20kW) with a lead acid battery to reduce costs. In another example, the UK-based company Ashwoods Automotive has developed a hybrid system for light commercial vehicles that offers at least 15% to 25% fuel savings by using lithium ion batteries. The system can be retrofitted in less than four hours.

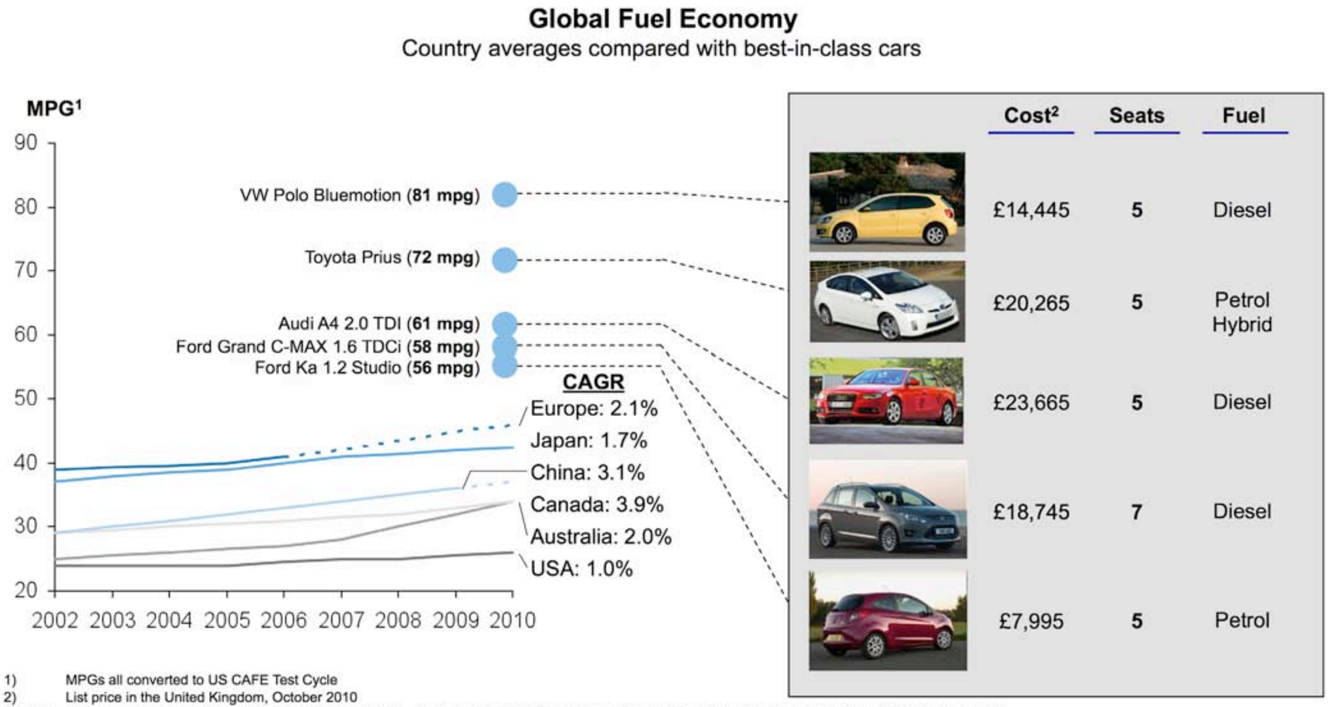
[13] OECD/IEA – Making cars more fuel efficient, technology for real improvements on the road

[14] Tests conducted by the Automotive Research Association of India.

While such figures for potential efficiency improvements may appear aggressive at first, they are supported by a range of factors:

- **Historical precedent**: Many regions have demonstrated that relatively high improvement rates can be sustained.
- **Regional variation**: There is much scope for countries with low-average efficiencies to improve. Consumer preference for larger cars in these markets only explains part of the gap and this preference is waning.
- **Best-in-class examples**: Some LDVs on the market today offer more than 2.5 times the fuel efficiency of the global average; even some seven-seat cars have achieved more than two times the global average (see Exhibit 10).
- **Vehicle sizes**: The majority of demand in the coming decades is expected to come from consumers in developing nations, who are more apt to buy smaller, lighter cars because of affordability issues.

Exhibit 10: Global fuel efficiency in light duty vehicles[15]



Cost[2]	Seats	Fuel
£14,445	5	Diesel
£20,265	5	Petrol Hybrid
£23,665	5	Diesel
£18,745	7	Diesel
£7,995	5	Petrol

1) MPGs all converted to US CAFE Test Cycle
2) List price in the United Kingdom, October 2010
Source: Parkers; International Council on Clean Transportation - Passenger Vehicle Greenhouse Gas and Fuel Economy Standards; Booz & Company analysis

Electric vehicles (battery only and plug-in hybrids)

At the time of this writing, automakers are introducing the first wave of battery-only electric cars into the market. Despite strong support from many governments and a great deal of investment from manufacturers, analysts' sales forecasts vary widely. Many open questions remain regarding the technology, infrastructure, the future of oil prices and consumer behaviour (see Exhibit 11).

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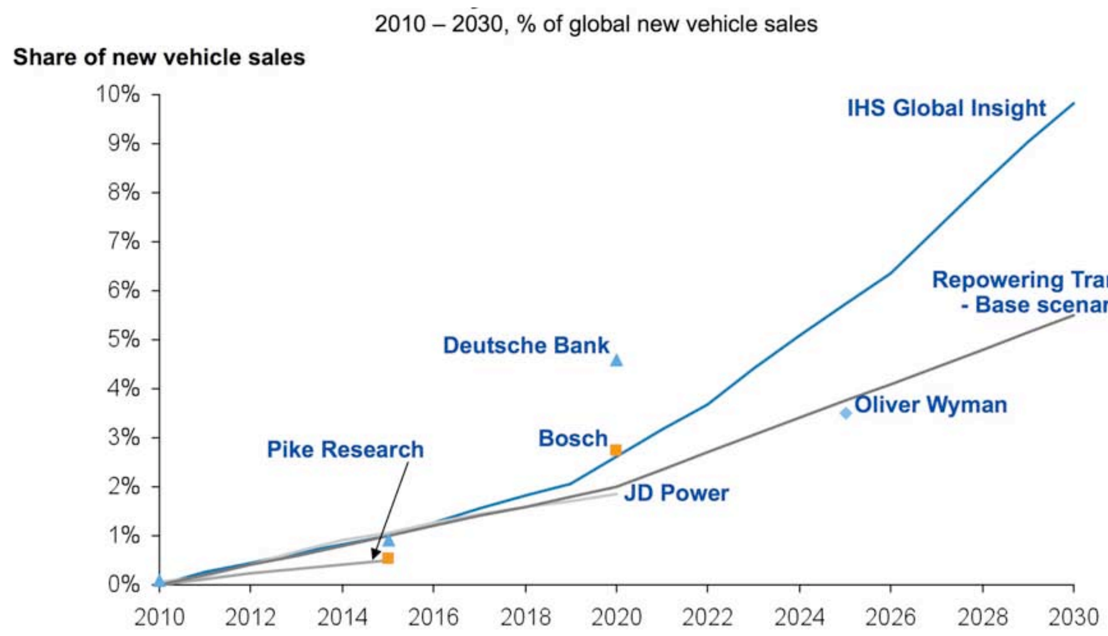
[15] MPG ratings all converted to US CAFE test cycle equivalent; List price in the United Kingdom, October 2010

[2] Sources: Parkers; International Council on Clean Transportation, 2007 – Passenger vehicle greenhouse gas and fuel economy standards: a global update

Exhibit 11: Global battery electric vehicle sales forecasts



Electric vehicles must be more economical than ICE-powered vehicles if they are to reach significant market share. Moreover, they must be perceived to be at least as convenient as ICE-powered vehicles. Both the economics and the convenience of electric vehicles are heavily dependent on the usage patterns and regional factors. For some market segments, electric vehicles already have a lower total cost of ownership (TCO) and comparable convenience as ICE-powered vehicles. However, for many markets, parity in TCO and convenience is some way off because the introduction of any new fuel or technology is a market by market introduction, not a question of percentage of the world market.

Electric vehicles have two main advantages of low maintenance costs and high efficiency that lower running costs compared to ICE-powered vehicles. Since electric vehicles are mechanically much simpler, the maintenance costs will be much lower than for ICE-powered vehicles. Because of the high efficiency of electric motors and the ability to recover energy from braking, electric vehicles use only ~25% of the energy[16] that ICE-powered vehicles use (on a pump-to-wheels basis). Electricity prices are comparable with gasoline prices when measured on an energy equivalent basis; electricity prices are typically in the region of US$ 0.1 per kWh which is equivalent to ~US$ 3.4 per gallon gasoline – higher than the US but lower than Europe. It is worth noting that most governments rely on fuel taxes to support the road infrastructure, if electric vehicles reach high market share, this tax revenue may need to be replaced. Whether this is achieved by raising electricity prices, or by switching to a per-mile-driven tax, the running cost advantage of electric cars would decrease.

Despite their mechanical simplicity, battery prices and low production volumes make the upfront cost of electric vehicles very high. Lithium ion batteries have decreased in cost rapidly from ~US$ 1,000/kWh three years ago to US$ 375-450/kWh today (both Nissan and Tesla claim production costs of ~US$ 375/kWh), and are expected to cost less than US$ 300/kWh by 2020 for the complete battery. Current electric vehicles have batteries in the region of 25kWh, which puts the battery costs at ~US$ 10,000 today and likely under US$ 7,500 by 2020. In this context, leasing and subscription models for the battery are likely to be attractive options – with prices currently in the region of ~US$ 110 per month[17]. Electric vehicles (excluding the battery) are currently retailing at a small premium relative to ICE-powered cars.

The first clients for EVs are expected to be fleet owners attracted by a lower TCO, consumers concerned about the environment, technology friendly or looking to reduce operating costs, as well as consumers with more than one vehicle. Range anxiety is still a primary concern for many private vehicle owners. Modern electric vehicles are quieter, smoother than and just as easy to drive as ICE-powered vehicles. However, the range of electric vehicles is typically around 100 miles (the Nissan LEAF has an official range of 73 miles) and this will vary depending on traffic conditions, weather conditions and driving styles. A commonly quoted statistic is that over 90% of car journeys are less than 40 miles. For an owner of a single vehicle who expects to drive over a 100 miles a few times a year, agreements to have access to a

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[16] Repowering Transport project team analysis

[17] Renault are quoting €72 / month (excluding VAT) for a Kangoo battery lease (22 kWh

different type of vehicle may be necessary and alternative modes of transport may need to be taken into account. Pilot trials have found that range anxiety decreases as drivers become used to the vehicles. There are ways to mitigate the range anxiety. Better Place is pioneering a battery swap model which would allow drivers to swap their batteries for fully charged ones in around 60 seconds and swap stations; and electric vehicle companies are considering partnering with rental companies to offer free backup ICE vehicles in case customers need to make long journeys.

Charging is another hurdle. Although overnight charging is not a problem for people with car garages, few city dwellers have off-street parking or even a fixed parking space. These people would need a broad network of public charge stations which is not yet available in even the most advanced cities.

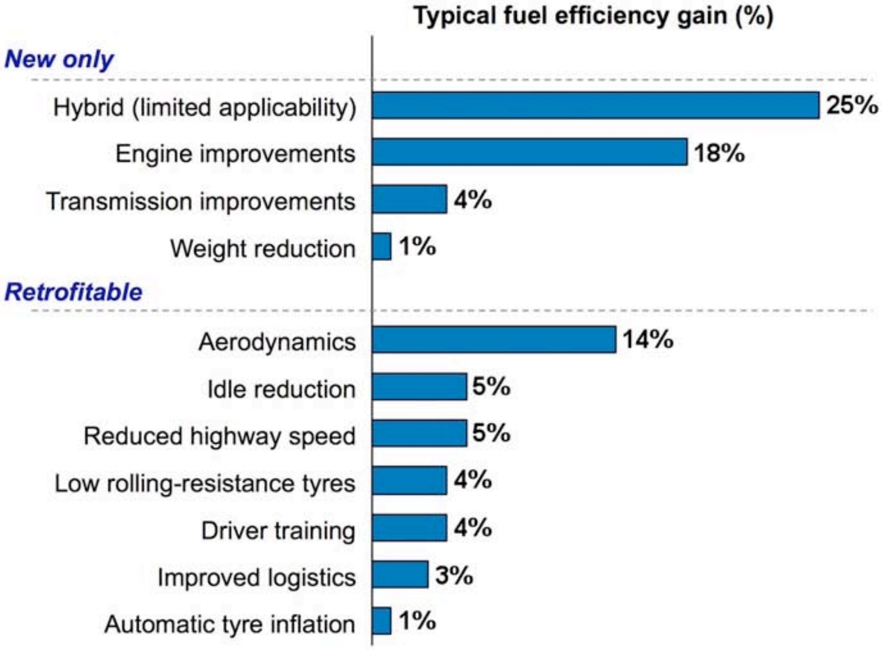
Electric vehicles face a tension – drives must cover high annual mileages to maximize the savings, yet this is difficult to do given limited vehicle ranges. At present, electric vehicles are only economic (without subsidies) for a small segment of the market. As battery and vehicle prices come down, electric vehicles will be the economic choice for a larger segment of the market. The critical unknowns are how consumers will react to range anxiety and how the infrastructure will develop.

Plug-in hybrids (PHEVs) incorporate a small ICE engine which can maintain the battery charge level once the electric-only range has been reached. This addresses the range anxiety concern by offering the same convenience and flexibility of a traditional ICE-powered vehicle. This arrangement also allows the battery to be smaller (and hence cheaper) since a relatively short electric-only range of ~40 miles will still cover the majority of journeys while the ICE backup is available for longer distances. PHEVs, however, are highly complex and have higher maintenance costs than pure EVs.

Heavy duty vehicles (HDVs)

Energy-efficient technologies suitable for HDVs share many similarities with those in the LDV sector (see Exhibit 12), but some key differences in the vehicle classes require changes in the approach. The vast majority of HDVs run on diesel. In HDVs, cargo accounts for a much higher fraction of the total weight, leaving less potential for weight reduction. On the other hand, the larger size of the engines in HDVs (and the greater space allowed for engines) makes more advanced heat recovery and thermal management technologies viable. Since HDVs are commercially operated, there is also greater potential for operational improvements such as enhanced logistics and driver training, particularly when coupled with telematics systems.

Exhibit 12: Technologies for increasing fuel efficiency of HDVs[18]



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[18] Data reconciled from numerous sources: NHTSA, 2010 – Technologies and approaches to reducing the fuel consumption of medium and heavy duty vehicles; US EPA SmartWay; Argonne 2002 – The potential effect of future energy-efficient and emissions-improving technologies on fuel consumption of heavy trucks

More so than for LDVs, the potential benefits of any energy-efficient technology used in HDVs depends heavily on the duty cycle. For example, long-haul trucks spend most of their time travelling at relatively high, constant speeds. This characteristic makes hybrids unsuitable for HDVs, but it raises the potential of technologies that improve aerodynamics and reduce rolling resistance. Buses and refuse trucks are at the other end of the spectrum; because they travel relatively slowly and make repeated stops, they have more to gain from hybrid power trains, and vehicle aerodynamics is much less important.

Aviation

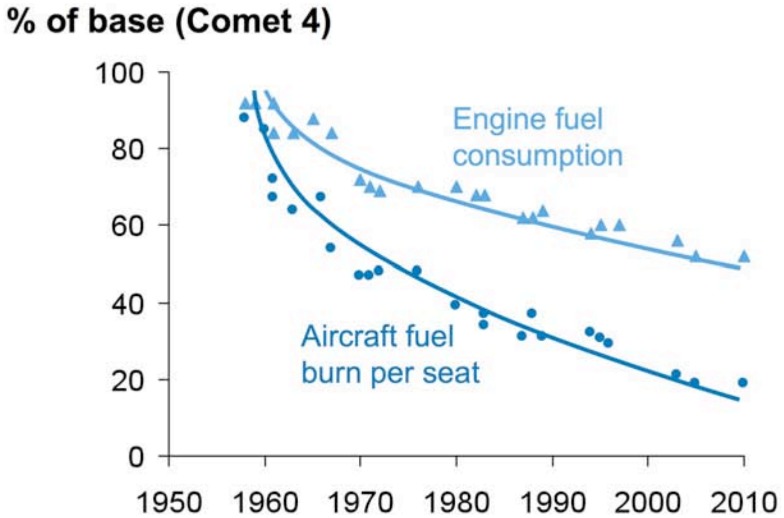
Aviation currently accounts for ~10% of global transport energy consumption, with a forecast increase in revenue-tonne-kilometres of ~5.1% per year to 2030.[19]

A number of levers exist that could enable the aviation industry to further reduce its fuel consumption. They fall into the following categories: aircraft technology and fleet improvements, infrastructure improvements, operations improvements and biofuels.[20]

Aircraft technology improvements

Aircraft efficiency has increased significantly over the last 50 years with a rate of 1.5 - 2.0% per year. Because of the cost and weight of fuel, aircraft fuel efficiency has historically been a major focus of innovation. As a result, the potential for further improvements is diminishing which is reflected in the declining annual fuel efficiency improvements over the last decade.

Exhibit 13: Aviation efficiency improvement over time[21]



The industry assumes improvements of ~1.5% per year in overall fleet fuel efficiency; improvement will be possible until 2030 with the further development of today's technologies. Radically new aircraft technologies such as open rotor engines and blended wing body airframes would be required to achieve efficiency improvements beyond this rate.

A number of improvements on airframes and engines are under development to improve aerodynamics, weight and fuel efficiency. Advances in aerodynamics modelling and materials science have enabled new designs for turbofans – the engines typically used in long-range aircraft. Improvements such as high pressure-ratio cores, super high bypass-ratio fans and better integration between the engine casing, engine and airframe have the potential to increase engine efficiency by over 15%. Geared turbofans have been used in small aircraft for many years. Developments by Pratt and Whitney allow this technology to be used on narrow-bodied commercial aircraft and could deliver efficiency improvements of 15-20% and are expected to be ready to enter service in 2013.

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[19] Source: ICAO, FESG, industry, World Economic Forum/Booz analysis

[20] Discussed on page 26

[21] IPCC - Plane Simple Truth, 2008; ATAG – Beginners guide to aviation efficiency

The use of advanced materials such as carbon fibre composites can dramatically reduce aircraft weight. These composites can be used throughout the aircraft, from the airframe to the brakes and can generate weight savings as high as 20%. The use of composites has been shown to have the potential to reduce fuel consumption by ~9%. The first "full" composite aircraft, the Boeing 787, is currently scheduled for delivery in the third quarter of 2011. Winglets can be retrofitted to aircraft to reduce drag. They have been shown to reduce fuel use by up to 8%.

More radically new structural changes to an aircraft such as different wing and aircraft body configuration could greatly reduce fuel use in the future. The most discussed is the blended wing body (BWB), which is essentially a hybrid of a conventional aircraft and a flying wing. The idea is to maximize wing surface (i.e. lift surface) to allow the aircraft to fly more effortlessly. One other wing configuration that is occasionally discussed is the forward-swept wing, which sweeps the wing from the rear of the aircraft forward and reduces drag. The BWB and forward-swept wings have the potential to reduce fuel burn by 15% and 10%, respectively, However, fundamental changes to the shape of the aircraft may require heavy investment in manufacturing and in airport infrastructure (such as jet way bridges and terminal gates).

A major limiting factor for overall fleet efficiency improvement stems from the long lifetimes of aircraft (aircraft can remain in service for 20-30 years, or longer, depending on geography) and thus the long lead times until new technologies represent a significant portion of the in-service fleet. Fleet efficiency could be further improved through a faster fleet turnover (e.g. through early aircraft retirement programmes); however, this is likely to be prohibitively expensive.

Infrastructure and operations improvements

There is great potential to make improvements in aviation infrastructure (in the areas of air traffic management (ATM) and airports) as well as in aircraft operations. On the ATM side the introduction of performance-based navigation infrastructure (e.g. SESAR in Europe and NextGen in the US) and airspace redesign, especially in China and Russia, have great potential to further increase operational and thus fuel efficiency. There is great scope to improve air traffic management through cooperation between civil and defence aviation and optimizing existing commercial protocols. For example, the US NextGen ATM programme encompasses a series of improvements to infrastructure and operations which could reduce flight delays and congestion by over 20% and allow more direct routings. A wide range of enabling technologies must be in place in the areas of monitoring (e.g. improved separation management services), navigation (e.g. integrated arrival/departure management, curved segments for de-conflicted flows between nearby airports) and communications (e.g. clearance delivery and frequency changes).

On the airport side especially in developing countries modernization of existing airports and new green field airports are needed to decrease congestion and cope with the strong air traffic demand growth.

Operational improvements that can help to further increase efficiency and reduce fuel consumption are improvements such as improved fuel management, continuous descent approach, reduced cabin weight (e.g. lightweight seats), centre of gravity optimization as well as optimization of speed. As mentioned above some of the operational improvements are linked to infrastructure improvements: the implementation of the continuous descent approach, for example, requires new ground infrastructure and aircraft equipment.

The combined impact of infrastructure and operations improvements leads to a fuel consumption reduction of ~8% by 2030 versus the base scenario[22].

Marine transport

The marine transport sector accounts for roughly 10% of global transport energy consumption, and the vast majority of this use stems from ocean-going bulk, tanker and container ships. Because container ships travel at much higher speeds (typically 20-25 knots vs 14-16 knots for tankers and bulkers), they consume a disproportionate fraction of oil (see Exhibit 14).

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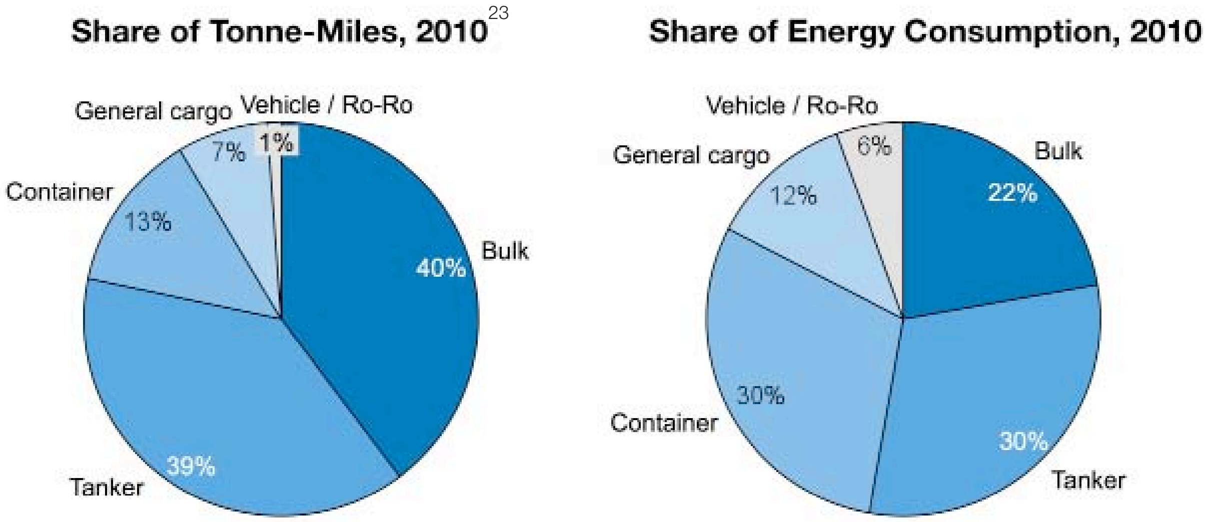
[22] Source: Numeric model from joint World Economic Forum, Booz & Co. project titled "Policies and Collaborative Partnerships for Sustainable Aviation"

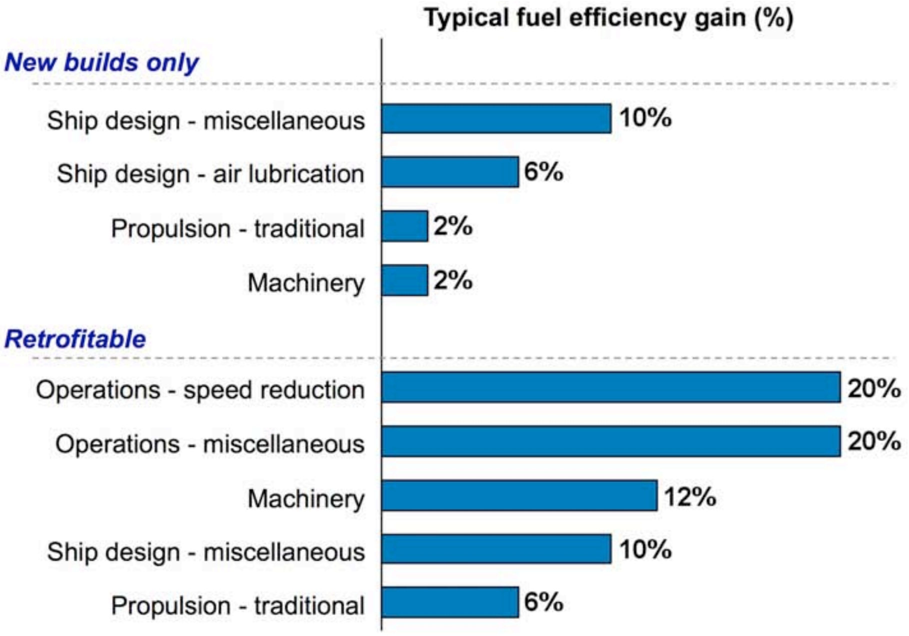
Exhibit 14: Where the Energy Goes in the Global Marine Sector



A particular challenge for new technology deployment in the shipping industry is the very long service life of ships. The average expected life of ships varies with economic cycles (ships are scrapped earlier in downturns), but it is typically around 30 years.

As a result, retrofit and operational technologies are particularly relevant. Here, a wide range of technological and operational measures are available today that can dramatically reduce energy consumption. These technologies fall into four categories: ship design (where there is at least some opportunity for retrofits); propulsion; machinery; and operation and maintenance (see Exhibit 15). All combined, these technologies and operations improvements could improve existing ship efficiency by 40% or more, compared to 65% or more for newly constructed ships.

Exhibit 15: Technologies for increasing fuel efficiency of ships[24]



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[23] IMO, 2009 – Second IMO GHG study

[24] Data reconciled from multiple sources: IMO, Marintec, 2000 – Study of greenhouse gas emissions from ships; Wärtsilä, 2008 – Boosting energy efficiency

Within each of the four technology categories, there are a wide range of technologies. Because of the diverse nature of shipping, not all technologies can be applied to all ships. Moreover, the efficiency gains cannot simply be added together; for example, an advanced hull shape may reduce the potential for a propeller design to improve efficiency further. Finally, the efficiency gain potential for particular technology will vary not just by ship type but will be different for every ship and will be dependent on how the ship is operated.

Ship design improvements are modifications to the hull shape and fittings, for example, optimizing main dimensions or adding a ducktail waterline extension. Air lubrication systems reduce frictional drag by creating a pocket of air bubbles under the hull. Traditional propulsion technologies, which are propeller-related, include CRPs (counter rotating propellers), propeller-rudder combinations and propeller winglets. Wind power can also be harnessed to great effect through use of kites, Flettner rotors or sails. Despite having ancient roots, these technologies are still at the pilot trial stage for commercial ships. Machinery improvements include main engine optimization (delta tuning and common rail fuel delivery), waste heat recovery systems, auxiliary systems improvements and automation (optimizing engine control, power generation and distribution, thrust control and ballast).

The scope for efficiency gains in operations and maintenance in particular is large. Basic maintenance of hull surface can increase efficiency by 3-5% while advanced hull coatings can increase efficiency by 9%. Propeller maintenance can achieve similar gains. Significant improvements can also be made in optimizing weather routing and fleet planning; as can reducing turnaround time in ports. Optimizing the running of the ship underway can also yield large fuel savings. The single largest opportunity is slow steaming which can achieve fuel efficiency as high as 30% (or even higher for bulkers). Reducing speed by 10% reduces the propulsion power required by ~19%. However, engines become less efficient as they run at low loads so the fuel saving will be slightly lower than 19% for a 10% speed reduction. Slow steaming has other disadvantages: lead times increase; for a given level of demand, more ships will be needed and, hence, capital costs increase (this is not a constraint in an over-supplied market). As a result, ship operators must balance the fuel savings against the disadvantages to optimize the potential of slow steaming.

Rail

The rail sector carries both passengers and freight, together accounting for ~3% of total transport energy sector consumption and uses both electric and diesel power. Because of the long distances and large loads involved, battery-only electric trains are not feasible – electric trains require an expensive infrastructure of power lines. At present, ~50% of passenger rail uses electric trains while only 11% of freight rail is electrified. Electric trains have the potential to be more efficient than diesel powered trains since they can be made lighter and can make greater use of regenerative braking. However, the efficiency of the generation capacity must be high since there will be transmission losses in the grid and modern diesel engines are highly efficient. In addition to the efficiency gains, electrification of rail increases diversity of the energy supply.

Despite these limitations, there are a wide range of opportunities to increase energy efficiency in the rail sector, particularly by increasing the inherent efficiency of the trains themselves. These opportunities can be grouped in four main categories[25]:

- **Mass reduction**: There is much greater potential for mass reduction in passenger trains than in freight trains since the weight of passengers is very low compared to the weight of the train. New materials and new designs such as wide or double-decker trains have the potential to reduce mass-per-seat by more than 35%.
- **Reduced drag**: Aerodynamic drag accounts for the majority of drag, with mechanical friction accounting for only about 10% of a train's energy consumption. Technologies such as covers for open freight cars, and streamlined train sides and underfloor areas can reduce energy consumption significantly. Bogie fairings, for instance, can reduce energy use by 6% to 7%.
- **Propulsion improvements, electric**: The latest inverter technology now accounts for more than 50% of new trains and is significantly more efficient than the older technology. Though technically feasible, retrofits are typically cost-prohibitive. It is possible to optimize the traction software – software which controls the power electronics – and achieve savings of 1-3%. Improvements in regenerative braking also have substantial potential. Many older trains do not even have regenerative brakes; there is also potential to improve efficiencies by storing power since the power returned to the network under braking can only be used if another train needs the energy.

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[25] UIC International Union of Railways – Energy Efficiency Technologies for Railways project

- **Propulsion improvements, diesel**: Common rail direct injection, a variant of the direct fuel injection systems used by many passenger vehicles, has yet to achieve large-scale adoption in the rail industry. It can deliver efficiency gains as high as 20% when used in conjunction with improved injectors. Existing engines can be re-engineered to use common rail injection systems, though the efficiency gains will not be as dramatic as in a new engine.

Improving rail operations offers additional opportunities for improving the sector's energy efficiency. For example, increasing buffer times in train timetables can allow greater leeway for energy-efficient driving. Systems can be installed on trains to inform the driver of the optimal time to begin coasting in anticipation of reaching a station or stop signal. Such systems have demonstrated energy savings in excess of 5%. Harmonizing rail standards between adjacent countries (or states) has a double benefit since it can increase efficiency and improve intermodal optimization. For example, in Europe, standards are different in each country and, as a result, locomotives must be switched when crossing borders. Harmonizing the standards would save time, allowing more efficient planning and also making rail more competitive with road transport.

Alternative fuels

Biofuels

Biofuels today comprise ~2% of global transport fuels consumption (Exhibit 16). At first glance this may seem small, but first-generation biofuels already account for a large market share in certain countries (e.g. ~20% in Brazil and 10% in the US). At present, the market is dominated by first-generation biofuels, which are derived from edible crops: bioethanol from sugar or starch bearing crops such as sugar cane, corn and wheat; and biodiesel from oil bearing crops such as rapeseed, soy, canola and palm oil.

The first-generation process for producing bioethanol uses a combination of fermentation and distillation. The feedstock is prepared into a sugary solution (in the case of grain feedstock, this requires a saccharification step using enzymes; sugar cane only needs to be pressed to release the sugary cane juice). This solution is fermented to a beer at around 10% ethanol concentration. The beer is then distilled to around 95% ethanol concentration – this is known as hydrous ethanol and can be used as fuel (E100). Alternatively, the hydrous ethanol can be dehydrated to produce >99.7% pure ethanol which can be used as an additive to gasoline. The grain-based process produces the by-product DDGS (Distillers Dried Grain with Solubles), which can be used as a livestock feed.

Ethanol has a number of advantages as a fuel: it has a very high octane rating and burns particularly cleanly and efficiently. As a result, ethanol can increase engine power slightly and reduce emissions. Ethanol has also been used to replace tetraethyl lead and MTBE in fuel as an anti-knocking agent. However, ethanol does have a series of disadvantages when compared to gasoline. Ethanol is hygroscopic, i.e. absorbs water and is also more corrosive than gasoline, which makes distribution difficult. However, Brazil's experience has shown that pipeline distribution of ethanol is practical. Although ethanol can be blended at up to ~10% with gasoline (E10) and used in unmodified vehicles, modifications must be made to accept higher blends. Flex fuel vehicles (FFVs) can use any blend of ethanol. FFVs cost only US$ 100-200 more to produce than regular vehicles and though they have yet to reach high penetration in most of the world, in Brazil, ~80% of new light vehicle sales are FFVs. Ethanol has lower energy density than gasoline; as a result, vehicles achieve 25-30% lower miles per gallon when running on E85.

For biodiesel, the first-generation production process is an esterification process known as FAME (Fatty Acid Methyl Ester). In the process the feedstock oil reacts with methanol at high temperature and pressure over an alkaline catalyst. This stage is followed by numerous separation stages (also including neutralization with acid) which yield the biodiesel product and a crude glycerol by-product. From one litre of feedstock oil and 0.1 litres of methanol, the FAME process can produce ~0.95 litres of biodiesel and 0.1 kg of glycerol.

FAME biodiesel can be used pure (B100) but is typically blended with regular diesel at 5% (B5) or 20% (B20). The quality of biodiesel varies considerably depending on the feedstock. The cetane number[26] for biodiesel produced from certain feedstocks (e.g. soybean and sunflower) is lower than allowed in some regions. FAME biodiesels tend to have poor cold-weather performance (palm derived biodiesel in particular) since they form gels at relatively high temperatures. FAME

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[26] The cetane number (CN) is a measure of a fuel's ignition delay. Fuels with higher CN can operate more efficiently in vehicle engines. Standards vary by region: the minimum CN in the EU is 51 (set in EN590) and is 40 in the US (ASTM D975).

biodiesels can also be unstable, i.e. prone to degradation by oxidation. In Europe, a stability limit is specified by the iodine value of the fuel, whereas in the US there is no such limit. The European standard effectively precludes the use of soy- and sunflower-based biodiesels yet experience in the US has shown that these fuels can be run with minimal adverse effects. Despite these drawbacks, biodiesels have the advantage of virtually zero sulphur and ash content and have a very similar energy density to regular diesel.

Second-generation biofuels are beginning to reach the commercial stage. Second-generation technologies are not based on edible crops and include a diverse range of pathways and products:

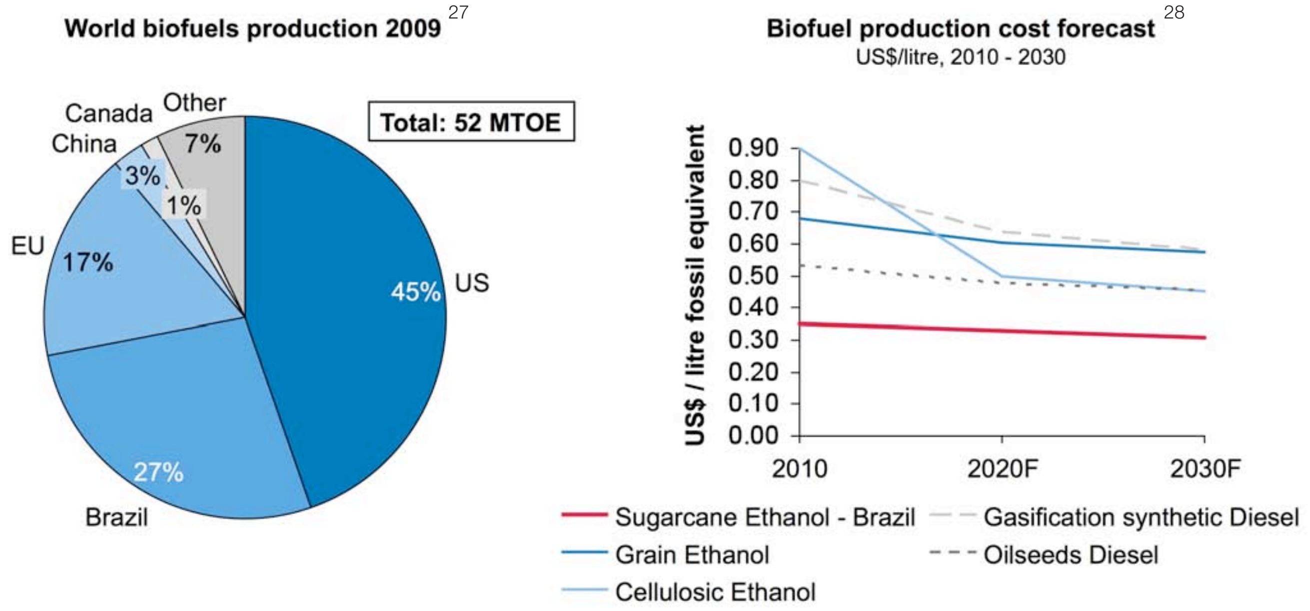
- Bioethanol, methanol, butanol and aviation biofuels can be made from cellulosic feedstocks.
- Biodiesel, gasoline, aviation biofuels, DME (Dimethyl Ether) and methane can be produced from almost any combustible biomass (commonly forestry waste) using gasification and synthesis technologies.

Algae can also be used to produce biodiesel, ethanol, butanol and aviation biofuels. It requires CO_2 (at fairly high concentrations) and nutrients (including nitrogen, phosphorous, iron and silicon) as feedstocks. The technology is still at the research stage. It is also possible to produce biodiesel, gasoline and aviation biofuel from a sugar source using genetically modified organisms; this is also at the research and development stage.

Second-generation ethanol is indistinguishable from first-generation ethanol. Butanol has many advantages over ethanol: it has higher energy density (close to gasoline); it is less corrosive and can be transported in existing pipelines; it can be blended at high levels in gasoline without requiring modification to vehicles; and it can be blended with diesel.

Fuels produced, using gasification and synthesis, are typically of extremely high quality – higher than fuels derived from crude oil. These fuels have very low sulphur contents, low aromatic contents and the diesels produced have very high cetane numbers. DME and methane are both gases which can be compressed and power internal combustion engines. Existing vehicles can be converted to run on DME or methane.

Exhibit 16: Global Biofuels Production and Cost Forecast



Biofuels costs vary greatly depending on the feedstock used, location and process technology. Sugar cane ethanol in Brazil is the lowest cost (~US$ 0.35/litre gasoline equivalent) because of the excellent growing conditions and because the sugar-rich content of sugar cane gives high ethanol yields. Cellulosic ethanol is currently expensive but there is great potential for process improvements and cheap feedstock to bring costs down. Diesel using gasification and synthesis technology is also expected to become substantially cheaper but not as cheap as oilseeds biodiesel. However, synthetic diesel can be extremely high quality.

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[27] IEA – World Energy Outlook, 2010

[28] IEA – Energy Technology Essentials, 2007; USDA GAIN Brazil biofuels annual report, 2010

The potential for biofuels to reduce CO_2 emissions is debated and depends on the feedstock used. Corn-based ethanol has the lowest potential, ranging from a 54% decrease in CO_2 to a 4% increase according to the US EPA[29]. Sugar-based bioethanol and first-generation biodiesel offer larger CO_2 savings, as high as 90%. Since first-generation biofuels use edible crops, the risk of an impact on food prices has been widely debated. Recent analysis from the World Bank[30] reverses their earlier position and concludes that the impact of first-generation biofuels on food prices is minor – and that energy prices are a much bigger contributor.

Second-generation biofuels have the potential for greater CO_2 reductions and do not use food crops. There is great potential to use waste such as rice straw, corn stover and forestry residues, though if biofuels are to contribute a significant fraction of total fuel use, dedicated crops must be planted. This raises concerns that second-generation biofuels will compete for arable land with food crops in addition to risks of soil degradation and water stress. However, a recent study[31] found that over 1,100 million hectares of land is available for second-generation biofuel production; this includes only abandoned or degraded cropland and marginal grassland (discounting pasture land). This area could produce 26-55% of current liquid fuel demand. To avoid competition for arable land, policies must be designed to ensure that farmers are not incentivized to grow energy on prime arable land.

There are currently more than 60 pilot-scale facilities in production, including a large-scale demonstration plant at Kalundborg in Denmark (owned by Inbicon, a subsidiary of DONG, the state-owned energy company). This plant is already supplying wheat straw ethanol to Statoil in Denmark, which is blended into E5.

Biofuels are considered particularly important for the aviation industry. Research and test flights conducted have shown that even the current in-service fleet, without any engine or aircraft modification, can fly with a certified 50% biofuel, 50% regular jet fuel blend. Moreover, Continental Airlines found that this blend displayed superior fuel efficiency (~1% better than regular jet fuel). It is expected that in the long term, aircraft could fly with up to 100% biofuels. Different technology routes for the production of aviation biofuels are being pursued: FT (Fischer-Tropsch) alternative fuels were qualified for 50% use in aviation in 2009, HRJ (Hydrotreated Renewable Jet) specification is expected in early 2011 and FRJ (Fermentation Renewable Jet) specification options are being evaluated.

Compressed Natural Gas (CNG)

Apart from biofuels, compressed natural gas (CNG) is the other key “alternative” transportation fuel. The CNG vehicle base has already reached significant size, estimated at 11.4 million vehicles in 2009 by IANGV. There are several advantages of CNG vs oil-based fossil fuels, namely1:

- Environmental factors: per mega jule of energy content, CNG emits less CO2 than gasoline (68 g/MJ vs 96 g/MJ). Particulate matter and nitrogen oxide emissions are also reduced.
- Abundant, widespread supplies: natural gas is widely available, with a more even geographic spread of reserves than crude oil. In addition, many countries have an existing natural gas infrastructure for widespread distribution, and supplies could potentially be made renewable in the future through biogas production.
- Practicality: the technology to convert internal combustion engines to run on CNG is proven and available now; CNG is suitable for all vehicle classes and requires minimal processing or refining requirements.

Despite these advantages, there are technical challenges with CNG vehicles. First, CNG engine efficiency is lower than that of standard ICEs. Despite improvements over time, efficiency for similar engine power/torque ratings and drive cycles is still ~85-90% that of a standard diesel engine. In addition, CNG vehicles have historically been 15-20% more expensive than conventional gasoline or diesel engines primarily because of costs for onboard gas storage.
The key advantage for CNG vehicles is that in many geographies, CNG is a cheaper fuel than gasoline or diesel (for example, EIA data shows the US diesel-CNG spread to be ~US$ 1.1-1.2/gallon diesel equivalent in 2010). The underlying economics of CNG vs conventional fuels (and hence penetration) are therefore driven by a combination of the fuel price spread (gasoline-CNG for LDVs; diesel-CNG for HDVs) in the specific geography in question and engine efficiency vs incremental upfront cost. The economics for CNG passenger vehicles (i.e. LDVs) in selected geographies have been positive for some time, driven mainly by lower natural gas prices – for example, IANGV estimates that Pakistan, Argentina, Brazil, Iran and India had 72% of the 11.4 million CNG vehicles on the road in 2009. As the price spread between diesel and CNG has opened up over the last few years, the relative economics for CNG-powered HDVs have also improved, and there is significant renewed interest for CNG in the commercial trucking sector.

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[29] US EPA – Greenhouse gas impacts of expanded renewable and alternative fuels use
[30] World Bank – Placing the 2006/08 commodity price boom into perspective, 2010
[31] X. Cai, X. Zhang, D. Wang – Land availability for biofuel production, 2011

The challenge of repowering transport

Main Findings

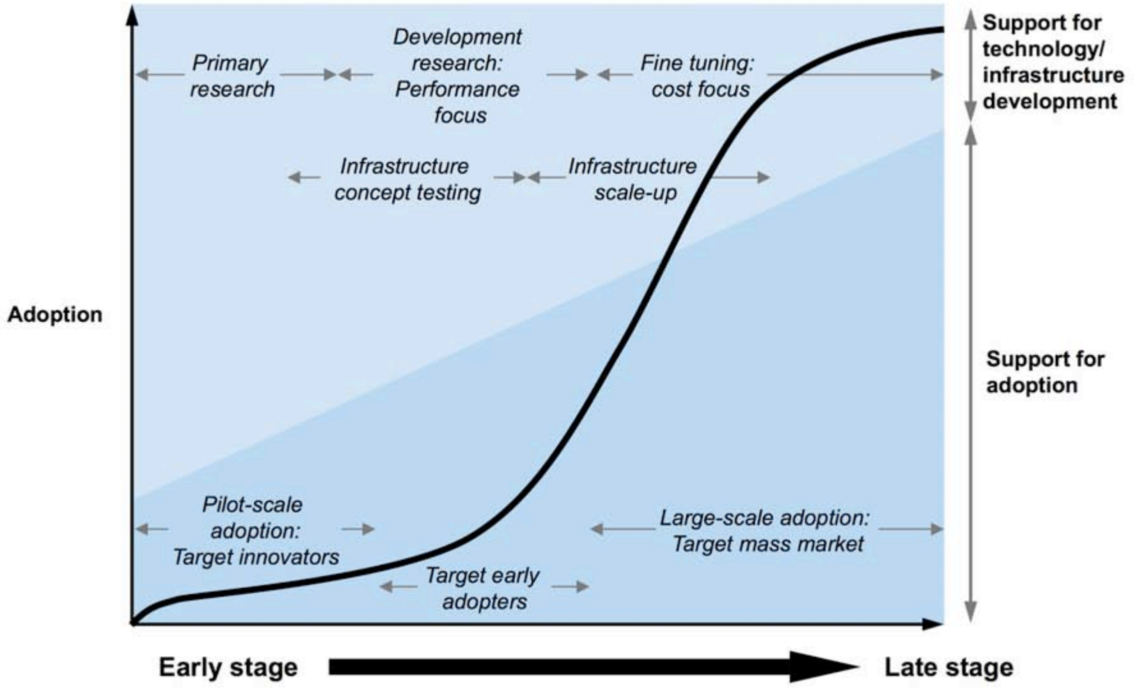
- As in other industries, the transport sector faces a number of challenges related to the arc of technology development, including conflicting interests, inadequate information and long payback periods.
- The need for support varies depending on how the technology will be integrated into the existing marketplace – incremental technologies need more help during the innovation phase, while breakthrough technologies often require investments in new infrastructure.
- A single hurdle at just one point in the technology development cycle can be enough to prevent the technology from reaching the market, and many new transportation technologies face a combination of these barriers.

In addition to the specific deployment challenges and constraints that the aforementioned technologies face for each mode of transportation, they are also up against the "S curve" of adoption that all technologies must follow if they are to succeed (see Exhibit 17). In the early stages of technology development, the focus is on research and development, and pilot-scale adoption. As technologies mature, the emphasis shifts towards infrastructure development in anticipation of a large-scale adoption.

The need for government support varies depending on how the technology will be integrated into the existing marketplace. For incremental technologies, the infrastructure is often in place, allowing public and private entities to target their support at R&D and other early-stage obstacles (see Exhibit 18). In the transport sector, these can include overcoming the disincentive to make large and irreversible investments since future oil prices – and hence competitiveness – are unknown. There is little incentive to share technology developments because of competition and poor intellectual property protection in many regions. In addition, there is the challenge of aligning incentives: in biofuels, this translates into individual transport sectors' reluctance to make unilateral investments since the benefits of biofuels will be shared by many industries.

For more groundbreaking technologies, these groups must also concern themselves with building the necessary infrastructure and creating a market. One of the biggest obstacles for such technologies is called "path dependency", which refers to innovations that make resulting products incompatible with existing infrastructure. Electric vehicles, for example, cannot use existing fuelling infrastructure, creating a competitive disadvantage against ICE-powered vehicles. Carbon fibre can dramatically reduce vehicle weight, but it cannot be used in traditional tooling, and recycling and cost issues also need to be resolved. By contrast, downsized, turbocharged (or supercharged) engines are an advancement on existing technology, making them compatible with today's infrastructure and allowing them to benefit from all the accumulated experience of designing ICE engines.

Exhibit 17: The "S Curve" Technology Deployment Challenge



There are also common challenges faced by new technologies, whether they represent modifications to existing technologies or brand new forays.

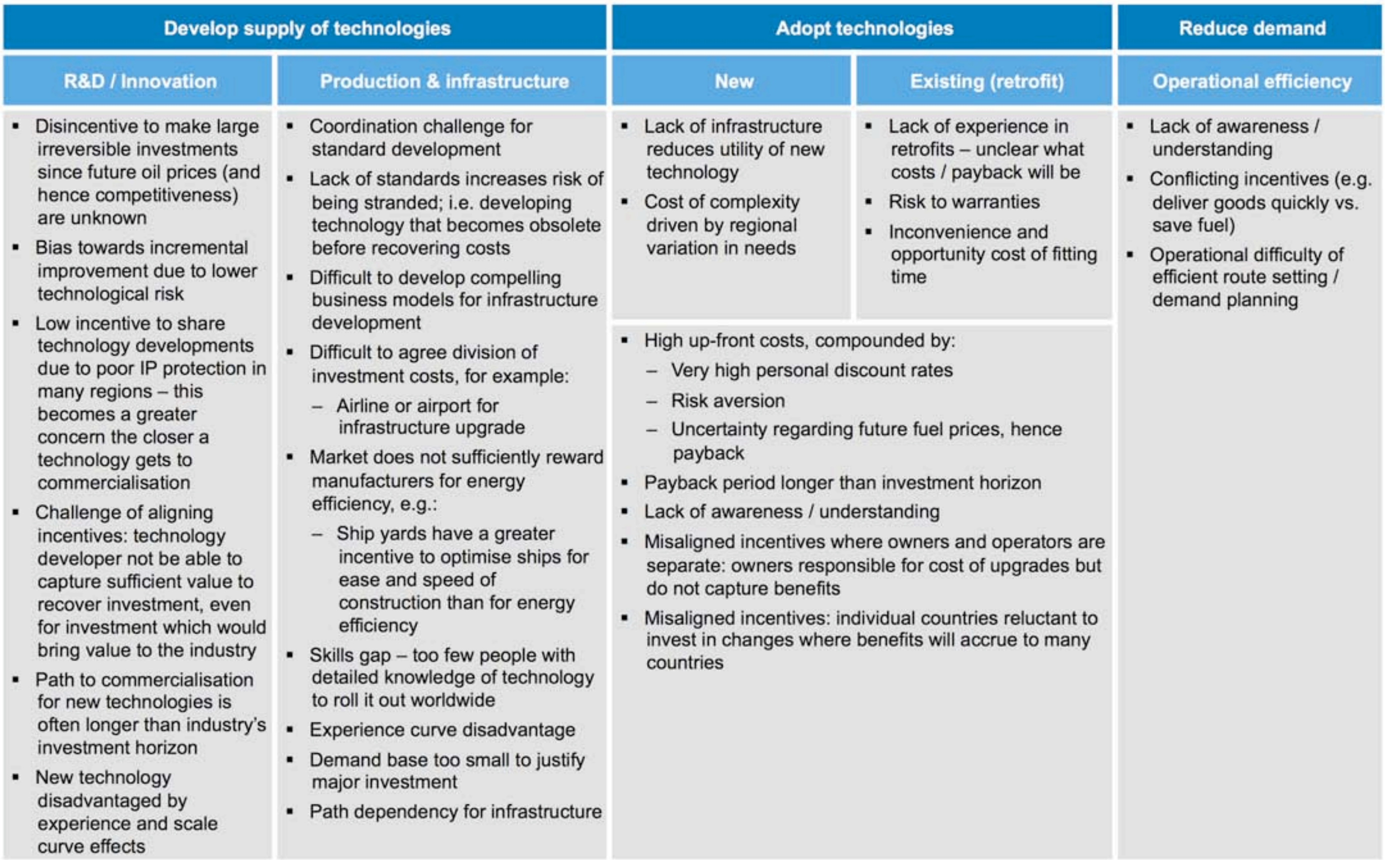
Conflicting interests typically occur in one of two ways. First, stakeholders may be unwilling to invest in a technology because they would be unable to capture enough of the benefit in the current contractual environment. Ship owners that charter their vessels on time charters, for instance, are reluctant to invest in retrofits for their ships because they do not pay for the fuel and, because of poor transparency on energy efficiency, the demand for ships may not vary much based on energy efficiency. Second, the market does not sufficiently reward manufacturers for energy efficiency improvements, resulting in suboptimal designs. One example of this is that automakers cannot charge a high enough premium for fuel-efficient designs because many consumers do not sufficiently account for future fuel savings when choosing a car.

Inadequate information is another common obstacle throughout the technology lifecycle. Insufficient information to make reliable risk assessments can block financing for the construction of alternative fuel plants, the purchase of fuel-saving retrofits for ships, or electric vehicle batteries. Truck (and ship) owners often do not have sufficient information or experience to know which retrofit technologies will be most suitable for their trucks (ships).

Long payback horizons also affect a wide range of technologies – both breakthrough and incremental. For technologies that are not well proven, this barrier is amplified by the higher risks that increase the cost of capital. Electric charging stations, already a risky investment because of uncertainty in the electric vehicle market, have very long payback periods because of the low price of electricity and high capital costs. Diesel cars in the US have gained far less market share than in Europe in part because of lower fuel prices in the US, which extend the time it takes consumers to recover the extra upfront cost.

A single hurdle at just one point in the technology development cycle can be enough to prevent the technology from reaching the market, and many new transportation technologies face a combination of these barriers. If the nations of the world are going to solve their fossil fuel dependency and reduce the related environmental hazards, all such barriers must be addressed. Individual policies, partnerships and financing models typically only address a few barriers at most. What these technologies need is unprecedented coordination and integration of these three enabling elements.

Exhibit 18: Barriers to technology deployment through the technology lifecycle



Develop supply of technologies		Adopt technologies		Reduce demand
R&D / Innovation	Production & infrastructure	New	Existing (retrofit)	Operational efficiency
▪ Disincentive to make large irreversible investments since future oil prices (and hence competitiveness) are unknown ▪ Bias towards incremental improvement due to lower technological risk ▪ Low incentive to share technology developments due to poor IP protection in many regions – this becomes a greater concern the closer a technology gets to commercialisation ▪ Challenge of aligning incentives: technology developer not be able to capture sufficient value to recover investment, even for investment which would bring value to the industry ▪ Path to commercialisation for new technologies is often longer than industry's investment horizon ▪ New technology disadvantaged by experience and scale curve effects	▪ Coordination challenge for standard development ▪ Lack of standards increases risk of being stranded; i.e. developing technology that becomes obsolete before recovering costs ▪ Difficult to develop compelling business models for infrastructure development ▪ Difficult to agree division of investment costs, for example: – Airline or airport for infrastructure upgrade ▪ Market does not sufficiently reward manufacturers for energy efficiency, e.g.: – Ship yards have a greater incentive to optimise ships for ease and speed of construction than for energy efficiency ▪ Skills gap – too few people with detailed knowledge of technology to roll it out worldwide ▪ Experience curve disadvantage ▪ Demand base too small to justify major investment ▪ Path dependency for infrastructure	▪ Lack of infrastructure reduces utility of new technology ▪ Cost of complexity driven by regional variation in needs	▪ Lack of experience in retrofits – unclear what costs / payback will be ▪ Risk to warranties ▪ Inconvenience and opportunity cost of fitting time	▪ Lack of awareness / understanding ▪ Conflicting incentives (e.g. deliver goods quickly vs. save fuel) ▪ Operational difficulty of efficient route setting / demand planning
		▪ High up-front costs, compounded by: – Very high personal discount rates – Risk aversion – Uncertainty regarding future fuel prices, hence payback ▪ Payback period longer than investment horizon ▪ Lack of awareness / understanding ▪ Misaligned incentives where owners and operators are separate: owners responsible for cost of upgrades but do not capture benefits ▪ Misaligned incentives: individual countries reluctant to invest in changes where benefits will accrue to many countries		

Policy and regulation

Policy and regulation: main findings

There continues to be debate regarding which type(s) of policy is/are "best". In practice, different types of policy address different challenges – all of which need to be addressed to effect the rapid deployment of a broad set of technologies. The real challenge is to develop an appropriately integrated set of policies and to allocate funds and resources as efficiently as possible among the various policies. Policies will also need to be developed at international, national, state and municipal levels.

Fuel taxes, carbon pricing and performance standards are particularly effective for technologies that are reasonably well developed. Performance standards are a good complement to fuel taxes and carbon pricing. However, these policies are less effective at developing earlier stage technologies, for which incentives (across the value chain) are more effective.

Dependent on the transport mode, fuel taxes (or equivalent carbon pricing mechanisms) and performance standards are particularly effective for technologies that are reasonably well developed. Performance standards are a good complement to fuel taxes and carbon pricing. However, these policies are less effective at developing earlier stage technologies, for which incentives (across the value chain) are more effective.

These mechanisms are necessary to achieve immediate impact, since they are the only policies which have significant impact on operating efficiency. Other policies target development and adoption of technologies which act slowly because of slow fleet replacement. Since fuel taxes and carbon pricing mechanisms increase the cost of travel, they should be weighed against the economic and social benefits of mobility.

Technology-independent policies are generally preferable since they allow private companies to choose the most economically efficient technologies. However, in some cases technology specific policies can have greater impact and so, under certain conditions, they may be justified. For example, where a country has a natural resource advantage and there is a clear path for the technology to reach cost parity with conventional technology within a reasonable time frame.

Production and consumption incentives require the largest government investments. Governments must decide how to allocate funds and resources as efficiently as possible between these types of policies. While R&D and infrastructure require substantial investment, supporting breakthrough technologies through to large-scale adoption and self-sufficiency is typically far more expensive.

The policies needed for the rapid deployment scenario are the same as those needed for the foundation-building scenario. The difference lies in the investment levels and stringency: in the rapid deployment scenario, much greater investment will be required in infrastructure and in production and consumption subsidies. Furthermore, performance standards will need to be more stringent and technology and process mandates more challenging. Finally, fuel taxes and or carbon prices may need to be adapted to support strategic policy decisions.

Overview

A broad portfolio of policies is necessary

A broad range of policy types exist. Exhibit 19 on the following page shows a taxonomy of policy types, along with an overview of which hurdles from the previous section each policy is best at addressing through the technology lifecycle. As detailed in the following pages, a broad range of policies is needed to address different challenges at each stage of the technology lifecycle. Many policy types are complementary; for example, fuel economy standards address a different set of barriers compared to taxes, and production subsidies are often necessary to make a process mandate (such as biofuels blend minimums) politically feasible. However, some policy types overlap: the interaction between performance standards and technology or process mandates; and between carbon taxes and tradable permit schemes must be carefully considered. When putting these policies in place, greater synergy between policies for different industry stakeholders (e.g. auto OEMs and energy providers) will lead to more effective technology deployment. For example, legislating higher blends of biofuels will be more effective if policy-makers have also ensured that OEMs have taken action on the fleet side to ensure demand can meet the supply.

Exhibit 19: Taxonomy of policy types and overview of the policy effectiveness versus barriers through the lifecycle

■ Highly effective
▨ Moderately effective
□ Somewhat effective

Class	Type	Examples	Develop		Adopt technologies		Reduce demand
			R&D / Innovation	Infrastructure	New	Existing (retrofit)	Operating efficiency
Removing road blocks	Remove existing policies	• Fossil fuel subsidies in Russia, Egypt, UAE, Bahrain...	□	□	▨	▨	▨
Economic	Fuel/carbon taxes	• Finnish Energy Tax	□	□	▨	▨	■
	Tradable Permits	• Personal tradable transport permits	□	□	▨	▨	■
	Hybrid	• Cap and trade with price floor	□	□	▨	▨	■
	R&D incentive	• US$ 25m US subsidy for biofuels R&D • US$ 2 billion US grant for 48 advanced battery projects	■				
	Infrastructure incentive	• US$ 200 million US grant for installation of alternative refuelling infrastructure		■	□	□	
	Production and consumption incentives	• CIDE tax break for bio-ethanol in Brazil • France's bonus -malus car scheme	■	▨	■	■	
Command and control	Performance standard	• CAFE mpg limits • ppm NO_X limits	□	▨	■	□	
	Technology/process mandate	• Catalytic converters • Minimum % bio-fuels in fuel	□	■	■	■	
	Enabling standard	• Safety and operating standards		■	▨	▨	
Information	Consumer Education	• US national tyre fuel efficiency consumer information program, eco-driving programs			▨	▨	▨
	Voluntary standards	• Voluntary industry labelling scheme	□	▨			

Typically technology *agnostic*

Typically technology-*specific*

Typically technology *agnostic*

Typically technology-*specific*

Fuel taxes and carbon pricing mechanism are necessary to achieve immediate impact

The majority of policies relies on fleet turnover to have an impact and, as a consequence, can have little immediate impact. The only policies that can have major impact on operating efficiency are fuel taxes and carbon pricing mechanisms. Subsidies and the vast majority of command and control policies focus on increasing adoption of advanced technologies but do not provide an incentive to operate efficiently. In fact, by decreasing specific fuel consumption, these policies both decrease the incentive to operate efficiently and increase the distance travelled. Studies[34] have shown that for every 10% fuel consumption saving, distance travelled increases by around 3%. Since fuel taxes and carbon pricing mechanisms increase the cost of travel, they should be weighed against the economic and social benefits of mobility.

At the same time, any new taxes or carbon pricing mechanisms need to be mode-specific. For example, aviation is a global transport sector that needs global coordinated policies under ICAO to avoid market distortions. Taxes or levies imposed on the aviation sector regionally may distort the international aviation market. Fuel taxes and carbon pricing mechanisms need to be tailored to each mode through proper monitoring and evaluation systems to ensure strong fiduciary standards, full disclosure and transparency of money flows and good recipient accountability.

Existing subsidies for fossil fuels should be phased out

Worldwide subsidies for fossil fuels are estimated to be in the region of US$ 700 billion annually[35] including tax effects (US$ 240 billion pre-tax). This is based on the price-gap approach, which has the advantage of (relative) simplicity and ease of measurement but is potentially inaccurate because of the influence of oil cartels, insensitivity to large subsidies to niche markets (which do not impact world prices), inability to capture producer subsidies such as government involvement in leasing reserves and subsidizing infrastructure. Clearly, subsidies of this size (~1% of world GDP) reduce the incentive to develop and adopt energy-efficient technologies and alternative fuels.

Momentum to remove these subsidies is increasing[36]; however, the extent of the challenge is large because of entrenched political positions, making this process slow-changing[37]. Petroleum subsidies are commonly used in developing nations as a means to control inflation for the poor – removing them would be highly regressive unless other measures are put in place to mitigate this effect. Powerful interest groups, such as industry lobby groups, benefit from the subsidies and act effectively to block reform. The challenge is made harder by the lack of consensus at the global level – a necessary step to take effective action. However, there is movement for change: in September 2009 the G20 nations announced a commitment to “rationalize and phase out over the medium term inefficient fossil fuel subsidies that encourage wasteful consumption.”[38] The next steps will be to recruit more countries to join this initiative and negotiate a binding agreement for fossil fuel reform – likely to be many years ahead.

Technology-specific policies can play an important role

The choice between technology-specific and technology-independent policies is often discussed. Overall, technology-independent policies are generally preferable, since they allow market forces to select the best technologies, however, under certain conditions technology-specific policies are more effective since they concentrate resources and provide a clear signal to industry. The challenge for technology-specific policies lies in achieving economic efficiency.

Forcing technologies to compete for funding can dilute the impact of the incentive. In a world where budgets are constrained, this can prevent any single technology from receiving support at a critical scale and result in very slow progress – or at worst, no progress. This is a particular problem at municipal or state level where budgets are relatively small and other urgent priorities such as local air quality may be tackled instead. If a government believes that it can identify the right technology (or close to right), it can be worth trading some economic efficiency for the big increase in impact resulting from focusing resources and providing a clear signal to industry. An example of this is the decision by Transport for London to focus on electric vehicles. This decision came after the city spent several years spreading their investment across a wide range of technologies (including biofuels, hydrogen, LPG, CNG) which yielded little impact.

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[34] S. Sorrel, 2007 – The rebound effect: an assessment of the evidence for economy-wide energy savings from improved energy efficiency (A review of 17 studies of rebound elasticity)

[35] IMF, 2010 - Petroleum Product Subsidies: Costly, Inequitable, and Rising

[36] IISD, 2010 - Increasing the Momentum of Fossil-Fuel Subsidy Reform: A Roadmap for international cooperation

[37] GSI, 2010 – The politics of fossil fuel subsidies

[38] G20 Leaders, 2009

At the national or international level, a broad package of technology-specific support policies can be effective if the country or region has a demonstrably advantaged position for the technology and there is a clear path for the technology to reach cost parity with conventional technology within a reasonable time frame. For example, Brazil decided in the 1970s that since it had ideal conditions for growing sugar cane, it had a competitive advantage. Moreover, experience with other crops and potential for improvement of the fermentation process gave Brazil confidence that production costs could be decreased substantially. Brazil ran the ProAlcool programme at a cost of ~US$ 16 billion and today spends ~US$ 2.5 billion per year on consumption subsidies and is now by far the lowest-cost producer of bioethanol worldwide. The industry also employs over 3 million people and contributes strongly to energy security since it provides around half of the fuel in the spark ignition (gasoline) market.

If these conditions are not met, technology-specific policies can be wasteful. For example, while the US subsidies for corn-based ethanol have succeeded in positioning the US as the world's largest ethanol producer, corn-based ethanol does not have high potential to reduce CO_2 or oil dependency. Policies to support second-generation biofuels in the US have more potential since the base of technical expertise is strong and the US is not disadvantaged with regard to the feedstock.

Governments that decide to subsidize a particular industry should use the best information available on the likely technological roadmap, and scale and learning curves to plan how long the technology will need support for and how much support is likely to be needed. For example, number of vehicles sold and number of years of support should both be considered when assessing support for electric vehicles. If a technology outperforms expectations, this support can be reduced in line. If the technology does not meet expectations, the decision to support the technology should be re-evaluated, paying particular attention to potential alternative technologies.

Industry acts most effectively when governments provide clear direction

Industry can act most effectively when government gives clear direction and commits to a stable set of policies. Companies can then redesign their strategies to take policy into account and invest resources and effort in a new direction, confident that this effort will be rewarded. However, when governments do not commit credibly to a policy (i.e. if the policy is short-lived, or would be easy to reverse), its impact is weakened since companies will be unwilling to change strategy for fear of being stranded by changing policies.

It is very difficult for governments to make credible long-term commitments. Any government that promises a long-term subsidy may find this position untenable if the economy enters a recession (for example, the Spanish government was forced to abandon feed-in-tariffs for solar electricity). In addition, in a democracy a newly elected government may repeal laws enacted by the previous government. Policies which do not rely on government finance (such as well-executed bonus-malus policies) can be committed to more credibly.

Production and consumption incentives require the largest government investments

Since a broad suite of policies is necessary, governments must decide how to allocate funds and resources as efficiently as possible between policies. While R&D and infrastructure require substantial investment, supporting breakthrough technologies through to large-scale adoption and self-sufficiency is typically far more expensive. For example, through the ProAlcool programme, Brazil invested ~US$ 3 billion on R&D and infrastructure compared to ~US$ 13 billion on consumption subsidies between 1975 and 1991. Even today, Brazil spends ~US$ 2.5 billion on consumption subsidies for ethanol. China is following a similar pattern with investment in electric vehicles. Over the last decade, China has invested ~3 billion RMB in electric vehicle development – mostly on R&D, but also including some small-scale trials. The Chinese government recently announced draft plans to invest 100 billion RMB in production subsidies over the next 10 years to develop clean energy vehicles. The broad suite of incentives for electric vehicles is shown in Exhibit 20.

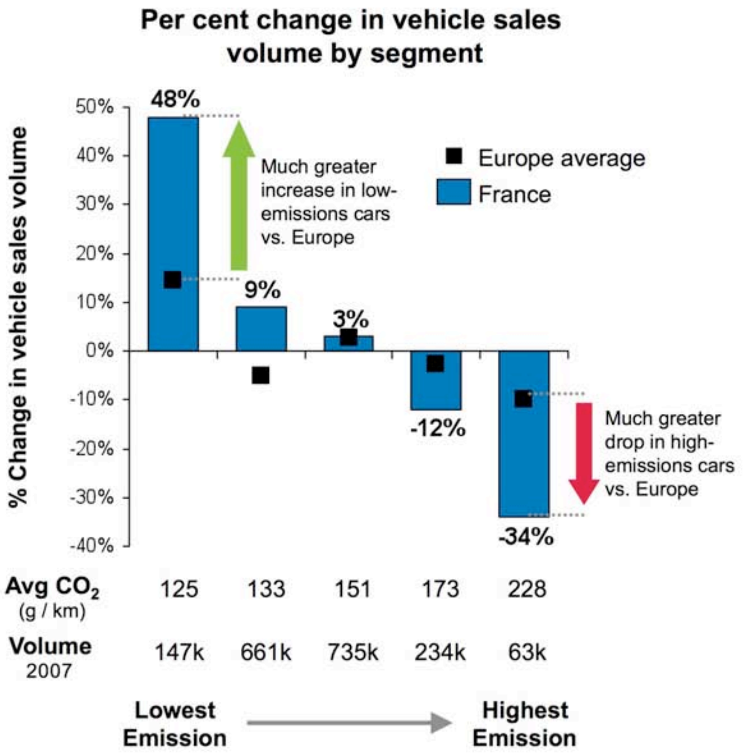
Feebate policies can transfer the burden away from government

The cost of supporting large-scale adoption may be too high for governments to afford. Feebate policies, if carefully designed, can allow the cost of production subsidies to be transferred to consumers and industry. These policies couple a penalty for buying energy intensive technologies (fee) with a subsidy or purchasing energy-efficient technologies (rebate). If the 'pivot point' – the point at which there is no fee or rebate – is set correctly, these policies can be revenue neutral for government. The French bonus-malus scheme (see Exhibit 21), launched in 2007, had high impact, but because of a shift in consumer concerns over future oil prices and the economic crisis, the pivot point shifted and the programme was much more costly than anticipated. Very high emissions cars have lost ~8 percentage points market share while low emissions cars have gained ~16 percentage points market share. The scheme was effective: the average fuel economy of the new vehicle fleet improved by almost 10% between 2007 and 2009. However, the greater than anticipated shift in consumption patterns has resulted in the malus generating only ~200 million euros in 2010 compared to the ~900 million euros cost of the bonus.

Exhibit 20: Examples of EV support policies[39]

Country	Target Outcome	USD / EV	Budget Allocation (US$ billion)	Others	Registration Tax Exemption (US$)	Road Tax Exemption (US$)	VAT Exemption (US$)
Canada	2018: 0.5m EVs	-	-	Charging infrastructure and special lanes	None	None	None
China	2011: 0.5m annual production	879-8,800	1.5	-	None	Full	None
Denmark	2020: 0.2m	-	0.047	Plans to subsidize fleet lease of EVs	Full	Full	None
France	2020: 2m	6,984	0.542	-	Full	None	None
Germany	2020: 1m	-	-	-	N/A	Full	None
India	-	15% discount in Delhi	-	Excise duty waived for EVs in 2010 Union Budget and on batteries	Full	Full	Full
Israel	2012: 0.04 to 0.1m	-	-	70 to 100 charging stations will open by 2011	Full	None	None
Italy	-	4,888	-	Plans to subsidize electric two-wheelers along with charging stations	None	Full	None
Japan	2020: 50% market share next gen vehicles	2,000	-	-	336	Full	Full
South Africa	Promote battery and EV production	-	-	Green tax on normal cars from September 2010	None	None	None
South Korea	2012: 30,000	-	-	-	860	344	11
Spain	2014: 1m	8,155	0.332	-	Full	None	None
UK	2020: 1.2m	8,073	0.386	-	None	Full	None
US	2015: 1m PHEV stock	4,000	2.8	Grants to produce electric drive components and ~ $400mln for test demonstrations	None	None	None

Exhibit 21: Structure and impact of the French bonus-malus policy[40]



Per cent change in vehicle sales volume by segment

Bonus-Malus structure

Emissions range (gCO_2/km)	Bonus/Malus (€)
0 – 60	-5,000
61 – 100	-1,000
101 – 120	-700
121 – 130	-200
131 – 160	0
161 – 165	200
166 – 200	750
201 – 250	1,600
> 250	2,600

Bonus

Malus

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[39] HSBC - Sizing the Climate Economy, September 2010

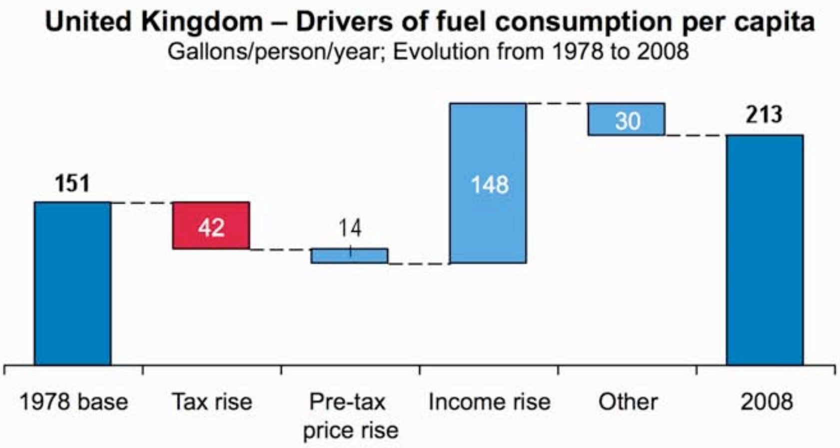
[40] Sources: Ministère de l'Écologie du Développement et de l'Aménagement Durables; Le Figaro; Le Monde; Cars & Transportation; Le Parisien; European Automobile Manufacturers Association; Booz & Company analysis

A brief analysis by policy type

Economic policies

The effects of fuel taxes and carbon pricing mechanisms are very similar; they reduce end-point use effectively and have an immediate impact. However, they are politically difficult to implement since they are regressive and have highly visible, upfront costs for long-term gains. An advantage of carbon pricing mechanisms is that the revenues from new carbon pricing mechanisms could be directed towards the transport sector more easily than those of existing fuel taxes. Studies show that a 10% increase in fuel price results in around a 2.5% decrease in consumption within a year and a 6.5% decrease in consumption after a few years. The United Kingdom experience (Exhibit 22) illustrates the potential of fuel taxes: it is estimated that fuel tax increases from 1978 to 2008 were responsible for a reduction in annual fuel consumption of 42 gallons per person.

Exhibit 22: Fuel Taxes Spur Less Consumption in the UK



R&D subsidies are critical since they are the only policy which can overcome the challenge of short, private investment horizons coupled with the inherently high risk of R&D investment. While R&D subsidies can lead to the creation of breakthrough technologies, they only impact oil consumption in the long term. Implementing the subsidies is relatively straightforward though setting up an organization to decide which projects to fund must be done with care to ensure it is independent of political pressure and has the technical and business expertise to make informed, unbiased decisions. These policies are generally politically easy to implement since the costs are spread out and the benefits accrue to well-organized groups. However, it is important that governments are able to demonstrate results for their investment.

Infrastructure subsidies can have great impact (though immediacy is low) but are only economically efficient under a narrow range of conditions. Where new technologies must compete with incumbents that have benefited from decades of subsidies in the past, infrastructure subsidies are likely to be the only way to overcome the challenge of short, private investment horizons. Government mandates can force infrastructure to be built – for example, a blend mandate regulating a minimum level of biofuels that distributors can sell. However, such mandates will typically require a counterpart subsidy to be politically feasible.

While it may appear operationally easy to provide subsidies for infrastructure, ensuring value for money and keeping control of administrative costs is very difficult. Governments must design a system that balances administrative burden and procurement diligence, and maintains a strong incentive for the private sector to act efficiently. Much has been written on the effectiveness of PPP (public-private partnership) models. While there have been high profile failures, recent experience suggests that PPPs can provide value for money if risk is allocated appropriately[41].

Production and consumption subsidies can have high impact. Production and consumption incentives can take many forms, for example: direct financial subsidies to manufacturers or consumers for each vehicle bought or sold; indirectly financial subsidies such as free parking, congestion charge waivers; or non-financial such as use of bus lanes. To ensure

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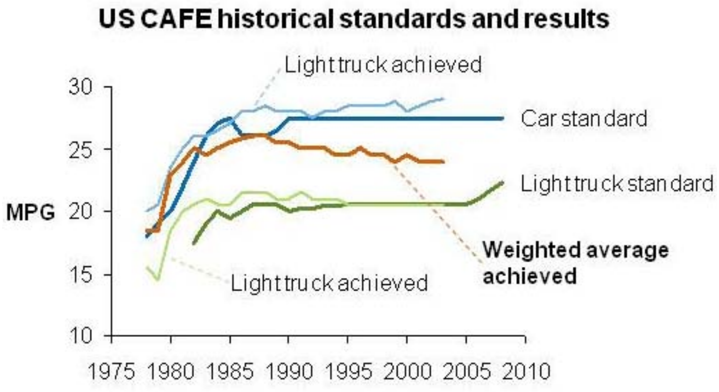
[41] Murphy – The case for public-private partnerships for infrastructure

economic efficiency, these policies should be designed to be technology neutral where possible – for example, basing a car purchase subsidy on CO_2 emissions rather than by type of technology. Production and consumption subsidies are easy to operate though feebates must be carefully designed to ensure they are revenue neutral. These policies are also relatively easy to implement politically.



Command and control policies

Well-designed performance standards can be highly effective. Where the desired outcome is measurable (e.g. CO_2 emissions from vehicles) these policies can be economically efficient since they directly mandate the outcome while allowing market forces to determine the best technologies to achieve this goal. Clearly, the standards must be set at the right level – too weak and not enough is achieved, too stringent and the burden on industry outweighs the benefit.

Performance standards are difficult to implement. Although they are typically quite easy to enforce, it is surprisingly difficult to design standards that avoid creating perverse incentives. For example[42], The US CAFE fuel economy standard has separate categories for cars and light trucks. Very large consumer vehicles (e.g. Hummer H2, Ford Excursion, Chevrolet Suburban 2500) are exempt and large consumer vehicles (e.g. Hummer H3, Ford Expedition) fall into the light truck category. Sales of vehicles in the light truck category for domestic use accelerated through the 1990s and early 2000s. As a result, the weighted average fuel economy of the US fleet actually decreased from 1988 to 2003 while manufacturers were still able to meet the standards in each category. In other sectors, the design of standards can be even more complex. For example, in shipping, it is clearly impossible to run a controlled test cycle on a ship before it enters service. In lieu of this, the IMO designed the EEDI (Energy Efficiency Design Index) which acts as a proxy for a test cycle standard for new ships. In aviation, ICAO is also working on aviation biofuels specifications, in addition to its ongoing work on CO_2 standards.

Performance standards are also difficult to implement politically. Although these standards cost government very little, they cost manufacturers – groups with very high lobbying power – immediately, and benefits to consumers are long-term and less visible. As a result, it is rare that these standards are sufficiently stringent. However, in Europe, policy-makers have recognized the need for government support in R&D to make stringent standards acceptable to industry. In an international industry such as shipping, reaching international agreement is very difficult as each nation fights for favourable terms. For example, as this report went to press, the IMO had not yet made the EEDI compulsory because of resistance from developing nations.

Technology or process mandates are moderately effective. These policies can have high impact where there is a tight link between the technology and the desired outcome – for example, the mandate that cars be fitted with a catalytic converter. However, in other cases, the link between the desired outcome and the policy is less clear. For example, because of the limited ability of corn ethanol to reduce lifecycle CO_2 emissions, the blend mandate for corn ethanol in the US only has a moderate impact. Moreover, technology or process mandates are typically economically inefficient since by forcing the path industry must take, they can stifle innovation in other areas and hence prevent a superior technology from gaining adoption. A case in point is the mandatory use of catalytic converters in cars, which slowed the development of lean burn technology.

Technology or process mandates are fairly difficult to implement. The mandates are often complex and expensive to enforce. For example, to enforce US exhaust emissions (NO_X, SO_X, CO) standards, hundreds of test centres are needed across the country. As with performance standards, these policies are difficult to implement politically since they cost industry groups in the short term for benefits to consumers or society in the long term.

Information policies

The final policies are information policies, which are technology-specific by nature. Labelling and consumer education campaigns are the most common form of information policy. In general, the impact is moderate and reasonably quick if there are no implementation lead times. Making consumers aware of the presence of a consumption incentive is considered a type of information policy.

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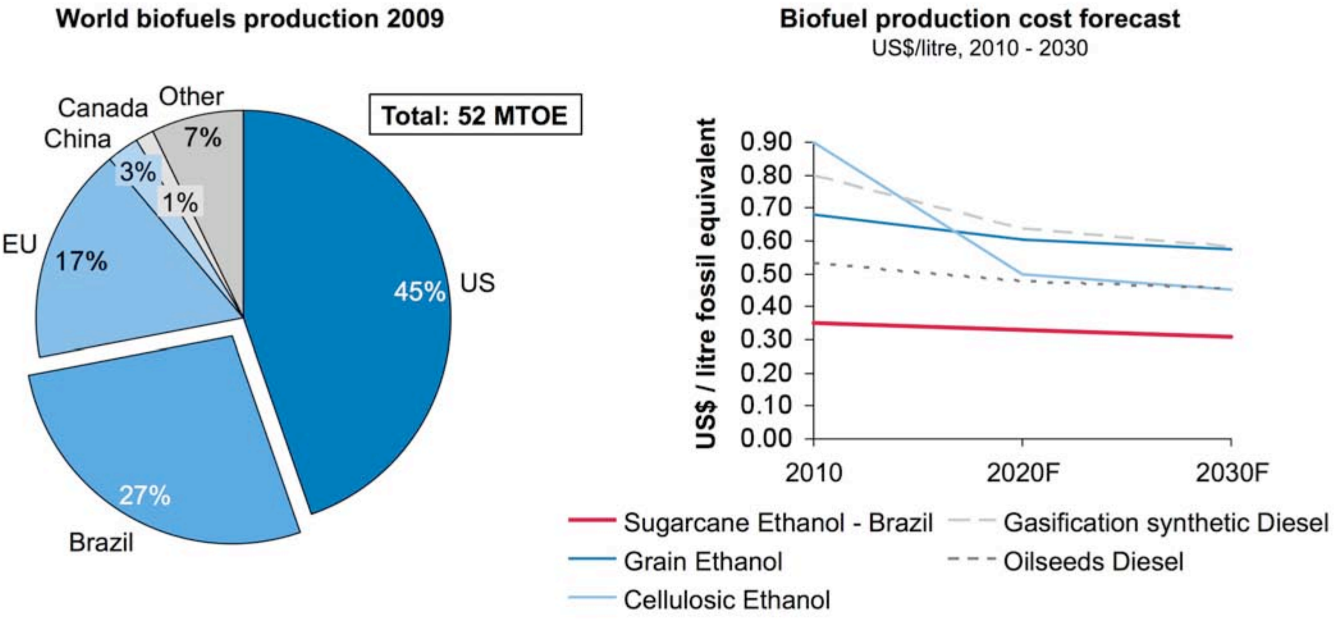
[42] An and Sauer, 2004 - Comparison of Passenger Vehicle Fuel Economy and GHG Emissions Standards around the World

Biofuels in Brazil: A case study

Brazil now supplies nearly 20% of its transport fuel demand from domestic biofuels and also exports large quantities of biofuels. It is the second-largest producer of biofuels in the world (Exhibit 23) and has the lowest-cost base by a wide margin. Despite this progress, Brazilian biofuels are still dependent on consumption subsidies. Brazil's experience illustrates how policy must align with the technology lifecycle: early-stage technologies require R&D and infrastructure support and some command-and-control policies; late-stage technologies require consumption support through economic policies.

Exhibit 23: Global Biofuels Production by region and production cost forecast



Brazil's biofuels industry is the result of decades of government investment and technology, and market development. In response to the oil supply crises in the 1970s, Brazil launched the ProAlcool programme in 1975 – a state-driven intervention programme to develop a national ethanol supply base and market. The ProAlcool programme included a mix of government-run R&D, mandated distribution infrastructure investment, production subsidies and price setting. The cumulative programme cost was ~US$ 16 billion (2010 US$) in total: ~US$ 3 billion on infrastructure and ~US$ 13 billion on consumption subsidies (effected through price controls).

In the 1970s, the programme's focus was on ethanol as an additive to gasoline. The government mandated that distilleries be built and conducted research into sugar cane, both through the Planalsucar National Sugar Cane Improvement Programme and in partnership with CTC (part of the Copersucar Coop), to develop varieties of sugar cane which today account for 40% of total plantation. By 1977, production had increased to a stage where the government was able to mandate a minimum blend of 4.5% ethanol in gasoline. Between 1975 and 1979, the government developed ethanol-fuelled cars, which by 1984 accounted for 94% of domestic car production.

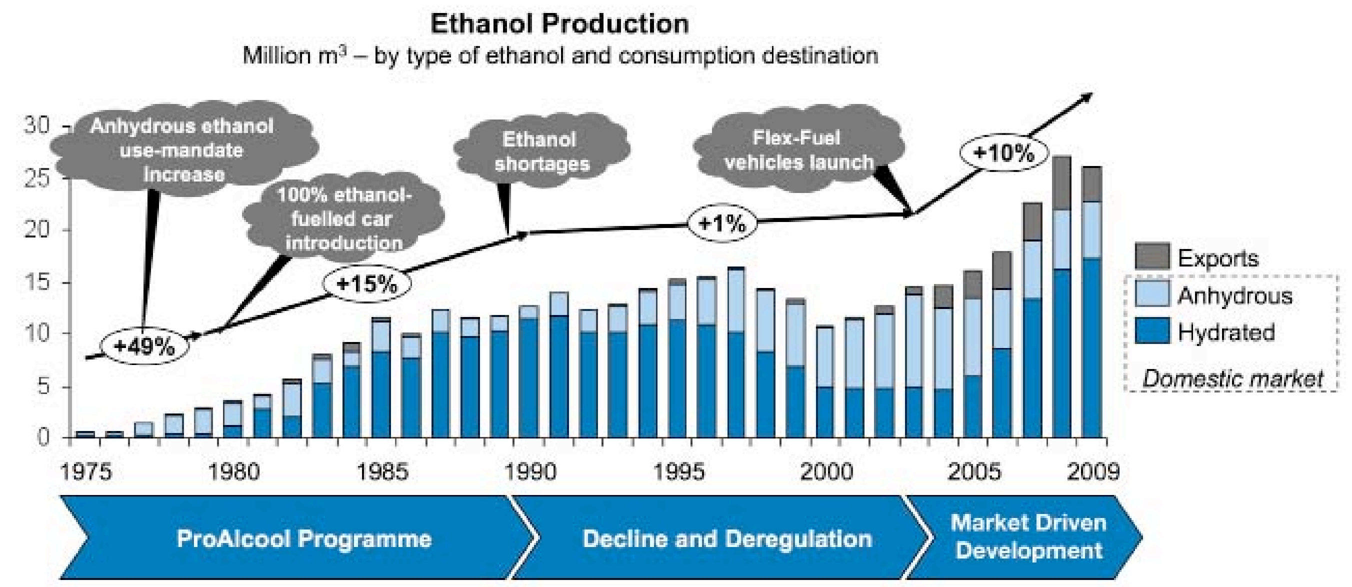
In the 1980s, the government continued the R&D investment and stepped up the consumption and infrastructure subsidies and blend mandates. The government developed a national E100 distribution infrastructure and regulated sugar cane acreage and ethanol production volumes. The minimum blend standard was raised to 22% in 1984. The government also put in place a number of tax incentives for the purchase and ownership of ethanol-fuelled cars and regulated prices to ensure gasoline was more expensive than ethanol.

In the early 1990s the new, democratic government deregulated the industry substantially – allowing market price setting and removing many subsidies. Combined with low oil prices and high sugar prices, this led to a stagnation of the ethanol market.

A resurgence in the demand for ethanol took place at the turn of the century, spurred by the development of flex fuel vehicles (FFV) and high oil prices (14 manufacturers now supply FFV). Government intervention in the ethanol market is now largely restricted to consumption incentives in the form of tax breaks (CIDE, the transport infrastructure and maintenance fund, and ICMS, the Brazilian VAT); these currently cost ~US$ 2.5 billion annually.

Brazil recently launched the National Biodiesel Production Programme (PNPB). Mirroring the policy path of ethanol (though in a less-regulated manner), the programme currently focuses on R&D and production incentives since biodiesel in Brazil is in its early stages relative to ethanol (~5% of diesel sold is biodiesel).

Exhibit 24: Historical Annual Brazilian Ethanol Production



Partnerships

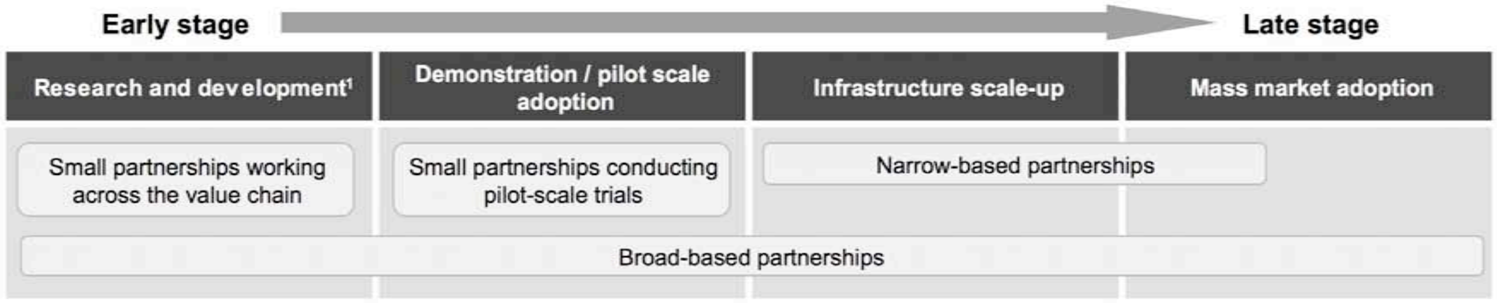
Partnerships: main findings

Value chains in the transport sector involve a wide range of stakeholders. New technologies such as electric vehicles or alternative fuels add to this complexity, requiring new players and overlapping infrastructure. Public-private partnerships and multistakeholder partnerships are emerging to address these complex challenges. Our analysis suggests that there are four different types of partnership, designed to address different challenges through the technology lifecycle.

Early-stage technologies require a focus on R&D and pilot-scale adoption for testing. Small–scale partnerships which link different parts of the value chain, but do not include direct competitors, can resolve IP protection issues common at the research stage. Government and industry trials at the local level are an effective means to reduce technology and business risk. By keeping the scale small, such trials simplify the standardization challenge and limit the amount of investment required to build infrastructure. These trials can also provide proof-of-concept, making it easier to secure financing for large scale investments. Broad-based partnerships can also start providing the momentum for technology standards and lobbying for policy support which are critical at this stage.

In contrast, late-stage technologies must focus efforts on large-scale adoption and infrastructure scale-up. Broad-based partnerships are better suited than small-scale partnerships to solve major challenges such as lack of standards, poor consumer awareness and consumer technology risk aversion. Narrow-based, high-investment partnerships can be effective at developing infrastructure. The most effective broad-based partnerships typically begin with a select group of pioneering companies rather than an all-encompassing industry group to avoid laggard companies holding back the ambitions of the leaders. Furthermore, by acting progressively, these companies often create advantaged positions for themselves, forcing competitors to copy them.

Exhibit 25: The roles of partnership types in the lifecycle



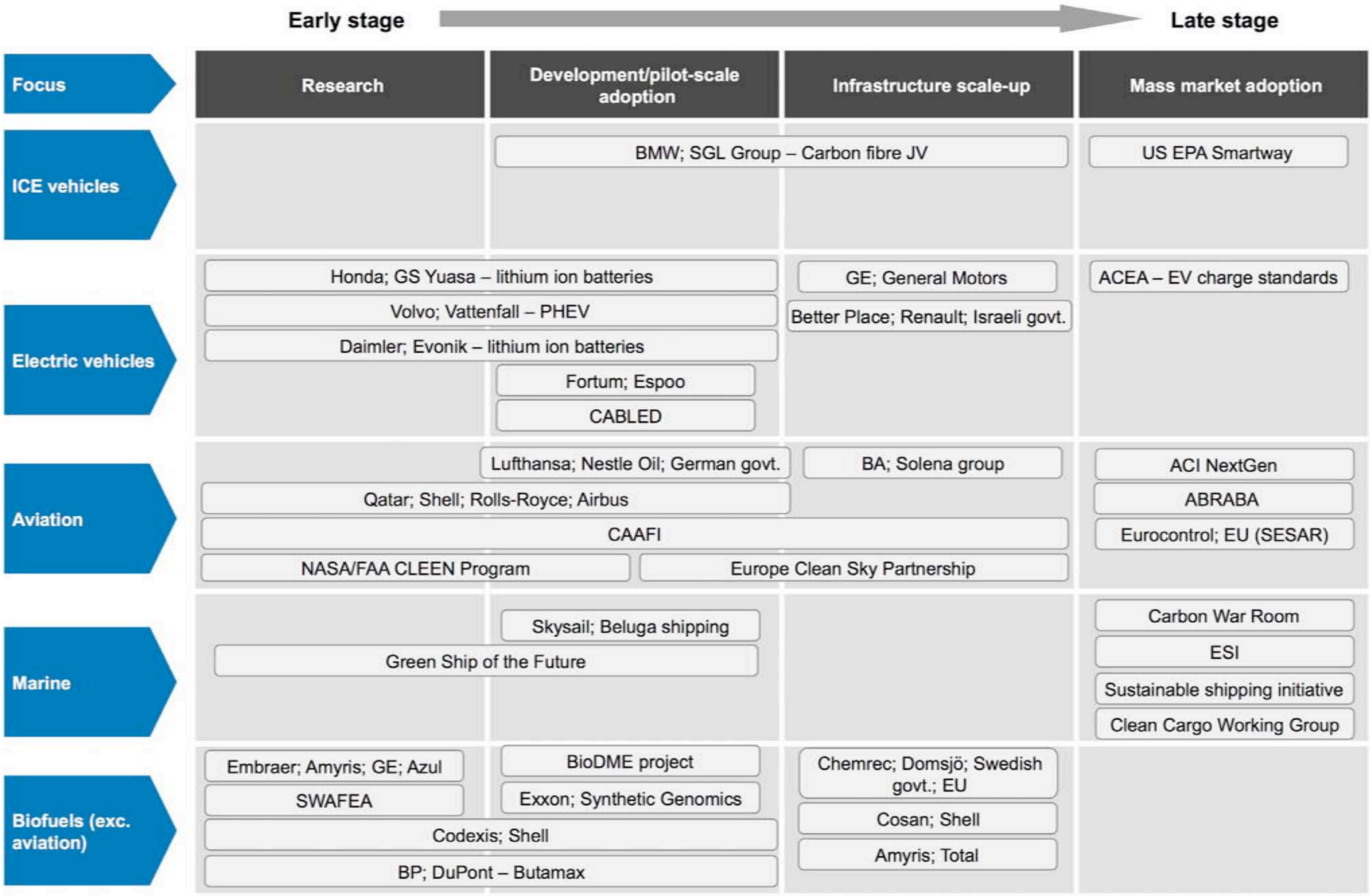
The characteristics of partnership types

Types of partnerships	Small partnerships working across the value chain	Small partnerships conducting pilot-scale trials	Narrow-based partnerships	Broad-based partnerships
Typical partners	▪ May include government research organisations ▪ Unlikely to include NGOs ▪ No competitors	▪ May include government organisations (national or local) ▪ May include NGOs ▪ May include competitors	▪ Few parties involved ▪ May include competitors ▪ May include NGOs ▪ May include government	▪ Includes many competitors ▪ May include NGOs ▪ May include government organisations (national or local)
Challenges addressed / success factors	▪ Promotes open sharing – Small size makes IP ownership issues easier to resolve – Partnering across the value chain rather than with competitors is critical to enable open sharing of information ▪ Small scale reduces coordination challenge and helps to foster innovation ▪ In some cases, it may be possible to resolve 'who should pay' issues by forming a joint venture	▪ Technology and infrastructure concept tested in a real world setting ▪ Partnering with governments develops expertise and understanding within government of the challenges the technology faces – this will help to ensure that future policies are well designed ▪ Including competitors in trials avoids narrowing in on a particular technology too early ▪ Small scale has many advantages: – Reduces co-ordination challenge – Easier for governments to fund projects, which may otherwise not be commercially viable – Innovative financing agreements easier to arrange	***Infrastructure roll-out*** ▪ Government support is often required to aid permitting and/or to provide finance support due to the long payback and high-risk nature of these projects ▪ Large investment requirements	***Standard / target setting²*** ▪ Governments are often reluctant to set standards / targets due to lack of expertise, or may be unable to agree international standards ▪ Industry can take the lead to speed up the process and so, set a path for government to follow ***Information gaps*** ▪ Customers are often unaware of new technologies or do not have the information or experience to prepare a business case ▪ These partnerships can improve information transparency through accreditation schemes, publicising metrics, etc.

1 – Before this stage is reached, fundamental science research and feasibility research must be conducted – broad-based collaboration is suitable for these very early stages but less suitable for development work

2 – Although standards and targets are most commonly set in preparation for mass market adoption, in some cases (e.g. biofuels in aviation) they are necessary at the development stage to enable trialling.

Exhibit 26: Examples of recent partnerships



Early stage → Late stage

Focus	Research	Development/pilot-scale adoption	Infrastructure scale-up	Mass market adoption
ICE vehicles		BMW; SGL Group – Carbon fibre JV		US EPA Smartway
Electric vehicles	Honda; GS Yuasa – lithium ion batteries Volvo; Vattenfall – PHEV Daimler; Evonik – lithium ion batteries	Fortum; Espoo CABLED	GE; General Motors Better Place; Renault; Israeli govt.	ACEA – EV charge standards
Aviation	Qatar; Shell; Rolls-Royce; Airbus CAAFI NASA/FAA CLEEN Program	Lufthansa; Nestle Oil; German govt. Europe Clean Sky Partnership	BA; Solena group	ACI NextGen ABRABA Eurocontrol; EU (SESAR)
Marine	Green Ship of the Future	Skysail; Beluga shipping		Carbon War Room ESI Sustainable shipping initiative Clean Cargo Working Group
Biofuels (exc. aviation)	Embraer; Amyris; GE; Azul SWAFEA Codexis; Shell BP; DuPont – Butamax	BioDME project Exxon; Synthetic Genomics	Chemrec; Domsjö; Swedish govt.; EU Cosan; Shell Amyris; Total	

Overview

The number of partnerships springing up in the transport sector is increasing dramatically. These partnerships, which often involve a large number of participants from industry, government, international organizations and academia, seek to address the complexity of deploying new technologies in the transport sector and fill the gaps along the value chain. These non-traditional partnerships come in addition to a growing number of two-player B2B partnerships.

These multistakeholder partnerships fall into four types, as illustrated in Exhibit 25. The nature of the partnership changes as they progress along the technology lifecycle: as technologies mature, the challenges that partnerships need to address move from R&D to large-scale deployment.

The remainder of this section describes a number of partnerships of different types against this framework and begins to highlight some success factors. It is important to note that virtually all partnerships reviewed are recent in nature; hence, this report does not attempt to measure their performance.

Partnership examples

Small partnerships along an industry value chain

A small partnership between companies in the wind industry was able to resolve IP protection issues and bring together diverse knowledge to solve a complex problem: how to model wind turbine power trains. Four partners were involved: Repower Systems (OEM), Eickhoff (gearbox supplier), Schaeffler (roller bearing supplier) and Samtech (software supplier). The partnership produced the world's first simulation software for wind turbine power trains which can model the interaction of stresses between components throughout the power train. Other examples include:

- The joint venture of Evonik Industries AG and Daimler AG developing, producing and marketing large-scale lithium ion battery cells for automotive applications and battery systems for industrial and stationary applications
- Honda and GS Yuasa setting up a joint venture (JV) to develop and market lithium-ion batteries for hybrid vehicles
- BMW and SGL Group forming a JV with ~230 million euros investment to manufacture carbon fibre parts to build lightweight vehicles
- Volvo and Vattenfall forming a JV to develop a PHEV, planned to be introduced in Europe in 2012

Small partnerships conducting pilot-scale trials

The city of Austin, Texas, partnered with car2go, Daimler's Smart car-based car-share initiative, to launch 200 Smart cars in the Austin area for a six-month pilot. This initiative is a barter agreement: the City of Austin provides free parking, worth ~US$ 85,000 to car2go in exchange for free use of the fleet for the city's employees. Other partnerships are more traditional in their use of financing mechanisms. For example, the Victorian government in Australia committed US$ 5 million to a more traditional partnership for a 180-vehicle trial of electric vehicles. The partnership is supported by a wide range of companies including Better Place, ChargePoint, Nissan, Mitsubishi, Powercor and TRUenergy. The partnership between Lufthansa and Neste Oil to pilot jet biofuel is another example of government catalytic funding. In April 2011, Lufthansa will begin a six-month trial of jet biofuel, produced by Neste's NExBTL process, on scheduled commercial flights. This will be the first time jet biofuel has been used in scheduled flights. The trial will cost Lufthansa ~US$ 8.6 million, of which ~US$ 3.3 million will be provided by the German federal government as part of the FAIR (Future Aircraft Research) initiative.

Not all of these partnerships include government. For example, GE announced that it will buy 25,000 electric vehicles by 2015. The first 12,000 will be supplied by GM, starting with the Chevrolet Volt in 2011. GE stands to gain more than goodwill from this arrangement: it manufactures technology that is used throughout electric vehicle charging infrastructure systems – such as smart meters and the WattStation charge point – and so has a vested interest in the success of electric vehicles. Another example is the joint venture between British Airways and Solena Group to develop Europe's first renewable jet fuel plant. The plant will use a gasifier and the Fischer-Tropsch[43] process to convert 500,000 tonnes per year of waste that would otherwise go to landfill into 16 million gallons of jet fuel, 8 million gallons of naphtha and 20MW of electricity exported to the grid. British Airways signed a letter of intent agreeing to purchase all the fuel produced by the plant. This reduces the revenue risk for the Solena Group, which reduces the difficulty of raising the US$ 300 million investment required.

Broad-based partnerships

Broad-based partnerships rely on network effects – i.e. the partnership becomes more effective as more members join. However, it is typically most effective to start relatively small. Large industry associations tend to move slowly to cater to the least-progressive members. By starting with a select group of leaders, a partnership can move quickly and pursue ambitious goals. This approach allows the partnership to get a draft solution onto the market quickly, which provides a blueprint for international agreement subject to future refinement.

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[43] The Fischer Tropsch process is a chemical process which converts a synthesis gas, composed of carbon monoxide and hydrogen, into hydrocarbons.

European automobile manufacturers faced a challenge with electric vehicle charging connections to the grid. In June 2010, ACEA, the European automobile manufacturers association, announced a uniform solution for passenger cars and light commercial vehicles which will become a standard by 2017. Critical to the success of this agreement is the influence of ACEA, which represents all the major vehicle manufacturers in Europe, and its composition. ACEA has fewer than 20 members, all of which are progressive organizations, which makes reaching decisions easier than in organizations with a larger, more diverse membership base.

The Carbon War Room is currently leading a partnership to provide free, online access to efficiency data for ships worldwide (see the case study below for further details). While the IMO had been able to create a standard for measurement (the EEDI – Energy Efficiency Design Index), an agreement for mandatory implementation and score disclosure has been delayed. By partnering only with leading players, the Carbon War Room was able to launch a website which places the best available information covering efficiency standards for individual ships online and which can be updated as ships are validated by third parties.

The SmartWay programme, led by the US EPA, adopted a similar approach for the road freight industry (further details can be found in the case study below). The SmartWay programme includes an accreditation scheme whereby truck owners (carriers) commit to monitoring and improving their fuel use and shippers commit to preferentially using SmartWay accredited carriers. The programme started with only a few leading companies, allowing rapid development and proving the concept. The success quickly attracted broader adoption and the scheme now has over 2,000 partner companies.

Partnership case studies

Biologic and Process Technologies for Renewable Jet Fuel Programme

In Canada, Bombardier Aerospace is part of a six-member consortium that brings together the full aviation biofuels production chain – from seed to oil to fuel end-user. The goal is to develop “drop-in” bio-based jet fuel technology to realize a substantial reduction in greenhouse gases and other emissions. The consortium is working on a project known as the Biologic and Process Technologies for Renewable Jet Fuel programme, the funding for which will be provided by Sustainable Development Technologies Canada (SDTC) and the Green Aviation Research and Development Network (GARDN). For the first time, a Bombardier *Q400* aircraft will be flown using fuel from an oilseed crop as part of a new biofuel test programme. The expectations are to demonstrate the emerging biofuel produced from camelina in a Porter Airlines *Q400* aircraft by early 2012.

The ESI, Environmental Shipping Index

The ESI is a project, run by 55 of the world’s most important ports, which intends to provide a basis for ports to reward owners of clean ships and to increase information transparency for shippers and carriers. The project is an example of a broad-based partnership which is founded by the most progressive organizations in an industry seeking to catalyse change.

The IAPH (International Association of Ports and Harbours) is a global alliance of ~230 ports. In April 2008, the IAPH requested its Port Environment Committee to provide a mechanism to help ports combat climate change. This led to the formation of the WPCI (World Ports Climate Initiative), a group of 55 of the world’s most important ports, committed to reducing greenhouse gases, which was launched in November 2008. The ESI is a WPCI project run by six-member ports: Le Havre, Bremen, Hamburg, Antwerp, Amsterdam and Rotterdam.

The project is intended to affect the market through two mechanisms:
- Offering rewards at ports worldwide for clean, efficient ships
- Creating market pressure for cleaner, more efficient ships by providing shippers and carriers with publicly available information on ship emissions in a consistent, transparent format

The ESI is a scoring system for ships that gives points according to NO_x and SO_x emissions and whether or not energy efficiency is reported. NO_x is weighted twice as heavily as SO_x as it causes nearly twice the environmental damage. Since there is not yet a formally agreed CO_2 reporting standard for ships, the ESI awards a small points bonus to ships which report energy efficiency based on the IMO’s (International Maritime Organisation) draft EEOI metric. Ships that want to participate must report their scores publicly on the ESI’s website.

Participating ports will offer a reward for ships that report high ESI scores. For example, the port of Amsterdam will offer a discount on port dues of up to 1,750 euros per visit (the discount varies depending on both ship size and score). The ports of Amsterdam, Moerdijk, Dordrecht and Rotterdam will start using the ESI in January 2011 and the ports of Antwerp, Hamburg and Bremen have announced their intention to join the scheme. The goal is to attract as many ports as possible and thus to get as many ships as possible reporting.

The US EPA's SmartWay programme

The SmartWay programme is an example of a broad-based partnership which has already achieved significant results. SmartWay was developed by the US EPA (Environmental Protection Agency) and is designed to improve environmental performance of the freight delivery system in the US. It is a voluntary scheme which increases take-up of clean and energy efficient technologies through market demand and information transparency. The scheme involves both carriers (companies which provide and hire trucks) and shippers (companies which create the demand for freight services).

- Carriers can become members if they commit to monitoring and improving their fuel use.
- Shippers can become members if they commit to sourcing at least 50% of their goods through SmartWay member carriers.

Shippers benefit from increased transparency in their sourcing and from gaining a way to react to consumer's environmental concerns. Carriers benefit from increased visibility and demand. In addition, SmartWay provides help identifying and financing fuel-saving opportunities and offers use of the SmartWay brand (to companies which achieve high standards). There are four SmartWay programmes which provide this support:

- *Financing programme*: offers below-market-rate loans and rebates to participating companies to help acquire fuel-efficient technology. SmartWay also maintains a platform, the SmartWay Financial Center, which links lenders and carriers seeking financing for SmartWay certified new trucks or retrofits.
- *Technologies programme*: tests and certifies fuel-saving vehicle specifications for new vehicles and trailers.
- Information on *Technology upgrade kits*: SmartWay provides information on potential savings for various retrofits and links to certified vendors.
- *National transportation idle-free corridors*: aim to eliminate unnecessary idling by partnering with truck stops to provide electrified truck stop infrastructure and information on the benefits of cutting idling.

The SmartWay programme has been effective because it simultaneously tackles information gaps, which make it difficult for carriers to know which technologies to fit, and increases the reward for adopting energy-efficient technologies by increasing demand. The value of the partnership increases as more companies join: the SmartWay brand becomes more valuable as awareness of the brand increases and the pressure from shippers on carriers increases.

There are, however, risks to the approach. By setting technology specifications for new vehicles and trailers rather than performance standards, there is a risk that SmartWay could stifle innovation. Similar risks apply to the technology upgrade kits component of the programme; there have been complaints that the technology appraisal process is too restrictive. Finally, while the programme is effective at providing incentives for poor performers to improve, it provides little incentive for good performers to continue to improve.

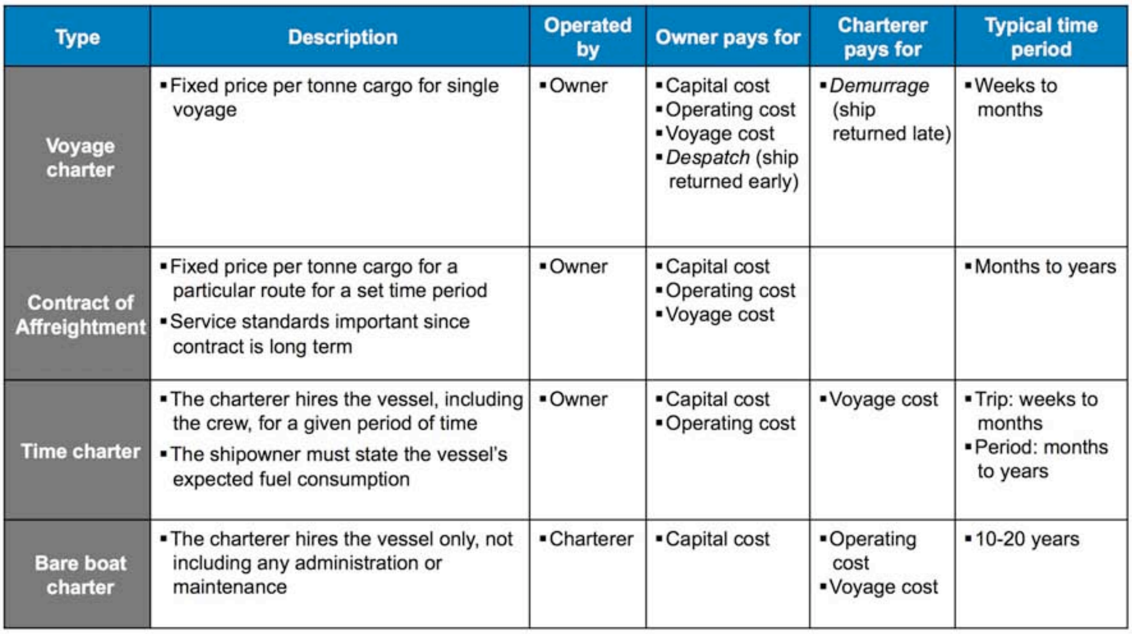
Overall, in its first two years, the programme has created annual savings of ~300 million gallons of diesel. The EPA expect SmartWay to deliver >3,000 million gallons of diesel annual savings by 2012. There are now over 2,000 partners registered with SmartWay, covering the majority of land-based shipping in the US.

The Carbon War Room – Operation Rock the Boat

Operation Rock the Boat aims to create the conditions for the global shipping industry to transition towards a lower carbon fleet – targeting over 0.5 billion tonnes of annual CO_2 reduction by 2020. The partnership aims to achieve this by resolving market failures, with the primary focus on increasing information transparency regarding ship energy efficiency. The programme is led by the Carbon War Room, an NGO which has partnered with companies from across the industry, including shippers, ship operators, port authorities, financiers, technology providers and NGOs.

There is a split incentive problem in the shipping industry: ship owners are not able to capture the full benefit of fuel-saving retrofits (or costly specifications on new builds) on vessels that are chartered since the charterer captures much of the benefits. This problem is faced to a greater or lesser extent by all parts of the charter market. Exhibit 27 shows the various types of marine charter.

Exhibit 27: Types of maritime charters



Type	Description	Operated by	Owner pays for	Charterer pays for	Typical time period
Voyage charter	▪ Fixed price per tonne cargo for single voyage	▪ Owner	▪ Capital cost ▪ Operating cost ▪ Voyage cost ▪ *Despatch* (ship returned early)	▪ *Demurrage* (ship returned late)	▪ Weeks to months
Contract of Affreightment	▪ Fixed price per tonne cargo for a particular route for a set time period ▪ Service standards important since contract is long term	▪ Owner	▪ Capital cost ▪ Operating cost ▪ Voyage cost		▪ Months to years
Time charter	▪ The charterer hires the vessel, including the crew, for a given period of time ▪ The shipowner must state the vessel's expected fuel consumption	▪ Owner	▪ Capital cost ▪ Operating cost	▪ Voyage cost	▪ Trip: weeks to months ▪ Period: months to years
Bare boat charter	▪ The charterer hires the vessel only, not including any administration or maintenance	▪ Charterer	▪ Capital cost	▪ Operating cost ▪ Voyage cost	▪ 10-20 years

In time charters and bare boat charters, the charterer pays for the fuel cost. The ship owner must state the vessel's expected fuel consumption under fair weather conditions (Force 4 or less) which, in theory, should allow the market to reward ship owners for providing efficient ships. However, these figures are generally not representative of real world conditions and are typically highly optimistic.

The spot market comprises voyage charters and contracts of affreightment. Ship owners pay fuel costs in the spot market. Clearly, fuel costs are factored into market prices and therefore are indirectly passed to charterers. In addition, Bunker Adjustment Factor (BAF) clauses adjust for variation in bunker prices over the charter period, though not volume consumed. Hence, for a given voyage, there is effectively no link between what the charterer pays and how much fuel was consumed on the voyage. Although this creates cost-pressure for ship owners to reduce fuel consumption, demand is no higher for energy-efficient ships than for inefficient ships since there is no way for charterers to know how fuel efficient a ship is.

To address this information gap, Operation Rock the Boat launched www.ShippingEfficiency.org – an online database of "beta" efficiency data for >60,000 of the world's ships. Since there is not yet a standard agreed by any of the major classification societies, the database currently calculates a rating based on the IMO's draft EEDI (Energy Efficiency Design Index) calculated from data from IHS Fairplay. The ratings will be updated as this data changes.

BioDME Project, Sweden

The BioDME project is a pilot-scale demonstration of DME from biomass, a gaseous fuel which can be used in converted diesel engines, which covers the value chain from production of fuel through to distribution and vehicle production and testing. The pilot plant in Piteå was inaugurated in September 2010 and can produce around 500,000 gallons of DME per year from a feedstock of black liquor – a by-product from the pulp and paper industry. The plant uses a gasification and synthesis process.

The project is a small-scale partnership with support from the Swedish Energy Agency and the EU's Seventh Framework Programme. Including partners from across the value chain was critical to the project's success since it allowed a demonstration of the entire DME ecosystem:

- Domsjö provides the feedstock, black liquor, from its Domsjö Fabriker biorefinery.
- Chemrec, a gasification specialist, led the plant design, construction and operation. Haldor Topsoe partnered with Chemrec on the plant design and provided a novel DME synthesis technology. ETC (Energy Technology Centre, Piteå), a research and development organization, provided laboratory support.
- Oil major Total led the fuel and lubricant oil specification. This involved testing materials compatibility with DME, determining the quality specifications necessary to ensure engine longevity and establishing engine oil requirements and degradation profile when using DME.
- Preem, a Swedish petroleum company which owns over 500 fuel stations across Sweden, will build four DME filling stations and will be responsible for blending the DME with additives and delivering the fuel from the plant to the filling stations.
- Volvo partnered with Delphi to prepare the vehicles. Delphi developed a DME injector and high pressure pump which Volvo integrated into a new, 13-litre, 440-hp engine. Volvo developed a DME tank and feed system and built 14 trucks to be tested in real world applications.
- The Swedish Energy Agency and the EU's Seventh Framework Programme are providing ~US$ 40 million.

The success of this pilot plant has led to the launch of an industrial-scale demonstration project, which will be the first of its kind in the world. The industrial-scale demonstration plant will be built at the Domsjö Fabriker biorefinery site in Örnsköldsvik and has a target capacity of 40 million gallons of DME and biomethanol combined. Chemrec will again lead the plant design, construction and operation.

The project is expected to cost ~US$ 440 million with funding to come from a variety of government and private sector sources. The Swedish Energy R&D board will provide an investment grant of ~US$ 73 million. VantagePoint Venture Partners (investors in Chemrec), and the European Investment Bank are also investing in the project.

CABLED Consortium, West Midlands, United Kingdom

CABLED is a consortium of 13 partners from the public and private sector to trial ultra-low-carbon vehicles in real world conditions. Extensive data is being gathered which will be used to inform future policy decisions and to give manufacturers and infrastructure providers insights into how customers use the vehicles. The partners are:

- The engineering design firm, Arup (project managers)
- The city councils of Birmingham and Coventry
- Aston University (data analysis); Coventry University (drive selection); Birmingham University (access to hydrogen fuelling station)
- Electricity provider, E.ON, delivering charge points
- Mitsubishi (iMiev); Tata (Indica Vista EV); Smart (ForTwo electric); Land Rover (Range-e); MicroCab (urban car)

CABLED is the largest of eight trials commissioned by the Technology Strategy Board's (TSB) Ultra Low Carbon demonstrator programme, which has £25 million (~US$ 40 million) funding, of which £7.5 million (~US$ 12 million) is allocated to CABLED. In December 2009, 22 Mistubishi iMievs were delivered to independent drivers for a 12-month test period. Each car has an automated data recorder which monitors a wide array of variables including speed, temperature, charge state, charge location and energy use.

The results from the first two quarters are encouraging and have provided useful behavioural insights. Average daily mileage was 25 miles with three of the cars averaging over 35 miles per day. Drivers were comfortable using the majority of their battery's capacity: drivers frequently allowed the state of charge to decrease to 13-18% of full capacity before charging. Moreover, there were signs that range anxiety decreased fairly rapidly: daily mileage skewed higher in the second quarter than in the first. The most popular time to charge was overnight, though top-up charges during the day were also common.

The trials suggest that for some drivers, electric vehicles are already an economic choice (for a driver averaging 35 miles per day (365 days p.a.), with electricity at £0.1/kWh and fuel at £1.20/litre (typical price in the United Kingdom, 2010).

	Small electric vehicle	**Small, efficient diesel vehicle**
Efficiency[1]	0.22 kWh/mile	55 mpg (real world)
Energy cost[1]	£0.10/kWh	£1.20/litre
Average daily mileage	35	35
Fuel cost per year	£281	£1,254
Battery lease cost per year[2]	£878	-
Total fuel + battery annual cost	**£1,159**	**£1,254**

A few major decisions influenced the success of the project. The consortium decided that E.ON should own the charge points rather than the cities to speed the connection process. The permitting process was new territory and though Coventry and Birmingham had different styles, there were common themes which E.ON is preparing documentation on. The test drivers had to pay for the use of the cars – this was critical to ensure that the cars were used as regular cars not as novelty gadgets. Drivers covering a range of duty cycles were selected, from mothers doing school-runs to people using their cars for business. Initial feedback from interviews conducted by Oxford Brookes University indicates that the cars were viewed positively and that the drivers were able to use them as they would their regular vehicles.

[1] United Kingdom gallons – 4.5 litres/gallon

[2] Battery lease cost based on Renault quote of 72 euros/month exc. VAT for Kangoo battery to be launched in 2011.Estimate is conservative for small car since Kangoo battery is 22kWh vs 16kWh for iMiev.

Due to the rapid growth of the number and type of partnerships in the transportation sector, there is value in consolidating this information in a single source. A partnership database is available at http://www.repoweringtransportpartnerships.com/main.html.

Financing

Financing: main findings

Total capital availability/requirement is not a constraint, although capital is spread across a large number of actors (e.g. governments, manufactures, service providers, individual consumers). While the amount of capital needed is large in absolute terms (this report estimates between US$ 4-8 trillion over the next 20 years), it is small in relation to industry turnover or comparable investments in other sectors.

In addition, transportation technology financing issues are quite distinct to the technology under consideration:

- Energy Efficiency – the biggest issue is lack of information. Models similar to energy service companies (ESCOs - who are paid on the basis of energy savings) in other sectors can address some of these challenges.
- Electric Vehicles – battery leasing models will be an important enabler for achieving substantial market share. However, the challenge lies in setting a residual value for batteries and developing the secondary market for batteries. Commercial infrastructure will need either a rapid reduction in the cost of charging stations, new business models or government support to be viable.
- Biofuels – generally, projects with a good business case are receiving funding, typically first generation. Second generation plants have both technological and demand-side risks driven by uncertain, ineffective and conflicting policies. The high risk of being the "world's first ..." requires governments to support the financing for these projects. Once the first few commercial-scale plants have been built and policy clarified, the market has enough information to evaluate risk satisfactorily and private capital flows efficiently.

Overall, private sector investors will invest in the transport sector, if they can assess the risks involved with reasonable confidence. It is, however, extremely difficult to secure private sector financing for high-risk projects with long payback periods. This is characteristic of technology development projects so governments will need to be involved at this stage.

Overview

There is little clarity about the financing challenges of deploying technology in the transportation sector. The financing section explores a few questions:

- Capital availability: is there enough capital available in the market, given the magnitude of investment required?
- Are transport-related projects inherently more difficult to finance than other sectors?
- What financing mechanisms are available (either new or borrowed from other sectors) to address the specific issues relating to transportation technology deployment?

This report therefore focuses on narrowing down the problem definition of financing in the transport sector to allow a more structured set of discussions going forward.

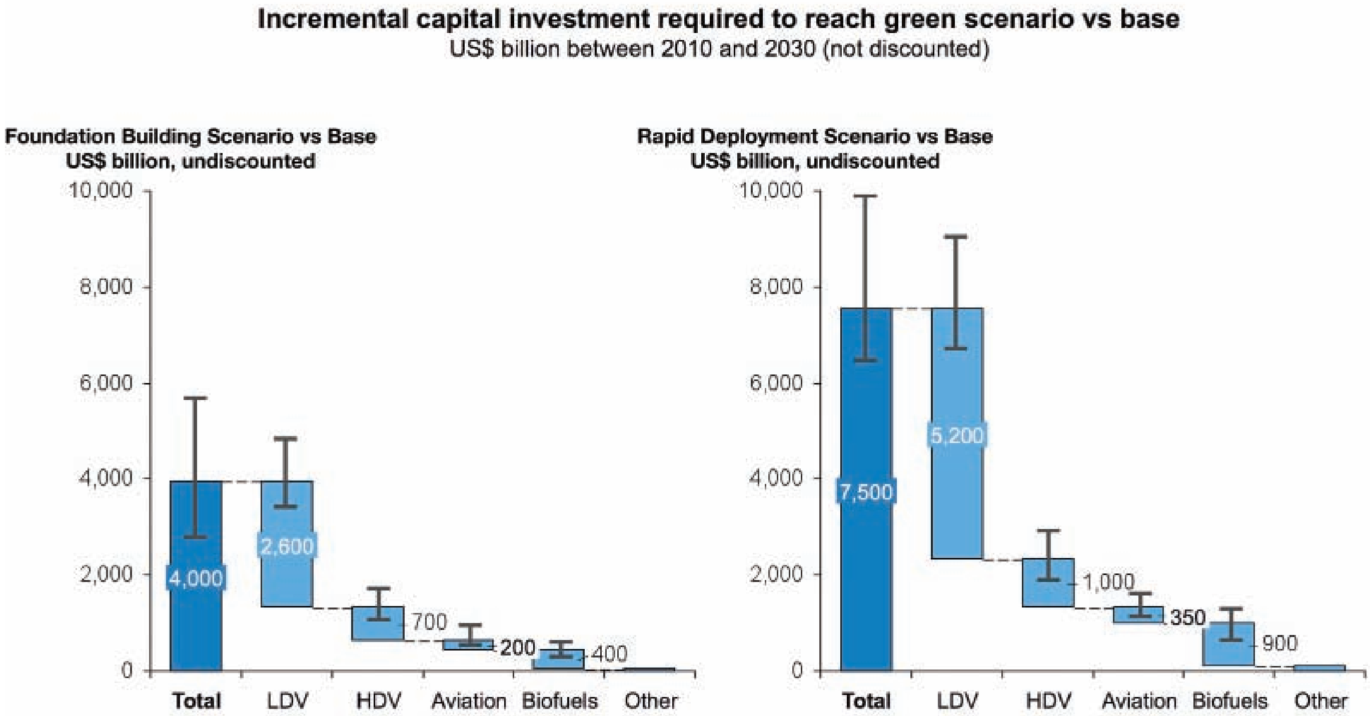
There is no general solution to the financing issue. Several questions remain unanswered and specific details unresolved. The responses to the abovementioned questions, however, are straightforward:

- Total availability of capital is not likely to be a constraint; the incremental amount of capital required is large in absolute terms, but small in relation to other comparators.
- In addition to public funding, there are a wide range of sources of capital from the private sector. Investors are willing to invest at a broad range of rates of return – provided they can assess the risk involved with reasonable confidence.
- There are new and existing financing models to be deployed in the transport sector (e.g. models similar to energy service companies (ESCO), global carbon financing). However, these approaches are specific to modes and technologies; there are no generic solutions.

We estimate the total incremental capital required from 2010 to 2030 to be ~US$ 4 trillion in the foundation building scenario and ~US$ 8 trillion in the rapid deployment scenario (Exhibit 28).

- These figures are incremental – as the transport sector develops, existing technologies will be deployed without extra impetus (our "base scenario"). These numbers reflect how much additional capital would be required, upfront, to deploy more efficient and energy-diversifying technologies.
- The figures are cumulative, undiscounted and do not include any savings or ongoing costs –including savings, many technologies could be deployed at positive NPV.
- These figures include different types of upfront costs, for example, infrastructure deployment costs, additional costs to build plants, upfront vehicle purchase costs, etc. – i.e. attempt to understand the total outlay required.

Exhibit 28: Incremental capital investment required from 2010 to 2030



Sources: Repowering Transport team analysis

A combination of public and private sector funding will be required to deliver this magnitude of investment. However, in comparison with other figures, this number (an averaged US$ 200 billion to US$ 400 billion p.a.) becomes more manageable:

- Global energy subsidies for fossil fuels are currently estimated at US$ 240 billion excluding tax effects and US$ 700 billion including tax effects[44].
- In other analysis[45], Booz & Co. estimated the likely total investment in urban light vehicle transportation at ~US$ 42 trillion over a similar timeframe – our LDV figures here represent only 6 to 12% uplift in total investment.
- Global transport industry turnover (including fuel) is ~US$ 4.5 trillion per year, 10 to 20 times larger than the capital requirement.

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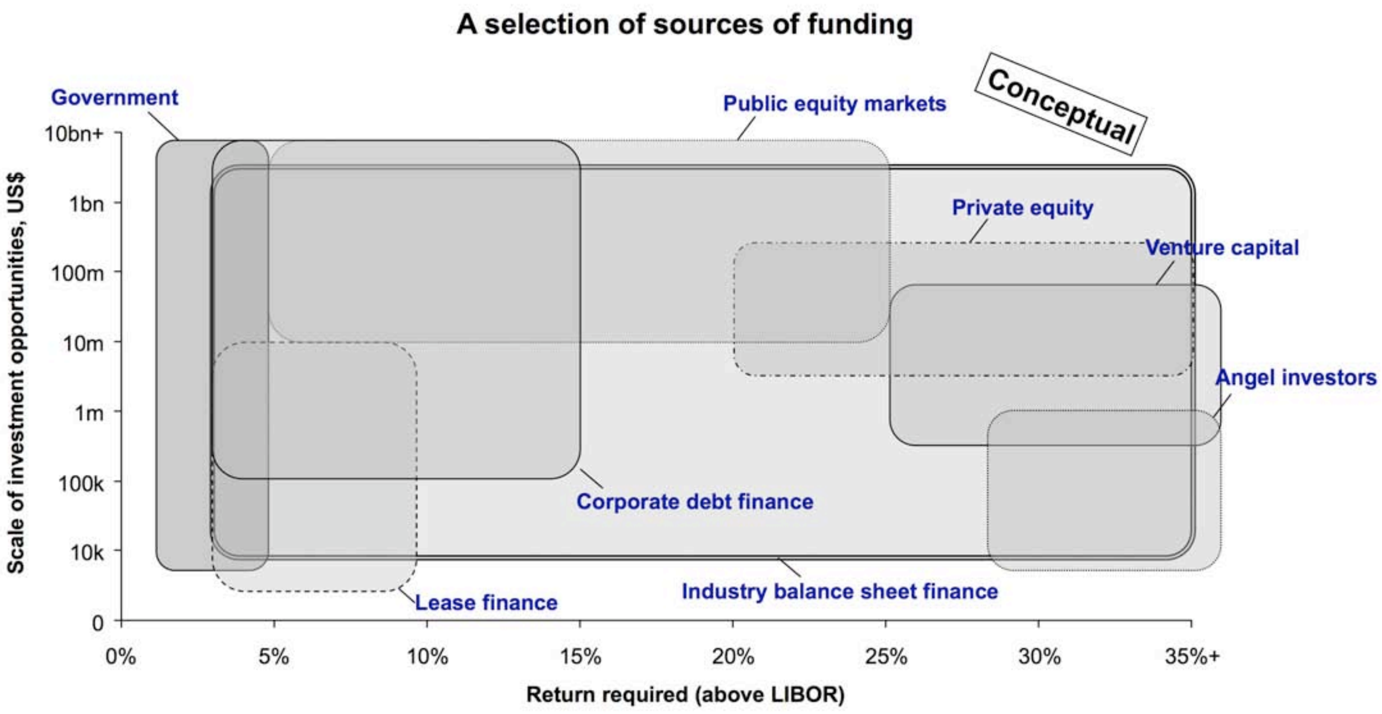
[44] IMF, 2010 - Petroleum Product Subsidies: Costly, Inequitable, and Rising

[45] WWF, Reinventing the city – three prerequisites for greening urban infrastructures

There is a very wide range of sources of capital from the private sector (Exhibit 29). Investors are willing to invest at a broad range of rates of return – provided they can assess the risk involved with reasonable confidence. For example, through corporate debt finance or project finance, companies can secure finance for very large amounts for low-risk projects for which the lenders require low rates of return (because of the low risk). At the other extreme, large oil companies will invest many billions in a single oil rig – often featuring new technology – which is highly risky (hence, they expect very high rates of return).

Exhibit 29: A selection of sources of capital funding



It is, however, extremely difficult to finance high-risk projects with long payback periods. Low-risk projects with long payback periods can secure funding from leasing companies, debt finance or a number of other sources. However, when high risk is coupled with long payback, it is impossible to reliably assess the risk. As a result, these types of projects are typically only funded by governments in situations where there is a strong social benefit case for the investment.

The financing needs of each technology are unique – it is not possible to generalize a finance solution. From a high-level perspective, there are two common challenges:

- The commercial viability of many technology solutions remains to be proven – a good financing solution can match parties' liabilities to the risks they can control and help to align incentives but cannot alter the fundamentals of a technology.
- There is not enough information available about many new technologies for the financial sector to evaluate risks (or the methodologies are untested) or to validate returns.

The first of these challenges requires technologies to be developed further – this will most likely require government investment since at this stage of development the risks are very high and the payback periods very long. The second of these challenges requires the finance community, government and industry to work together to accelerate the process of gathering the right information and so may require development of new business models to unlock existing sources of financing.

Energy efficiency

Light duty vehicles

Financing new vehicle purchases is very well established – either with outright purchase or a variety of loan or lease options. Fleet and commercial buyers are economically rational so will purchase technologies that decrease total cost of ownership and/or achieve corporate objectives for CO_2 emission reductions. Technologies that do not satisfy the cost-value proposition will not be adopted unless regulation is implemented – no financing mechanism can solve the fundamental economics of a technology. Individual consumers often have very high personal discount rates (studies have found rates between 20-25%) which will undervalue future fuel savings. While lease financing can mitigate this problem, many consumers prefer to buy outright. Hence policies – performance standards in particular – will be needed to solve this problem.

Retrofits for light duty vehicles can also be financed through a variety of loan or lease mechanisms. There are no major financing barriers to the adoption of retrofit which can reduce total cost of ownership.

There are few major barriers to financing energy-efficient technologies in the technology development or infrastructure stage. The infrastructure for conventional vehicles is already very well established – energy-efficient technologies do not need extra infrastructure. There are many sources of finance for technology development through the major OEMs and key suppliers, private equity, venture capital or government R&D grants.

Heavy duty vehicles

As with light duty vehicles, the financing needs in the R&D and infrastructure development stages are well met. There are also well-established financing options for new vehicles and commercial operators can be expected to make economically rational decisions provided they have sufficient information. For large operators, gathering sufficient information about new technologies is typically not a problem. However, smaller operators face a number of information-related challenges for both new vehicle and retrofit technologies:

- Lack of awareness of the relevant technologies.
- Inability to choose between them since costs and benefits are unclear. The precise fuel savings require expertise to predict since they will depend on a wide range of variables including vehicle type, duty cycle, driving style and mileage. Moreover, different technology providers claim different savings and costs.
- Even if the operator is willing to take the risk, justifying the savings to the bank will be difficult.

As discussed in the partnerships section, partnerships such as SmartWay can be very effective at solving the problem of information gaps. However, there is also potential for the application of an ESCO-type model. In this model, the ESCO develops expertise of a technology (or technologies); the ESCO installs the technology and bears the upfront cost. In return, the client pays the ESCO a portion of the energy savings (there are many ways to structure this). An example in the transport sector, similar to this model, is the Shell FuelSave Partner service which is outlined below.

Shell FuelSave Partner

Shell FuelSave Partner is a subscription-based telematics service which allows commercial transport fleet customers to cut fuel costs by up to 10%.

Shell partnered with IBM, Airbiquity (a provider of vehicle information connectivity services) and Continental Automotive to develop the service, which uses telematics to monitor engine and driving data, and fuelling data from the euroShell Fuel Card. This information is relayed wirelessly to a data server which integrates the information and provides managers with metrics, via a Web portal, that can be used to improve operations. The system can calculate metrics such as:

- Output measures: MPG; g CO_2 per tonne-mile
- Operational measures: idle time; average payload; urban driving %
- Driving style measures: harsh braking; # gear changes/mile; sharp acceleration
- Shell is responsible for the upfront installation costs and system management costs. Customers are charged a subscription for the service. The service is offered to Shell's euroShell Card customers, allowing Shell to have confidence in the credit worthiness of the customers.

Aviation

The aviation industry is relatively consolidated, and airlines have good information about the technology options and are rational buyers. Airlines spend very significant amounts of money to replace older aircraft and to cover air traffic growth through new aircraft. From 2010 to 2030, the aviation industry is expected to invest ~US$ 2,600 billion to buy ~30,000 new aircraft. There is a well-established financing market, with lease financing for planes being the most common source. Accelerated fleet rollover through early aircraft retirement would come at a high cost because of the large upfront investment and the long aircraft lifetimes of up to 40 years. Thus, this would not be very economically efficient considering the large cost and relatively low additional fuel efficiency improvements.

The anticipated ~US$ 10 billion of incremental financing required for research on radically new aircraft technology that could then be built into new generations of aircraft earlier as otherwise anticipated (e.g. would lead to open rotor engines and blended wing bodies being commercialized by 2030 rather than 2040) is relatively small. The challenge here lies more in a lack of policy incentives and differing interests. Financing from private investors in these areas seem rather unattractive because of the early stages of the current research and the long payback periods in the industry.

For operation improvements, financing is not an issue as the improvement opportunities identified by the industry could be implemented at a net benefit by the airlines.

In regard to aviation infrastructure improvements, most investments such as new ATM systems are financed by the government with the cost later being charged back to carriers for the use of the system. In developed countries, governments have already committed to fund new aviation infrastructure such as SESAR in Europe and NextGen in the US. The challenge in these countries is more the lack of political will and perceived urgency for implementation. By contrast, in developing countries an issue is seen in the availability of financing for new aviation infrastructure. Here, the development banks can play a major role as possible sources of additional funding.

The largest financing need for the aviation industry exists on aviation biofuels which are still at an early stage of development. Government funding is critical and funding from development banks could also have a significant impact for biofuel projects set up from a developmental agenda perspective in developing countries.

A global emissions trading scheme (ETS) tailored to the aviation industry could be a good way to give security to investors and channel additional funding to clean technologies including research and scaling of radically new aircraft technology and aviation biofuels. Some of the funds raised, for example through auctioning of a portion of allowances or penalties, should be reinvested in the industry for fuel efficiency improvement and CO_2 emission reduction and credits could be given to companies making early investments in fuel efficiency. The global nature of the aviation industry lends itself well to such a scheme; however, getting commitment would still require a great deal of coordination from global policy-makers.

Marine

Two challenges in particular affect the ability of ship owners to secure financing for energy-efficient technologies:

- The split incentive problem – ship owners may not capture the full benefit of fuel savings. As a result, energy-efficient ships are undervalued which makes finance companies reluctant to support retrofits or expensive energy-efficient options on new builds.
- Ship owners lack experience of new technologies and so find it difficult to validate performance or cost claims. Even if a ship owner would like to install a retrofit, they will find it difficult to build a compelling business case to secure financing.

The split incentive problem is significant in the time charter and bareboat charter markets but is minimal in the spot market, which currently comprises 70% of the market (see the earlier case study on the Carbon War Room for details). There is little opportunity for financing to solve this problem. However, partnerships such as Operation Rock the Boat are already tackling the information gap. Moreover, this reporting could be made stronger if the IMO mandates reporting with independent validation from a classification society.

The problem of lack of experience is more widespread. In this case, policy and partnerships are less well-suited to address the challenge. Large companies can undertake pilots of new technologies and spread the trial costs over a large fleet (see the Maersk Line case study below). Moreover, these companies have ready access to finance. However, the shipping industry (particularly the tanker and bulker sectors) is highly fragmented and smaller companies do not have the in-house expertise to run such assessments and cannot afford to undertake pilot trials.

This suggests a role for an independent party to test technologies and provide information to make it easier for small companies to prepare business cases. However, there are a number of problems with this approach. First, industry associations in the marine industry must be international and, as a result, are extremely slow moving. Second, since shipping is international, no single government has sufficient incentive to set up such a scheme. Finally, ships are not standardized. A tailored analysis needs to be conducted for each ship to assess the best technology options and the potential. This would require dedicated experts – who would likely need to be employed by the financer – to align incentives to ensure accurate assessments.

An ESCO-type model could also work in the marine sector. Although there are challenges associated with earmarking the cash flows, there may be mechanisms to make this work. For example:

- The Shell Europe case from the road transport sector demonstrates the principle.
- BP marine already has contracts in place with many ship operators (where they are able to charge differential prices based on credit-worthiness) so might have the information and contractual mechanism in place to provide a similar on-bill financing product.

Maersk Line retrofit programme

Maersk Line has begun a retrofit programme for their fleet. The programme will systematically identify fuel-saving retrofits to be rolled out across the fleet over the next five to seven years.

The programme team was formed one year ago and began work on an analysis tool which would enable Maersk Line to analyse their fleet to establish which retrofit technologies would be appropriate for which vessels. At the time of printing, this stage was nearing completion.

The next stage includes conducting detailed studies for each ship to validate the potential efficiency gains and preparing business cases for the retrofits. The retrofits will be scheduled to fit with each ship's drydock schedule (typically a five to seven year cycle) to avoid the high opportunity cost associated with bringing a ship out of service outside of its scheduled maintenance cycle.

Maersk Line will invest in technologies which have a reasonable payback time, probably in the order of two to five years. Maersk Line may invest in technologies with longer payback, but only for new ships. The programme is expected to cost hundreds of millions of dollars, perhaps billions. Although this is a large investment, the potential prize for even a modest percentage saving is huge: Maersk Line's annual fuel bill is US$ 5-6 billion.

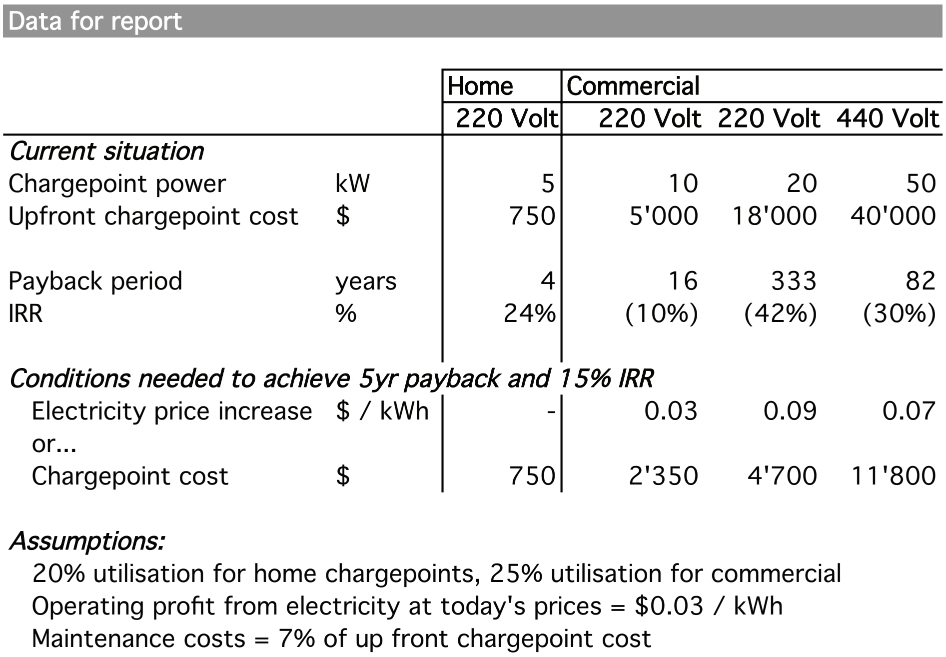
Maersk Line will primarily install the retrofits only on their own vessels. However, the company may also try to make arrangements for installing retrofits on vessels they have on time charter if the outstanding period of the charter far exceeds the payback period for technology by some margin. However, it is more challenging to embark on retrofits on charter vessels and a special model will probably need to be developed. Potentially, a programme for retrofitting charter vessels could become a success story on how to overcome the split incentive problem by engaging ship owners to negotiate a way of sharing the investment costs.

Electric vehicles

Financing the infrastructure

As we discussed in the technology overview section, in addition to private charging stations a broad network of public charging stations will be necessary for electric vehicles to reach large-scale adoption (switching stations would also aid adoption). At today's electricity prices and charge station costs, public charging points are highly unlikely to be profitable. A distinction should be made between super-fast public charging stations and regular public charging points. Super-fast public charging stations (with ~30 minute charge times) could operate similarly to current fuel stations and would hence be able to gain revenue from concession stores. However, these stations alone will not be sufficient – on-street parking will be necessary for large-scale adoption and in the absence of other revenue sources, at today's electricity prices, these stations are not economic. As a result, new business models, and potentially government support, will be needed to finance public, on-street charging points.

Exhibit 30: Typical charging point economics, 2011



Data for report

		Home	Commercial		
		220 Volt	220 Volt	220 Volt	440 Volt
Current situation					
Chargepoint power	kW	5	10	20	50
Upfront chargepoint cost	$	750	5'000	18'000	40'000
Payback period	years	4	16	333	82
IRR	%	24%	(10%)	(42%)	(30%)
Conditions needed to achieve 5yr payback and 15% IRR					
Electricity price increase	$ / kWh	-	0.03	0.09	0.07
or...					
Chargepoint cost	$	750	2'350	4'700	11'800

Assumptions:

20% utilisation for home chargepoints, 25% utilisation for commercial
Operating profit from electricity at today's prices = $0.03 / kWh
Maintenance costs = 7% of up front chargepoint cost

The deployment of the public charging infrastructure is critical to the market success of EVs. The capital investment required is high. Although the cost of charging stations is expected to decrease as volumes increase and the technology evolves, innovative investment solutions are needed.

There are a variety of ways to achieve this:

- Charge customers on a subscription basis for the use of charging and/or switch stations (Better Place uses this model).
- Utilities could differentially price the electricity they provide depending on the destination, i.e. use smart meters to charge customers more for charging vehicles than using electricity at home. A risk with this approach is that customers may feel uneasy paying a higher rate for electricity for their cars than for their homes.
- Government support – either direct or indirect. For example, municipalities could cede control of public parking (and associated revenues) to private operators on the condition that they make the necessary investment in the charging infrastructure.

Financing the vehicles

In addition to an attractive total cost of ownership (TCO), electric vehicles need to offer a total value proposition that is attractive to the customer, which may include no local CO_2 emissions, access to city centres and overall vehicle performance. As discussed in the technology overview section, there are already segments of the market where TCO is lower – customers who drive high annual mileage spread across many predictable, relatively short journeys, in regions where fuel costs are high. However, for the majority of the market, electric vehicles remain too expensive at present unless subsidies are in place.

However, in many markets, even when the TCO is lower for electric vehicles, there are two major financing challenges: the high upfront cost and uncertainty about residual values. The uncertainty about residual values is the result of a number of factors:

- Batteries are expected to retain at least 80% of their capacity for 8 to 10 years, dependent on how they are used.
- The future cost and performance of new batteries and, hence, replacement cost are unknown (although costs are universally expected to fall rapidly).

- The take-up rate for electric vehicles and rate of development of infrastructure are unknown. As a result there is great uncertainty regarding future demand for second-hand vehicles.

The high upfront cost problem can be resolved either by leasing the battery or by selling batteries on a subscription plan. This relies on companies being willing to provide lease finance for batteries which, although not trivial, is workable. The lease provider must be willing to underwrite the risk that battery failure rates will be higher than expected and will also need to assume a residual value.

Assigning a residual value to the batteries is perhaps the biggest challenge for financing electric vehicles. Although there are many risk factors, these risks can be controlled.

- There is already sufficient information about batteries to gain a reasonable idea of failure rates so the extent of any error vs expectation should not be high – modern lithium ion batteries are monitored at the individual cell level. The lessor can use a conservative estimate at first until better data is available. The cost of error is limited because sales volumes in the first few years will not be high as electric vehicles are at the beginning of the adoption S-curve.
- There is limited risk of a step-change technology arriving without warning. It would take a minimum of five years for a breakthrough technology to reach the market, by which point the downside would be limited since the residual value would already be low.
- While there are a number of potential markets for second-hand batteries (e.g. energy time-shifting, renewables firming, backup power, auxiliary power on trucks), these markets are not yet well developed and there is not yet enough experience to know how used batteries will perform in these applications. However, these markets are potentially huge and the economics suggest that for stationary power applications, the residual value of a battery would be determined by the difference between the on-peak and off-peak price of electricity, which varies greatly by region.

Generally, it will take some time until the secondary market for batteries is developed and with it the price for used batteries – the value of second-hand vehicles will be determined by the individual markets based on market penetration and customer preferences. Low residual values would require faster lease repayments which would increase the upfront cost of electric vehicles. However, many countries are offering large one-off subsidies for electric vehicles for the next few years which will reduce the upfront costs for long enough for the finance industry to become comfortable estimating residual values. Moreover, even with slightly higher upfront costs, electric vehicles will still be attractive to a large enough segment of the market to create demand for the first few years until residuals can be estimated.

There is much debate regarding whether batteries should be purchased outright or leased (or paid for by subscription). There are good reasons why customers would favour a lease or subscription model for the battery:

- It avoids high upfront costs.
- The lease company is responsible for any faults with the battery.
- The lease company is responsible for the resale of the battery. Resale is likely to be to new markets which the lease company would have better information about and cheaper access to.
- If there is no leasing market, then towards the end of the battery's warranty (which may be long – Nissan and GM are offering eight year warranties) there is the risk of a large, imminent, upfront cost of replacing the battery if the battery fails.

Some parties in the leasing industry have voiced concerns that there are critical barriers which prevent a battery leasing model from working. The first concern is that it would be impossible to insure a vehicle if its battery is leased because it would be difficult to decide how to divide the payout in the event of a write-off. The simple solution to this is for the battery to be insured separately from the car, in the same way that a leased car is insured – i.e. the lease payment for the battery covers the insurance premium. The second concern is that it would be impossible to sell a second-hand electric car without a battery. A functioning lease market removes this concern – a buyer could simply begin a new lease.

Alternative fuels

The financing of first-generation biofuels and CNG/LPG is well established. Second-generation biofuels have been able to secure financing up to pilot scale but are struggling to get financing to build full commercial-scale plants. In addition to technology risks, feedstock agreements and off-take agreements need to be in place. There are also significant demand-side risks driven by uncertain and ineffective (and sometimes conflicting) policies. Very few companies have resolved all these issues.

Where companies are able to demonstrate that the technology is ready, they have been able to get financing – typically a mix of government and private sector. For example:

- Chemrec and Haldor Topsøe received funding to construct a plant which will produce 40 million gallons per year of bioDME (a gaseous fuel which can be used in diesel engines). The plant will be located in Piteå, Sweden, and will use forest residues as feedstock. It will be the first of its kind at this scale. The investment is estimated to be ~US$ 400 million and will come from a variety of sources, including the Swedish government (providing a ~US$ 70 million grant), VantagePoint Venture Partners and the European Investment Bank.
- Wisconsin-based company Virent recently raised US$ 46 million, including follow-on investments from Shell and Cargill. This funding followed the successful start-up of the world's first biogasoline plant in March 2010, which can produce 10,000 gallons per year of biogasoline.
- Inbicon (a subsidiary of Danish state-owned energy company, DONG) has established one of the world's largest second-generation ethanol plants at Kalundborg in Denmark, fed by wheat straw. Inbicon established a partnership with Statoil to supply them with ethanol for blending into E5 for the Danish market.
- DuPont partnered with Danisco in R&D to build demonstration scale second-generation ethanol plants. In January 2011, it was announced that DuPont intended to buy Danisco in a US$ 5.8 billion deal, which some analysts suggested indicated that technology for second- and third-generation ethanol was moving closer to commercial exploitation.

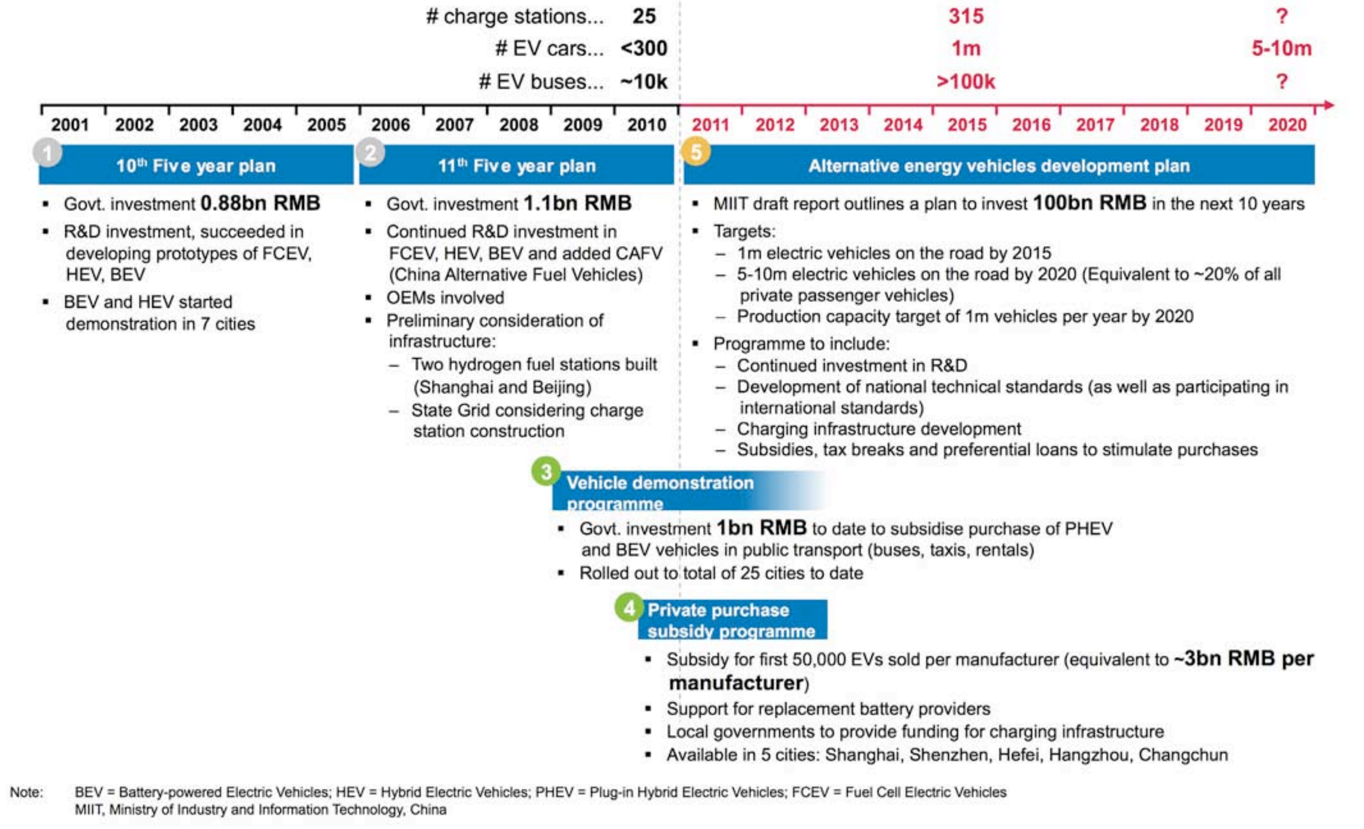
Experience from first-generation biofuels suggests that the information curve is steep. Building the world's first plant invariably poses new risks which are difficult to assess. The second and third plants are much less risky and after a few plants have been built, the market will have enough information to evaluate risk satisfactorily, allowing capital to flow efficiently. This suggests the role of government is to support the first few investments to overcome the initial lack of information barrier and then allow private investment to take over, as well as helping with clear policy to minimize demand-side risks.

Electric vehicles in China: A case study

China has set high targets for electric vehicle sales: 1 million electric vehicles on the road by 2015 and 5-10 million electric vehicles on the road by 2020. Yet so far, car sales have been slow (<300 in total, though ~10,000 electric buses are now on the road) and little charge station infrastructure is in place.

The government has invested in R&D over the last decade and recently introduced generous production subsidies targeted at mass adoption (Exhibit 31). However, the technology is not yet sufficiently mature and infrastructure development is minimal which has so far prevented the production subsidies from attracting much take-up. To address these issues, the government recently formed a large partnership of state-owned companies to develop EV standards and technology, though whether such a large partnership will prove to be suited to R&D is as yet unclear. A further barrier to EV deployment is the government price controls which maintain artificially low gasoline prices. Despite the drawbacks, China is likely to develop the market rapidly since the government is strongly committed to EVs and has the ability to put in place drastic regulations.

Exhibit 31: Chinese EV policies and targets roadmap



# charge stations...	25	315	?
# EV cars...	<300	1m	5-10m
# EV buses...	~10k	>100k	?

10th Five year plan

- Govt. investment **0.88bn RMB**
- R&D investment, succeeded in developing prototypes of FCEV, HEV, BEV
- BEV and HEV started demonstration in 7 cities

11th Five year plan

- Govt. investment **1.1bn RMB**
- Continued R&D investment in FCEV, HEV, BEV and added CAFV (China Alternative Fuel Vehicles)
- OEMs involved
- Preliminary consideration of infrastructure:
  - Two hydrogen fuel stations built (Shanghai and Beijing)
  - State Grid considering charge station construction

Alternative energy vehicles development plan

- MIIT draft report outlines a plan to invest **100bn RMB** in the next 10 years
- Targets:
  - 1m electric vehicles on the road by 2015
  - 5-10m electric vehicles on the road by 2020 (Equivalent to ~20% of all private passenger vehicles)
  - Production capacity target of 1m vehicles per year by 2020
- Programme to include:
  - Continued investment in R&D
  - Development of national technical standards (as well as participating in international standards)
  - Charging infrastructure development
  - Subsidies, tax breaks and preferential loans to stimulate purchases

Vehicle demonstration programme

- Govt. investment **1bn RMB** to date to subsidise purchase of PHEV and BEV vehicles in public transport (buses, taxis, rentals)
- Rolled out to total of 25 cities to date

Private purchase subsidy programme

- Subsidy for first 50,000 EVs sold per manufacturer (equivalent to **~3bn RMB per manufacturer**)
- Support for replacement battery providers
- Local governments to provide funding for charging infrastructure
- Available in 5 cities: Shanghai, Shenzhen, Hefei, Hangzhou, Changchun

Note: BEV = Battery-powered Electric Vehicles; HEV = Hybrid Electric Vehicles; PHEV = Plug-in Hybrid Electric Vehicles; FCEV = Fuel Cell Electric Vehicles
MIIT, Ministry of Industry and Information Technology, China

(1) China's 10th Five Year Plan: The government invested 0.88 billion RMB in electric vehicles, almost exclusively on R&D. This resulted in prototypes of FCEVs (fuel cell electric vehicles), HEVs (hybrid electric vehicles) and BEVs (battery electric vehicles). BEV and HEV pilot trials were started in seven cities.

(2) China's 11th Five Year Plan: The government invested 1.1 billion RMB in electric vehicles, focusing primarily on R&D and involving domestic OEMs. The government began consideration of infrastructure: two hydrogen fuel stations were built and the state grid considered charge station construction.

(3) Vehicle demonstration programme: The government has invested 1 billion RMB to date to subsidize the purchase of PHEV and BEV vehicles in public transport (buses, taxis, rentals). This has been rolled out to a total of 25 cities to date.

(4) Private purchase subsidy programme: A subsidy programme is rolled out in five cities: Shanghai, Shenzhen, Hefei, Hangzhou and Changchun. Up to 60,000 RMB per vehicle is available (based on the battery size) for the first 50,000 EVs sold per manufacturer (equivalent to ~3 billion RMB per manufacturer). Support is given for replacement battery providers. Local governments are instructed to provide funding for charging infrastructure.

(5) Alternative energy vehicles development plan: A Ministry of Industry and Information Technology (MIIT) draft report outlines a plan to invest 100 billion RMB (~US$ 15 billion) in the next 10 years in new energy vehicles. The programme is to include continued investment in R&D; development of national technical standards (as well as participating in international standards); charging infrastructure development; subsidies, tax breaks and preferential loans to stimulate purchases.

These policies have influenced the long-term plans of local OEMs: Dongfeng Motor, Guangzhou Automobile, Tianjin Qingyuan, BYD, Haima Automotive and Wanxiang are all developing electric vehicles, and many more companies are developing hybrids. However, these efforts have not yet translated into sales. BYD is the first Chinese OEM to have launched an electric car on the market – the F3DM, a plug-in hybrid. Since December 2008, fewer than 300 F3DMs have been sold, the majority of which were to government, despite the F3DM being available to the public in Shenzhen since March 2010. The lack of infrastructure (only ~25 charging stations across the country at the end of 2010) and the high price of the F3DM, which is double the price of the equivalent non-hybrid F3, are the main reasons for the slow sales.

The Chinese government recognizes these challenges and recently formed an alliance of 16 state-owned enterprises to accelerate EV development. The SASAC[1] announced a coalition in August 2010 of 16 state-owned enterprises (SOEs), designed to help China reach 500,000 annual sales of plug-in vehicles within three years by sharing technology developments. To allow for some competition, while co-developed technologies will be shared and technical interfaces will be standardized, independently developed technologies can be owned individually. The SASAC will allocate 1.3 billion RMB in 2010 to the alliance and plans to invest a total of 100 billion RMB by 2012. The alliance includes companies from across the value chain:

Auto manufacturers...
- SAIC
- Dongfeng
- FAW

Other transport...
- China South Locomotive and Rolling Stock Corp.
- China Aviation Technology Import-Export Corp.
- Air China Industry and Technology
- Aviation Industry Corporation of China

Oil companies...
- China National Offshore Oil Corporation
- China National Petroleum Corp.
- China Petroleum and Chemical Corp.

Utilities...
- China Southern Power Grid Company
- Dongfang Electric
- State Grid

Other...
- General Research Institute for Nonferrous Metals
- Chial Poly Group
- Chian South Industries Group

The large-scale SASAC partnership seems ill-suited to fostering innovation. Although IP issues are mitigated by common government ownership, the coordination challenge in such a large partnership will be high. Moreover, the companies involved do not have a reputation for being innovative. A further risk of this approach is that government support for the alliance could damage privately held companies such as BYD and Geely, which are currently both more advanced and more innovative.

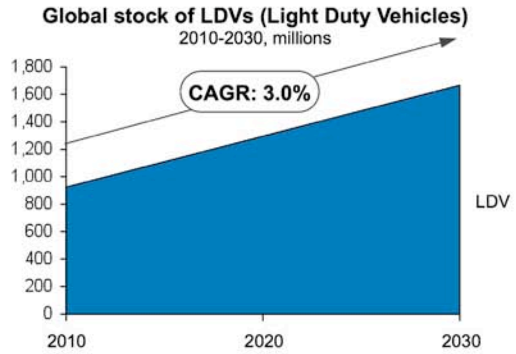
The government is also promoting smaller scale partnerships. In May 2010, BYD formed a JV (Pengcheng Electric Taxi Co. Ltd) with the state-owned Shenzhen Bus Group (SBG) to trial electric taxis. BYD has now supplied 50 of its E6 vehicles for US$ 40,000 each. It had planned to supply 100 for the end of 2010 but missed that target since the trials were hampered by a lack of infrastructure. There are only three charging stations in Shenzhen and, although the government planned 13 by the end of the year, only one had been added in the six months leading to November.

Nissan and Wuhan city signed an agreement in March 2010 to develop electric mobility in the city. Nissan will provide 25 of its Leaf vehicles for a market feasibility study to begin in 2011. To support the effort, the Wuhan government will build 250 charging points in selected areas. In addition, Nissan and the Wuhan government will collaborate on a consumer education and awareness programme.

[1] The state-owned Assets Supervision and Administration Commission of the State Council (SASAC) manages and regulates the state-owned enterprises (SOEs). It reports directly to the State Council.

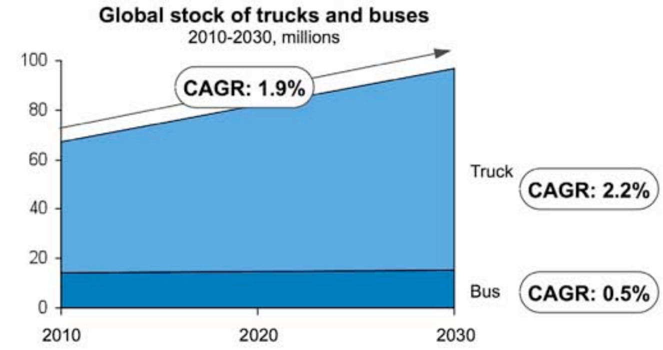
Appendix

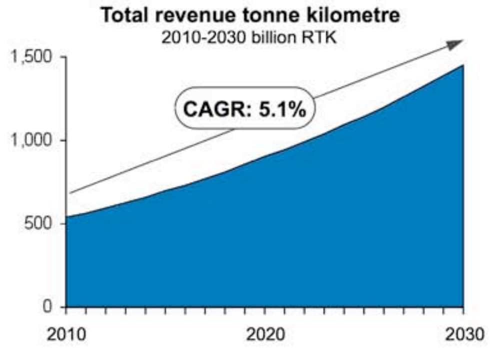
Assumptions for the scenarios



Comments

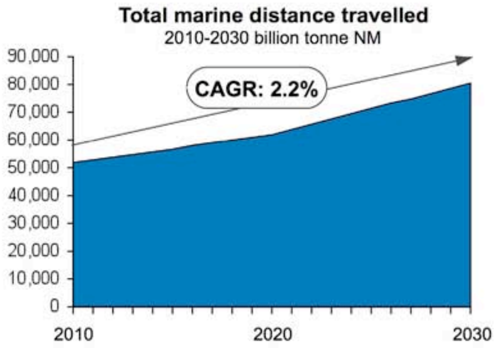
- The majority of the growth is driven by China and India with low growth in OECD countries





Comments

- The World Economic Forum aviation project titled "Policies and Collaborative Partnership for Sustainable Aviation" is considering airline industry trends in more detail
- Much of forecast data from FESG task group at ICAO
- For passenger planes, the revenue passenger kilometre metric (RPK) has been converted to RTK using ICAO conversion rate



- IMO uses the IEA's global growth assumptions, we are using the "B1" scenario
- Majority of growth is driven by container shipping, which grows by 13,000 billion tonne NM

Sources: IEA, IMO, IATA, Booz & Company

- Base scenario assumptions -

Overall assumptions and output

	2010	2030	2010 - 2030 CAGR
# Vehicles			
LDV	921	1,668	3.0%
Truck	53	82	2.2%
Bus	14	16	0.5%
Aviation (billion RTK)	26,000	45,500	2.8%
Marine (billion tonne miles)	51,796	80,555	2.2%
Indexed energy consumption baseline (total working fleet)			
LDV	1.00	0.80	(1.1%)
Truck	1.00	0.79	(1.2%)
Bus	1.00	0.74	(1.5%)
Aviation	1.00	1.09	0.4%
Marine	1.00	0.77	(1.3%)
Energy consumption baseline (Mtoe / year)			
LDV	1,144	1,667	1.9%
Truck	379	464	1.0%
Bus	81	66	(1.0%)
Aviation	215	411	3.3%
Marine	227	272	0.9%
Rail	71	76	0.4%
Other	69	125	3.0%
Total	2,186	3,082	1.7%

Share of new LDV sales

	2010	2020	2030
Gasoline	81%	74%	68%
Diesel	17%	19%	19%
PHEV	0.0%	1.8%	2.9%
EV	0.0%	2.0%	5.5%
CNG / LPG	1.5%	2.8%	4.0%

Average vehicle lifetimes

	Years	Source
LDV	15	IEA
Truck	28	TIAX
Bus	20	EC – TREMOVE
Marine	30	IMO
Aviation	21	CNS team

The base scenario energy baseline is the same as the base case from the WEF aviation project titled 'Policies and Collaborative Partnership for Sustainable Aviation'

- Foundation building scenario assumptions -

Overall assumptions and output

	2010	2030	2010 - 2030 CAGR
# Vehicles			
LDV	921	1,668	3.0%
Truck	53	82	2.2%
Bus	14	16	0.5%
Aviation (bn RTK)	26,000	45,500	2.8%
Marine (bn tonne-miles)	51,796	80,555	2.2%
Indexed energy consumption baseline (total working fleet)			
LDV	1.00	0.70	(1.8%)
Truck	1.00	0.70	(1.8%)
Bus	1.00	0.65	(2.1%)
Aviation	1.00	1.00	0.0%
Marine	1.00	0.61	(2.5%)
Energy consumption baseline (Mtoe/year)			
LDV	1,144	1,443	1.2%
Truck	379	413	0.4%
Bus	81	58	(1.7%)
Aviation	215	377	2.8%
Marine	227	214	(0.3%)
Rail	71	76	0.4%
Other	69	77	0.5%
Total	2,186	2,654	1.0%

Share of new LDV sales

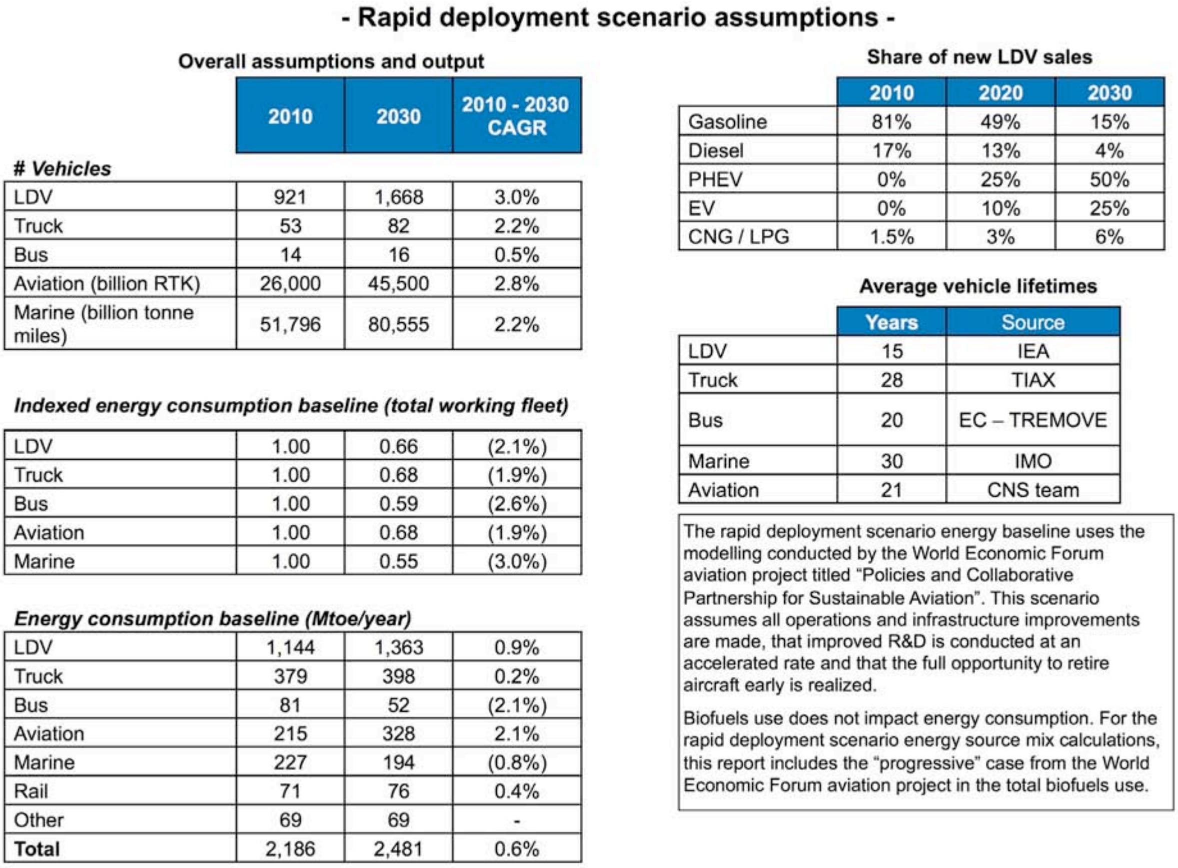
	2010	2020	2030
Gasoline	81%	68%	37%
Diesel	17%	17%	10%
PHEV	0%	8%	35%
EV	0%	4%	12%
CNG / LPG	1.5%	3%	6%

Average vehicle lifetimes

	Years	Source
LDV	15	IEA
Truck	28	TIAX
Bus	20	EC – TREMOVE
Marine	30	IMO
Aviation	21	CNS team

The foundation building scenario energy baseline uses the modelling conducted by the WEF aviation project titled 'Policies and Collaborative Partnership for Sustainable Aviation'. This scenario assumes all operations and infrastructure improvements are made, that improved R&D is conducted at an accelerated rate and that half of the opportunity to retire aircraft early is realised.

Biofuels use does not impact energy consumption. For the foundation building scenario energy source mix calculations, this report includes the 'conservative' case from the WEF aviation project in the total biofuels use.



- Rapid deployment scenario assumptions -

Overall assumptions and output

	2010	2030	2010 - 2030 CAGR
# Vehicles			
LDV	921	1,668	3.0%
Truck	53	82	2.2%
Bus	14	16	0.5%
Aviation (billion RTK)	26,000	45,500	2.8%
Marine (billion tonne miles)	51,796	80,555	2.2%

Indexed energy consumption baseline (total working fleet)

LDV	1.00	0.66	(2.1%)
Truck	1.00	0.68	(1.9%)
Bus	1.00	0.59	(2.6%)
Aviation	1.00	0.68	(1.9%)
Marine	1.00	0.55	(3.0%)

Energy consumption baseline (Mtoe/year)

LDV	1,144	1,363	0.9%
Truck	379	398	0.2%
Bus	81	52	(2.1%)
Aviation	215	328	2.1%
Marine	227	194	(0.8%)
Rail	71	76	0.4%
Other	69	69	-
Total	2,186	2,481	0.6%

Share of new LDV sales

	2010	2020	2030
Gasoline	81%	49%	15%
Diesel	17%	13%	4%
PHEV	0%	25%	50%
EV	0%	10%	25%
CNG / LPG	1.5%	3%	6%

Average vehicle lifetimes

	Years	Source
LDV	15	IEA
Truck	28	TIAX
Bus	20	EC – TREMOVE
Marine	30	IMO
Aviation	21	CNS team

The rapid deployment scenario energy baseline uses the modelling conducted by the World Economic Forum aviation project titled "Policies and Collaborative Partnership for Sustainable Aviation". This scenario assumes all operations and infrastructure improvements are made, that improved R&D is conducted at an accelerated rate and that the full opportunity to retire aircraft early is realized.

Biofuels use does not impact energy consumption. For the rapid deployment scenario energy source mix calculations, this report includes the "progressive" case from the World Economic Forum aviation project in the total biofuels use.

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