New Business Models for Alternative Fuel and Alternative Powertrain vehicles; an infrastructure perspective

by

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Appendix 1 – EV charging and business models
1. Introduction

This report investigates the business model challenges of bringing to market new infrastructures for alternative fuel vehicles. There is a perception that there needs to be a co-ordinated co-deployment of vehicles and infrastructures to assure both the producers of vehicles and alternative fuel infrastructures, and of course to allay consumer concerns. In the context of substantial uncertainty over which bundles of alternative technologies and fuels will prevail, and in which locations, there is clearly a concomitantly high degree of risk in the face of substantial investment costs.

In recent decades, the car industry has not taken much interest in infrastructure; the roads were largely provided at public expense, while the oil industry provided the fuel for its vehicles – mostly competently enough. Car manufacturers could therefore concentrate on making and selling cars, providing spare parts and engaging in a few other services. However, with increasing electrification of cars, these past certainties are coming under growing pressure. These developments also put new demands on local authorities, car park providers, garage forecourt owners, and others who need to provide space to accommodate new fuels, parking provision with charging for EVs, and who also need to cope with new potential safety issues with such novel fuels and energy sources. Hydrogen, for example, is still associated with various dangers.

However, infrastructures in this context also includes issues such as the readiness of the supply chain to deliver the required technologies both in terms of vehicles and their support infrastructure. Although a comprehensive review and quantification of such issues is beyond the scope of this report, examples will be reviewed highlighting some of the constraints to further penetration of novel technologies presented by such issues. It is here that we are often confronted with a chicken and egg situation whereby the supply chain is waiting for demand, which is itself dependent on the supply capacity being available. For example, existing and planned automotive fuel cell capacity means that by 2015 only about 600,000 stacks could be supplied, with capacity rising to around 1.5 million by 2020. This would be sufficient for less than 2% of the world’s new cars to be fitted with fuel cells by then – hardly enough to make a major impact (Nieuwenhuis 2009).
2. Context: Economic austerity and environmental pressure

There are two general causes of technological and structural change in the automotive industry. The economic conditions include the state of demand and supply, prices, market structure and segmentation, the geographic distribution of such events, and of course competition and collaboration. The environmental conditions arise as a combination of an understanding of the actual or potential environmental consequences of the manufacture and use of cars, and the ways in which that understanding is fabricated, negotiated and translated into changes in the ‘regulation’ of the industry and its products. The two sets of issues are closely inter-twined in many ways; for example ACEA issued a press release in which it was claimed that the CO₂ regulations in the EU:

“...are far more stringent than those in the US, China or Japan. This will increase manufacturing costs in Europe, creating a competitive disadvantage for the region and further slowing the renewal of the fleet... Considering that most manufacturers are losing money in Europe at the moment, the industry needs as competitive a framework as possible. Targets - while ambitious - must be feasible. The overall regulatory framework and market environment must be supportive, as also agreed in the recently concluded CARS 21 process.” (ACEA, 2012)

It is not surprising therefore that Gordon et al. (2012), writing about the US case, also observe a degree of ‘pushback’ for support for AFVs and raise the possibility that this may be attributed to a lack of political willingness to support such initiatives during a period of fiscal austerity. There are two features that are unique about this historical moment. First, the industry as a whole (though not uniformly) is facing an unprecedented twin set of pressures from economic austerity and escalating environmental imperatives, having largely neglected the opportunity of previously profitable years to resolve the environmental issues more fully. Second, the automotive industry is unlikely to be able to make the forthcoming transition alone, but will probably have to do so in intersection with other previously distinct and separate sectors (Internet Service Providers; electricity generators and distributors; etc.), and with the state at national or local (city) level. Hence there are issues surrounding the orchestration of change processes, particularly in terms of the appropriate format to deploy alternative fuel vehicle infrastructures. The following points shape the analysis in this report:

- The automotive industry is under even more competitive pressure and stress than ever due to prolonged economic downturn in the EU and to some degree in certain other markets, such as the US.
• The industry faces major challenges realigning capacity to market demand on a global and regional basis with plant closures in traditional, more saturated markets becoming imperative.

• Further consolidation is expected, but on a global level the share taken by the top 5 and top 10 will continue to fall as new players from newly motorizing economies enter the market.

• Air quality and carbon emissions concerns continue to grow; possibly to be joined in the future by concerns over raw materials supply.

• Electricity generators are faced by energy supply concerns, de-regulation and carbon costs.

• Doubts remain over who should supply alternative energy vehicle infrastructures: state or private sector or a combination; precedents exist for all combinations.

Consolidation of the global automotive industry has not proceeded as expected by many. In particular, the share of the leading groups has actually fallen in the period from 1998 to 2010 as a consequence of declining sales in traditional locations, the break-up of some industry groups (e.g. DaimlerChrysler; Ford sale of Volvo, Land Rover, Jaguar, Aston Martin), and the protection afforded to emergent companies in India, China and elsewhere.

Table 2.1:

<table>
<thead>
<tr>
<th></th>
<th>1998 (m)</th>
<th>1998 (%)</th>
<th>2008 (m)</th>
<th>2008 (%)</th>
<th>2010 (m)</th>
<th>2010 (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top 5</td>
<td>28.6</td>
<td>54.1</td>
<td>33.2</td>
<td>47.9</td>
<td>34.8</td>
<td>44.7</td>
</tr>
<tr>
<td>Top 10</td>
<td>40.8</td>
<td>77.0</td>
<td>47.9</td>
<td>68.9</td>
<td>51.4</td>
<td>66.1</td>
</tr>
<tr>
<td>Total</td>
<td>52.9</td>
<td>100.0</td>
<td>69.5</td>
<td>100.0</td>
<td>77.7</td>
<td>100.0</td>
</tr>
</tbody>
</table>

(Source: OICA)
Despite the structural problems facing the automotive industry, and global economic conditions, there remains a broad consensus that a) global vehicle sales and total vehicles in use will continue to grow to at least 2030 and b) the majority of those vehicles will continue to use petrol or diesel power rather than any of the alternatives. For example BP (2012) forecast that the global fleet of vehicles will grow by 60% to 1.6 billion by 2030, mostly outside the OECD, and that petrol, diesel or biofuel will power 94% of those vehicles; compared with 4% for natural gas and only 1% for electricity. BP highlights the lack of policy support and infrastructure as constraining the growth in share of alternatives. The World Economic Forum predicts that across all transport modes by 2030 petrol, diesel and biofuel will account for 80% of energy consumption, compared with 3% each for gas and electricity, 8% for jet fuel, and 6% for ‘other’ (WEF, 2012). The European Commission, in their outlook for energy consumption by transport to 2030, noted that transport energy consumption (all types) grew from 27% of the EU25 total in 1990, to 31% in 2000 and with growth expected to continue with car use growing at 1.4% per annum from 2000 to 2030 (European Commission, 2005) – though this was in advance of the global economic crisis. There is rather less doubt about the expected growth in carbon emissions and the consequences for global climate change.
3. Alternatives Today

It is often thought that the global automotive car-scape is increasingly homogenised, and there is some validity in this view. Previously distinct national enclaves have been increasingly eroded by inter-market penetration and the deployment of cars broadly intended to be appropriate in all markets around the world. The ubiquity and underlying commonality of products, made possible through platform strategies, global sourcing and modular systems components design becomes readily apparent when large scale recalls are announced due to faulty components, which cover ranges of models. Nonetheless, car markets and indeed car cultures remain stubbornly different both at the trivial and at the substantive levels.

The diversity is evident in, for example, the significance of the Kei class segment in Japan; of diesel engined cars in Europe; of the ‘light truck’ segment and automatic transmissions in North America; and of the importance of two-wheeler and three-wheeler vehicles in many Asian markets.

As the search for alternatives to ICEs progresses, so to some degree does more diversity emerge. Hence the growth of the sugarcane-derived ethanol in Brazil and the use of E100 fuel are almost unique to that country; while India has been progressing the use of natural gas in urban areas. At one time Iceland appeared ready to become the world’s first hydrogen economy, with a fleet of hydrogen vehicles to accompany that accolade. In recent years they have inclined more towards battery electric vehicle (BEV) technology.

At present, different countries (and sometimes even regions within countries) appear to have different priorities and expectations with regard to AFVs. Thus countries with a significant renewable energy potential or with a substantial installed nuclear power base might be more inclined towards battery electric vehicles (BEVs) or plug-in hybrid vehicles (PHEVs). Germany, with an automotive industry orientated around higher value vehicles and long driving distances, as well as the newly identified need to store excess electricity from renewables, has a stronger association with fuel cell electric vehicles FCEVs running on hydrogen.

Moreover, the process of hype cycles and of meeting obstacles to progress in one technology or another has resulted in fluctuations over time in the ‘promise’ each alternative may be thought to hold. Further technological breakthroughs or shifts in the external context can then suddenly render a moribund technology potentially viable once again. A crucial issue is whether (and when) a new dominant technology is likely to emerge
from this increasingly fragmented and chaotic picture to displace the established ICEs.

Many forecasts anticipate successive steps or phases of technology change with petrol ICE hybrids at one end of the process, and hydrogen fuel cells at the other. Such thinking informs many of the technology roadmaps. However, as the process of technological change plays out over time, and unevenly across different locations, the eventual outcome may be that no one technology comes to dominate as the ICE has done for the best part of 100 years or more. Actually, the equations that inform life cycle analysis and other attempts to define the most sustainable forms of mobility also tell us that it matters a great deal which locations are under consideration; and therefore we may conclude that the likely future is a tapestry of multiple and often over-lapping and competing technology packages embracing both vehicles and infrastructures.

The regionalisation of these technologies has become particularly clear in the case of biofuels, with the EU increasingly questioning its earlier support for these fuels, while Brazil’s programme enjoying a new lease of life due to flex-fuel technologies, and the US displaying significant support for these fuels. Other pockets of support exist in parts of Europe and Asia. For these reasons, we will review the technologies on a regional basis, in each case providing examples for each technology from a region that can be considered particularly advanced in providing for this technology.

**Biofuels – US**

The US EPA introduced the renewable fuel standard (RFS) in 2005. The standard mandates the amount of biofuel to be blended with gasoline. RFS informs any current infrastructure initiatives. In 2007 it was replaced by the RFS2. The mandate specifies the total volume of biofuel by year and divides it into categories, each with a GHG emissions reduction threshold (OECD 2012b).

In terms of the newly developing infrastructure for biofuels in the US, ethanol needs to be shipped to the more densely populated areas on the East and West coasts from the Midwest where it is produced (Schnepf and Yacobucci, 2007). It is expected that from about 2015 cellulosic ethanol will represent a large proportion of ethanol production (OECD 2012b). This may bring with it different infrastructure needs, as the supply chain is likely to change; feedstock for these fuels is available in the Midwest, but also in other parts of the country. If production is centralized, as with corn, economies of scale may be available for transport, if production is more dispersed, a more diverse solution may have to be used. The geographic distribution of the production of cellulosic ethanol will therefore determine infrastructure needs (BPC 2009)
Transport and distribution of ethanol raises a number of issues. Ethanol is corrosive and in many cases requires specialized pipelines, storage tanks and other transport equipment (Schnepf and Yacobucci 2007, DNV 2010). Furthermore, like brake-fluid, it is to some extent hydrophilic, attracting water and other residues (DNV 2010). In 2010 the modal mix for ethanol distribution was 66% rail, 29% road and a further 5% by barge (USDOE 2010).

Expansion of ethanol use will require investments in entirely new infrastructure (Schnepf and Yacobucci 2007, USDA 2010). McKinsey (2009) estimated that upgrading fuel terminals would cost some USD 2 billion, while upgrading rolling stock and rail terminals would cost USD 6.6 billion. Similarly, three or four new pipelines would cost USD 5 billion to USD 10 billion (Mckinsey 2009). This study also showed that increased blending would require a significant increase in investment. Also, with the removal of import tariffs, import of ethanol - e.g. from Brazil – creates the need for additional infrastructure in ports and transport from there to feed into the existing infrastructure.

There are currently only 276 forecourts in the US serving biodiesel and 2,268 offering ethanol (AFDC 2012). Fuel stations can add E85 on their existing forecourts, but additional costs would be involved for dispensers, excavation and concrete work, tanks and in some cases land. The US National Renewable Energy Laboratory (NREL) reports that for a new tank, the costs can range from USD 50,000 to USD 200,000. If an old tank can be retrofitted, the costs range from USD 2,500 to USD 30,000 (NREL 2008).

Currently most FFVs sold in the US run on ordinary petrol and diesel fuel, however, the size of the parc of such vehicles bought under various incentive schemes, means that potential for a greater uptake of bio-ethanol exists. A wider availability and attractive cost advantage combined with the risk reduction of flex-fuel technology could significantly increase the use of biofuels in the US.

**EVs – Norway and France**

There is a sense in which there has been an inexorable move towards vehicle electrification (see Fig. 3.1). Figure 3.1 focuses on powertrain electrification trends since the beginning of the IC car. In addition, many of the accessories added since the 1950s have been primarily electrical, such as electric windows. There is also a further trend towards electrification of traditionally mechanical or hydraulic systems such as power steering, brakes, etc.

**Fig. 3.1: Electrification of the Car**
Norway has wholeheartedly embraced the electric vehicle. It does have the history of local EV producers Th!nk and Kewett/Buddy, but it also has considerable hydroelectric resources, thus it is able to claim that much, if not most of the electricity used to run its electric cars comes from renewables. Electric vehicles also enjoy several incentives in terms of no purchase tax, no VAT, access to cities without charge, free parking, free charging facilities, no road tax, use of bus lanes, etc.

Yet this preference for electric vehicles was not an inevitable development. Norway is, after all, also a significant oil and gas producer and could just as easily have promoted natural gas vehicles, or stuck with conventional technology to support its oil sector. Battery electric vehicles do give zero emissions at point of use, thus improving urban air quality, which can suffer on a sunny windless winter day in cities like Oslo. The role of local electric vehicle producers, Th!nk and El-Bil, although both now defunct or at least in receivership, should also not be underestimated, although the main driver has been the comprehensive incentive programme in Norway.

Another relevant initiative was the Move About concept (www.moveabout.no). This was a car sharing scheme, or car club, linked with Th!nk and designed to use Th!nk vehicles to
deliver an urban mobility package based around this electric vehicle. The principles of the scheme were that it had to be ‘clean’ in terms of energy supply, it provides charging points at key locations and had to be ‘affordable and available’ so the largest number of users could use the cars with a minimum of hassle. The charge was NKR 100 (€10) per hour of use. The scheme was also extended in Sweden and Denmark. The smart card used for the system could also be used to access public bicycles that are part of the bike share system. Attempts to extend their use to public transport have not been successful.

France has long promoted the use of EVs. Its strong reliance on nuclear power, and to a lesser extent, hydro-electric power for its electricity supply mean that this is a very low carbon option in France. For example, in 2010, only 5% of French electricity came from fossil fuels, while 75% and 20% came from nuclear and renewable sources respectively (OECD 2012c). Thus by shifting a significant proportion of the vehicle parc to electric power, France can meet both urban air quality and carbon reduction requirements. However, this does mean an adequate charging infrastructure is needed (see Table 3.1).

**Table 3.1 --- Expected number of charging points in France**

<table>
<thead>
<tr>
<th></th>
<th>2015</th>
<th>2020</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic or work</td>
<td>900,000</td>
<td>4,000,000</td>
<td>9,000,000</td>
</tr>
<tr>
<td>Highway, normal</td>
<td>60,000</td>
<td>340,000</td>
<td>750,000</td>
</tr>
<tr>
<td>Highway, rapid</td>
<td>15,000</td>
<td>60,000</td>
<td>150,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>975,000</td>
<td>4,400,000</td>
<td>9,900,000</td>
</tr>
</tbody>
</table>

*Source: MEDDTL 2009*

The assumption under this scenario is for one charging point at work and one at home for each EV registered. As a result, the total number of charging points is more than twice the total number of EVs. Investments will therefore be needed to support the creation of these charging points, but also for improvements to the existing grid and generating capacity. Figure 3.2 gives an indication of the expected investment needs.
Figure 3.2 – Expected investment needs by the private and the public sector as well as research funding for electric vehicles in France

![Bar chart showing investment needs for electric vehicles in France](chart.png)

*Source: MEDDTL 2009; OECD 2012c*

€50 million is available for infrastructure development through the “Ville de demain” project run by the French environmental and energy agency (ADEME 2011). 50% of costs for normal and fast charge points and 30% of costs for rapid charge points are covered given that the points are made publicly available (OECD 2012c). EDF estimates that the costs for installing chargers were €500 to €3,700 for home, parking or workplace, €7,800 for fast charge on road and €55,000 for rapid charging (MEDDTL 2011).

**Hydrogen – Germany and Scandinavia**

*Germany* has long resisted AFVs under pressure from its car manufacturers. BMW promoted IC hydrogen to retain its competitive advantage in IC engines, for example. However, recent years have seen a change with manufacturers taking a more global market view and recognizing rapidly rising expectations of AFVs in many markets. BMW for example is now taking a pioneering role in EV development. In addition, hydrogen is now seen as a useful storage medium for excess energy generated by Germany’s rapidly expanding renewable generating capacity. Hydrogen thus produced would provide a useful vehicle fuel.
As of January 2012, there were 37 planned or operational H2 refuelling stations spread across Germany, with 20 of these open to the public, although 3 of these are only compatible with buses (OECD 2012d). The German government contributes primarily through public-private partnerships such as the GermanHY, Clean Energy Partnership (CEP) and H2 Mobility. Nine of the 17 stations are CEP stations, with a total capacity of 1040 cars per day, which should be able to support a fleet of 8320 cars and a population of 1,390,000 given a market share of 1% (OECD 2012d). A further 20 refuelling stations are planned by 2014 under an agreement between Daimler and Linde, in support of Daimler’s planned fuel cell vehicle due for commercialization that year (OECD2012d).

These refueling stations have a mix of on site H2 production through electrolysis, combined production, such as Enertrag’s site as well as more conventional truck-delivered liquid hydrogen. The largest electrolysers can supply 9 cars each hour. However, hydrogen is usually produced to be consumed in chemical processes, therefore, the potential surplus hydrogen in Germany was 0.68bn Nm$^3$, enough for 380,000 cars (OECD 2012d). Ten such stations could supply a large city in the first years of commercialization (McKinsey 2010). Hence, with only a few more stations deployed, FCEVs can be ready for commercialization.

In Scandinavia, Norway, Sweden and Denmark all have significant hydrogen activities. As OECD (2012e) points out, central to their efforts are networking organizations such as Hydrogen Link in Denmark, HyNør in Norway, and Hydrogen Sweden in Sweden. Three organizations operate across borders: the Scandinavian Hydrogen Highway Partnership (SHHP), H2 Moves Scandinavia and Next Move. SHHP is a public private partnership using the Scandinavian networking bodies as coordinators. Its goal is to create the first hydrogen region in Europe (OECD 2012e).

There are nine publicly available hydrogen refueling stations in the Scandinavian countries; three in Denmark, five in Norway and one in Sweden (OECD 2012e). The Scandinavian Hydrogen Highway Partnership aims to have 15 stations and 30 satellite stations by 2015. In addition, Denmark has four hydrogen refueling facilities for fork lift-trucks, three for fuel cell tow trucks and two for fuel cell golf carts (OECD 2012e).

In 2012, the Hydrogen Council of Norway stated that by-product hydrogen from Rafnes, a chlorine production facility, is enough for 100,000 cars (OECD 2012e). However, in order to achieve CO2 reduction and air quality targets, such ‘black’ hydrogen needs to be replaced with ‘green’ hydrogen from renewable. Thus Denmark, with its strong commitment to wind energy has introduced a 0.08 €/kWh tax exemption on electricity for hydrogen production. Producing hydrogen from renewable resources also allows hydrogen to store excess energy at times of high supply and low demand – an inevitable byproduct of renewable energy sources such as wind and solar. Denmark appears to have the greatest commitment to hydrogen, with Norwegian hydrogen interests having to compete with the very successful...
battery EV environment there, while Sweden also has a strong commitment to biofuels, both biogas and bioethanol.
4. Market Responses

For some of these technologies it is too early to capture genuine market responses, however, there are some clear results already for biofuels, while the market for EVs is beginning to develop. Below a brief summary of the current market situation.

**Market responses to biofuels.**

The market response to biofuels has been a mixed picture; Brazilians have embraced bioethanol in response to flex-fuel technologies that removed the ‘availability anxiety’ that the earlier single-fuel E100 option brought. In parts of the US, biofuel use has come to be regarded as a patriotic choice, reducing the nation’s dependence on imported fossil fuels. Fossil fuels are indeed imported in many cases from countries that are in other respects seen as the sworn enemies of all that the US stands for.

In Europe, on the other hand, earlier smaller pockets of biofuel use, in for example rural Austria and informal pockets of home-made biodiesel use have gradually been converted into an EU-wide biofuel policy, whereby biofuel is routinely mixed in with existing fossil fuels in small percentages in order to meet regulatory requirements. Many customers are therefore largely unaware they are using biofuels, and there is thus no true market response. Where there has been such a response this tends to be from the classic car movement, concerned about the effect of bioethanol in particular on aging fuel systems.

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**Case Study; proalcool in Brazil**

The consumer response in Brazil was directly influenced by the public perception of the new technology, the availability of ethanol in fuel stations and the resale value of ethanol-only vehicles. Another variable that fundamentally impacted on the demand function for sales of new ethanol vehicles was the fact that the conversion of a petrol vehicle to ethanol was relatively costly and only made sense for vehicles used for high annual mileages, such as taxis and delivery vans.

During the first and second phases of the programme, dedicated ethanol vehicles became the dominant automotive product sold in Brazil (Zapata and Nieuwenhuis, 2008). The demand for new ethanol-only vehicles was particularly responsive to the variations in supply of ethanol and the policies implemented to foster the use of ethanol, which included the initial marketing campaign based on nationalist arguments. However, during the third phase of the programme, the demand for E100 vehicles reached an historic low. According to a study conducted by Moreira and Goldemberg (2000) the crises of ethanol use and production was the result of a combination of economic factors and the consumer reaction to some
system inefficiencies. The trust of the consumer was shaken due to the end of direct subsidies to both consumers and ethanol producers and shortages of ethanol resulting from the latter. There was a general loss of confidence in the future of ethanol without government support. The demand for new ethanol vehicles was particularly elastic in relation to supply and price of fuel at the pumps, rapidly shifting from ethanol to gasoline vehicles, as the price of ethanol was approximately 80% of gasoline prices. The elasticity of demand is a key element in understanding the consumer behaviour at the time. Additionally, the consumer could retrofit ethanol only vehicles to run solely on gasoline. Drivers could purchase conversion kits at relatively low cost in response to the higher fuel price.

This reduction in subsidy coincided with an ethanol shortage in the internal market, as the international price of sugar rose significantly; a classic example of biofuels competing with other – notably food – markets for their feedstock. Many ethanol producers decided to produce sugar instead, which forced the national oil company, Petrobras, to import ethanol at higher cost. The ethanol production decline was also promoted by low petrol prices resulting from low oil prices, which made the economic feasibility of ethanol production doubtful. The international price of petrol plummeted from US$ 72.40 a barrel in 1980 to US$ 21.85 by mid-1986 (adjusted for inflation to 1999 US dollars), and remained relatively flat until the beginning of the gulf war in the 1990’s (EIA, 2007).

The stability of petrol prices during this period directly affected the prices of gasoline sold in Brazil. Consumers rapidly abandoned ethanol-powered vehicles in favour of cheaper petrol cars from the late 1980s until early 2000s. Petrol came to be considered a more reliable fuel as its price remained low for many years and appeared less susceptible to price fluctuations than ethanol. Also, petrol was known to be available at every fuel station, which became less true for alcohol as demand and production volumes slipped. The cost of Brazilian ethanol is about $35 per barrel, which means that the oil price needs to be above about $40 per barrel for it to compete with oil (Eggar 2007).

It was not until 2003, that ethanol demand recovered with the introduction of Flexfuel engine systems. These engine management systems, developed in Brazil by Bosch and Magneti Marelli, allow the vehicle to function with ethanol, gasoline or any mixture of the two. This eliminated consumer risk; the uncertainty that was previously inherent in the purchase of a vehicle that had to be either gasoline fuelled or ethanol fuelled. Consumer risk was thus dramatically reduced; the chance of running out of the right fuel and the risk of misfuelling were eliminated. Consumers now buy Flexfuel vehicles and tend to opt for ethanol whenever ethanol is at least 75% of the price of petrol as it provides enhanced performance – for this reason its use in motor racing is well established. The introduction of the flex engines at relatively low additional cost, combined with high oil prices, while the rising demand for cars in Brazil has led to rapid penetration of the new technology into the parc. This has sharply driven up domestic ethanol demand. By November 2005, flex fuel variants represented 70.9% of Brazil’s total vehicle sales (ANFAVEA 2007).
The key here was that a military dictatorship was able to impose the project initially, using its state-owned oil company, Petrobras, to ensure a distribution infrastructure and motivating the agricultural sector – a traditional support base – to deliver the raw material. After the collapse of the military government a period of low oil prices set in and the project withered on the vine. This century, a combination of higher oil prices and the new flex-fuel technology was able to revive the surviving infrastructure, to very rapidly revive the project and make it more successful than ever.

Market responses to EVs

There is a sense in the industry that electric vehicle sales are at a critical point in late 2012 and early 2013. Overall market conditions have not been robust, but equally sales have in general been well below expectations. For example it was reported in October 2012 that Nissan in the US had decided to offer the Leaf at a lease price of US$219 per month, down from the previous offer of US$249, with a US$2,999 down payment for 32 months (Prakash, 2012). In the crucial market of California, the lease rate was reduced to US$139 per month for a period of 24 months, covering 12,000 miles a year. Initially the Leaf was offered at US$349 per month. The concern for Nissan is that in the first nine months of 2012, Leaf registrations were 5,212 units, down 27.6% year-on-year.

However, all this needs to be put into perspective. If we compare sales of these new EVs with other novel vehicle sales in their first few years, we see a similar picture. Figure 4.1 shows early year sales of the Smart, the original Prius and three of the new generation of electric powertrain vehicles: Nissan Leaf, Chevrolet Volt and Toyota Prius plug-in hybrid. It is quite clear that these earlier cars, particularly the Prius displayed similar early sales patterns of a slow start, then a small decline, before sales took off.

In all these cases, these vehicles were initially sold only in their domestic markets, for this reason, here the figures have been restricted in a similar way, by using US sales figures, currently the largest single market for such vehicles. The purpose is to show comparable patterns. Although an unconventional vehicle type, the Smart was otherwise conventional, particularly in terms of powertrain, hence the more rapid take off, after an initially slow start. We could add the Renault Twizy to this, which in its French domestic market achieved 322 registrations in the first six months of sales, which represented a 4.7% share of the French quadricycle market (GSP, 2012, 14).
Figure 4.1: Sales of novel vehicles in first two years

![Bar chart showing sales of novel vehicles in first two years. Smart cars have the highest sales, followed by Prius, Leaf, Volt, and Prius Pi.](image)

[please note that in view of the short period these cars have been on sale, the 10 month period of 2012 has been calculated up to 12 months by dividing 10 month figures by 10 and then multiplying by 12]

User responses to EVs tend to be positive, such that those members of the public, or fleet users first exposed to EVs on the whole can see themselves repeating the experience in the future. This is also borne out by experience in the EU Interreg IVb ENEVATE project. When asked how likely they are to drive an EV in the future, most say they see themselves as being more likely to drive one after the initial experience (Fig. 4.2).

**Fig. 4.2: After this EV driving experience are you more or less likely to drive an EV in the future?**

![Bar chart showing user responses to EV driving experience.](image)

(source: Interreg IVb ENEVATE project results – Cardiff University EVCE)
Market responses to Hydrogen

There are currently no hydrogen vehicles commercially available in the true sense. There are around 1000 hydrogen cars in use on an experimental or semi-experimental basis. These include test vehicles owned by the manufacturers, some experimental vehicles in the hands of customers for experimental purposes, and a small number of leased vehicles. Among the latter is the Honda FCX Clarity, of which 52 have been built, and of these a number have been leased to – mainly celebrity – customers.

Where hydrogen has so far seen more serious use, is in local bus fleets in a number of cities, and for fleets of warehouse handling equipment, such as fork-lift trucks. In this respect, therefore we cannot yet speak of a true customer response. However, where members of the public have tried hydrogen vehicles, their response has tended to be positive. The H2 IC BMW cars drive like any BMW 7-Series, with the loss of power barely noticeable, while H2 fuel cell vehicles, such as the Honda FCX Clarity, drive like other EVs, as expected from their electric powertrain, and therefore meet with similarly positive user responses.
5. Automobility in the new era

There appears to be a broad consensus that there is a transition underway from what might be termed the traditional automotive industry, to the automobility industry (Rishi et al., 2008; Wells, 2010; Dammenhain and Ulmer, 2012). This transition may occur with or without AFVs, but AFVs are both suited to the wider definition of automobility and, according to most observers, need to be supported within an automobility system. Hence consultants such as Oliver Wyman (2010) claim that ‘mobility solutions’ are imperative if customers are to be reached profitably by the established vehicle manufacturers.

It is likely that the emergent shape of the AFV system will still largely be determined by the actions of the established major participants: the vehicle manufacturers and the utility providers, at least for the medium term (E&Y, 2011). Established car cultures have a strong bias towards traditional ownership of cars that transcends the mere utility and convenience of having a vehicle on the driveway, and includes a symbolic element – for example as an indicator of the passage into adulthood. The car also has a strong role in signalling status and attitudes via brands. In some EU markets the growing ‘affordability’ gap for younger drivers may help to shape a new automobility culture centred upon more flexible ‘usership’ attitudes to cars. In markets like the UK, burgeoning insurance costs alongside rising housing and education costs are helping to create a non-car generation. Increased urbanisation and the use of social media may accelerate this trend.

The merging at some level of the digital world with the automotive world is thus both a cultural phenomenon and an industrial or competitive one. The view that the car is just another (albeit large and expensive) mobile but connected device has prompted others to enter into the EV business. An example is BestBuy in the USA, an electrical goods retailer with a strong online presence. The integration of cars with ICT-based communication systems under the umbrella of telematics is an inevitability. It is this area that started car manufacturers’ thinking about infrastructures and first prompted their dialogue with infrastructure providers and infrastructure-based service providers, such as TomTom.

Many studies have identified both the complexity of the emerging EV market, and the scope for new participants at multiple points within this market. Narich et al. (2011) highlight the ways in which EV trials have been used to enable a better understanding of what this ‘wide definition’ automobility industry might look like and how it might operate, a notion developed further by Mitchell et al. (2010).
It is interesting that California is seeking (with some success) to position itself as a leader in the EV business in part on the basis of a strong cultural connection with automobility and innovation (Perry et al., 2011). Similarly, Tesla has attempted to profile itself as ‘the Apple of the auto industry’. However the picture remains highly fragmented with a great many urban experiments going on world-wide (OECD, 2012).

**Risk perceptions along the value chain**

It is important to emphasize that risks of moving to alternative vehicle types are perceived differently along different parts of the value chain, many of which are crucial in providing the necessary infrastructures. Outside observers, be they in government, or academia are often surprised by the slow pace of change in this area of low carbon vehicle technologies, however, a fuller understanding of automotive value chains makes this less surprising. In simple terms, the risks of moving to EVs, for example, can be summarized as in table 5.1.

**Table 5.1: Risk Perceptions along the EV Value Chain**

<table>
<thead>
<tr>
<th>Stage of Value Chain</th>
<th>Principal risks identified</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw materials suppliers</td>
<td>Will our materials still be needed? (e.g. steel); Can we now sell more of our materials to the automotive sector? (rare earths; carbon fibre; aluminium)</td>
</tr>
<tr>
<td>Component suppliers</td>
<td>Is there a future for our components? (e.g. camshafts, spark plugs); can we now become automotive suppliers and increase our capacity? (batteries, electric motors, lightweight composite materials)</td>
</tr>
<tr>
<td>Vehicle assemblers</td>
<td>What happens to our investments in internal combustion engine plants? And will we still be able to use our investments in all-steel body technology? What about the expertise in IC steel cars we have built up over the past decades? If we do invest in EV, will they actually sell?</td>
</tr>
<tr>
<td>Retail, distribution</td>
<td>How on earth do we sell these EVs? Do we need to train our sales staff? What training do our technicians need? What are the residual values, can we take them as trade-ins? What can go wrong with these EVs?</td>
</tr>
<tr>
<td>End-users</td>
<td>Why are they so expensive? Will I get anything back when I trade it in? What if something goes wrong? Will it be expensive to fix? Does it have enough range for my needs? Will I be able to find somewhere to charge it when I am out and about?</td>
</tr>
<tr>
<td>Energy distribution</td>
<td>How many of these are going to be? Will I need to build new capacity? Can I make money from these? Do we need to invest in smart grids?</td>
</tr>
<tr>
<td>Electricity generation</td>
<td>What is in it for us? Do we need more generating capacity? Do we need to get involved in smart grids?</td>
</tr>
</tbody>
</table>

( Source: Electric Vehicle Centre of Excellence, Cardiff University)
Doubts remain therefore over the size of the ‘alternative fuel’ opportunity and how that opportunity might best be captured by the many parties that are seeking to participate in this emergent automobility ecosystem (E&Y, 2011; Rishi et al., 2008). These doubts are a problem for industry facing high levels of risk in what could be pivotal technologies for the future; but also for governments seeking to allocate public funds into schemes that are increasingly beyond affordable niche socio-technical experimentation. Also, the transformative possibilities offered by networked and connected vehicles are as yet only partially being realised, with potentially revolutionary shifts in automobility – the connected car - being possible through such telematics infrastructures with or without AFVs.

While some doubt has been thrown on the lifecycle analysis benefits of EVs over ICEs (see below), this broader perspective still provides a strong rationale for government intervention to support the introduction of a wide range of AFVs. There is also the issue that AFV technologies are increasingly predicated on more esoteric materials, such as the rare earths. These raise new issues of risk and cost, with some only having a generation worth of known reserves. Both EV technologies and technologies for renewable energy supplies are increasingly dependent on such materials, notably for such crucial areas as magnet technologies (Webb, 2012).
6. How and why are AFV infrastructures different from ICEs?

The principal difference here is that as we begin to adopt alternative technologies, there is always a cost. For alternative fuels these costs are smaller than for alternative powertrain. For liquid biofuels, for example, these involve replacing parts of the fuel system and, ideally incorporating a ‘flex-fuel’ programme to the engine management system and its sensors. For solutions such as LPG (‘propane’), biogas or CNG these involve an additional tank as well as some modifications to the engine. This provides a relatively low risk scenario for the established automotive industry, as its core technologies and investments – in IC engines and all-steel bodies – are preserved.

For alternative powertrain the additional cost is greater, while also removing the key IC engine technology from the value chain; it is this that creates a significantly higher risk (see risk perceptions in chapter 5). Another feature with the alternative powertrain solutions is that the purchase cost/running cost relationship shifts. This is also reflected in the environmental impact, in that taking a full life-cycle approach, the impact of manufacturing such vehicles becomes greater than their in-use impact (Ricardo/carbon Trust 2011; Hawkins et al. 2012). The implication of this is that we should make fewer such vehicles and use them longer, which is helped by the fact that these alternative powertrain technologies are potentially more durable and more reliable. This too prompts the need for a different business model.

In all cases there are also infrastructure implications. For example, traditionally cars have just used oil-based fuels that were the responsibility of the oil industry. The automotive industry and the oil industry have therefore very much kept themselves to themselves. This is changing with alternative fuels. With EVs in particular, the question often arises: but where does the electricity for your car come from? This question has not been asked with oil. Car manufacturers do not always know how to engage with this issue, as it has not traditionally been seen as their responsibility. Similar questions arise with hydrogen. Conversely, electricity generators are having to take an interest in automotive issues, which also has not been part of their remit in the past.

Other issues affect the supply chain; as outlined under the risk perception in chapter five, the supply chain often adopts a wait and see attitude, waiting for demand to be evident before investing, while those players already engaged in such novel technologies tend to lack the capacity of management skills to upgrade to automotive supply chain demands in terms of quality and scale.
AFV Infrastructure Challenges

Much has been made of the infrastructure challenges of moving to alternative fuel and powertrain vehicles and much of this is real. Roads and the built environment can on the whole cope with such novel vehicle types, but for the delivery of their energy changes are inevitable and these can lead to changes in the business models employed.

Creating the liquid fossil fuel infrastructure of today took time and considerable investment, moving motorists gradually away from a regime of having to buy small canisters of fuel from local chemists and drug stores. Replicating such a development in a context where an existing developed infrastructure raises certain expectations is even more challenging.

One of the challenges in such infrastructures is the dispersed and concentrated nature of activities at various stages of the value chain. With conventional mineral oil, we start with a feedstock derived from a locally dispersed, albeit regionally confined system of oil wells that then feed into highly concentrated refineries which may be located near the source of feedstock, but more often are located closer to user markets. The very high investment in such facilities determines their centralised nature. From here, the products, which are now various and dedicated (petrol/gasoline, diesel, bitumen, kerosene, etc.) are once again dispersed into a distribution and local delivery network in order to bring the product to the end user. All these stages along the value chain can be delivered by a single firm under an integrated business model, or may be allocated to different players under a more disintegrated model. These models form the starting point for expectations of future alternative fuel business models (Table 6.1).

Table 6.1: Degrees of concentration along the fuel value chain

<table>
<thead>
<tr>
<th>Fuel type</th>
<th>Feedstock</th>
<th>Processing</th>
<th>Logistics</th>
<th>Distribution</th>
<th>Delivery</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineral oil</td>
<td>Dispersed/centralised</td>
<td>centralised</td>
<td>Pipeline, ship, truck</td>
<td>existing</td>
<td>dispersed</td>
<td>This is the existing system creating the benchmarks</td>
</tr>
<tr>
<td>Liquid Biofuels</td>
<td>Dispersed</td>
<td>Semi-dispersed</td>
<td>Ship, truck</td>
<td>Semi-existing</td>
<td>dispersed</td>
<td></td>
</tr>
<tr>
<td>Biogas</td>
<td>Dispersed</td>
<td>dispersed</td>
<td>truck</td>
<td>Semi-existing</td>
<td>dispersed</td>
<td></td>
</tr>
<tr>
<td>Hydrogen</td>
<td>Dispersed/centralised</td>
<td>Centralised/semi-dispersed</td>
<td>Truck, local pipelines</td>
<td>limited</td>
<td>dispersed</td>
<td>2 models: centralised, distribution via truck; local production at point of delivery</td>
</tr>
<tr>
<td>Electricity</td>
<td>Centralised or dispersed/</td>
<td>Centralised</td>
<td>grid</td>
<td>existing</td>
<td>Very Dispersed/</td>
<td>EV has a much more fragmented</td>
</tr>
</tbody>
</table>
Biofuel infrastructures

For biofuels there is also an existing infrastructure, but this currently operates according to a number of different models. Particularly the biodiesel model often envisages localised value chains whereby a dispersed network of farms feed oil-rich crops into localised facilities in the first instance. Making biodiesel is particularly suited to micro-scale activities, such that many private individuals have been known to make it at home. Making biodiesel on a farm or at the depot of a rural road haulier is perfectly feasible. In such cases the products feed into local, mainly rural markets. This model can be found in places ranging from rural Austria, to suburban California.

A more formalised model still involves feedstock moving into the value chain from dispersed farms and into local, or regional processing facilities. However, these then feed their output into a more formal distribution network for sale as 100% biodiesel, or, more commonly, to refineries, or post-refinery facilities for blending with conventional mineral diesel to create high mineral, low biofuel blends, such as those required to meet the lower biofuel content of the EU biofuels Directive. Blends of up to 10% biodiesel are normally sold without special labelling in this way, as there is no major impact on existing vehicle technologies from such blends. However, biodiesel is more corrosive than conventional mineral diesel and can thus affect steel and some non-ferrous metals in e.g. storage tanks (Sridhar, et al. 2010). Not all such effects are yet fully understood.

For bioethanol the situation is slightly different. Here the model was to some extent established by the Brazilian Proalcool programme of the 1970s (Goldemberg et al. 2003a,b; Zapata and Nieuwenhuis, 2008). Here bioethanol was used in an import substitution project to replace imported mineral oil-derived vehicle fuel with home-grown bioethanol derived from sugarcane. The value chain was created with dispersed farms feeding into regional processing facilities that then fed into the existing fuel supply infrastructure administered by state oil company Petrobras. To a large extent this is still the model used with varying blends of mineral and biofuel available on virtually all forecourts in Brazil. The fuel received a boost over the past decade after withering on the vine for many years in the face of lower world oil prices. This boost came not only from rising oil prices, but more importantly from the advent of flex-fuel technologies developed in Brazil by foreign-owned companies, which allow vehicles to run on any mixture of biofuel and mineral fuel. This has removed a major barrier to the adoption of biofuel in Brazil. It has made Brazil a major exporter of bioethanol (see case study, chapter 4).
Brazil vies with the US as the largest producer of biofuel. In the US, which has a bioethanol production capacity of around 15 billion US gallons a year (GAO 2009), a more regional model is used, whereby it is primarily in farming states where bioethanol is offered on the forecourt (see chapter 3). In addition, states that have adopted the more stringent California standards of vehicle emissions, tend to favour biofuels, whereby bioethanol can be used as an oxygenate in conventional mineral fuel.

Problems do arise when feeding biofuels into infrastructures designed for mineral oil products (USGAO, 2009 and 2011). Existing equipment incorporates materials that are adversely affected by bioethanol, in particular. This involves storage facilities, transport equipment (road and rail tanks) and also dispensing equipment. Certain metals and metal finishes can be affected, as can certain rubber and polymer seals and gaskets (DNV, 2010).

This can also affect in-vehicle systems. The GAO (2011) study indicates that the cost of installing a storage tank compatible with intermediate blend bioethanol (E15) would amount to $100,000, while the cost of installing a compatible fuel dispenser (fuel pump) would be more than $20,000. However, such investments would then also allow the equipment to deal with higher ethanol blends. Further research into the effects of these higher, intermediate, bioethanol blends on vehicles and infrastructure is still ongoing (DNV, 2010).

**Biogas infrastructures**

Sweden also pursued biofuel promotion policies for some years. Here the approach was to promote the use of bioethanol from forestry by-products (‘wood alcohol’), although in practice most was imported from Brazil, and to promote the use of biogas, often derived from landfill sites. In other countries, there is a long tradition of using this type of biogas, often to power waste collection vehicles. This type of biogas is primarily methane and thus similar to natural gas. For this reason it can be mixed with natural gas and can be used in any vehicle designed to run on natural gas, which is an established technology, used in many countries. The only additional infrastructure requirements involve the collection of biogas from the landfill site, and moving it to locations where it can be fed into existing natural gas distribution systems. The latter can often be done locally, which makes this a relatively low-cost way into biofuel.

**Hydrogen Infrastructures**

In some respects the fuel cell car is already competitive with the internal combustion-engined car. Problems appear to be in three areas: vehicle integration, manufacturability
and infrastructure (Nieuwenhuis, 2009). Hydrogen fuel supply is another issue to be resolved. This is a substance that does not occur naturally on our planet. On earth it only occurs bound with oxygen in the form of water, or bound with carbon in a range of hydrocarbons. In each case, some process is needed to separate the hydrogen from these other elements and this requires energy, such that the lifecycle impact of hydrogen does not always make it the most environmentally optimal fuel, although the fuel cell is more efficient than IC. Some have proposed using so-called ‘black’ hydrogen – hydrogen produced from fossil fuels – in order to establish a hydrogen infrastructure. In parallel we can then work on the transformation to a renewable hydrogen production infrastructure. In the interim we have to accept higher CO2 release, but this would be compensated for in the longer term by a faster transition to a zero carbon energy system. (Verdugo-Peralta 2007). As Verdugo-Peralta put it: “We cannot allow the perfect to be the enemy of the good” (ibid.). At present the main source of hydrogen is natural gas.

On-board reforming (on the vehicle) of hydrogen from hydrocarbon fuels such as methanol or petrol has also been suggested (Romm 2004, 92). This would add weight and complexity to the vehicle and would also use energy. It would however remove the need for large hydrogen production facilities and for a hydrogen distribution infrastructure. More recently, thinking in the industry has centred around reformers based at fuel stations, such that the existing hydrocarbon distribution infrastructure can remain in place, but vehicles could fill up with hydrogen at ordinary fuel stations (ibid.). This was the system used in the Icelandic H2 experiment. Developments with compressed hydrogen have at least shown that by using very high pressures of 700 bar, rather than the current standard of 350 bar, a sufficient amount of fuel can be carried in a car to give it an acceptable range of around 300 miles (McGowan, 2007).

Much has also been made of the need to replace or replicate the existing fuel supply infrastructure with a hydrogen version. The building of a dedicated infrastructure is very expensive: it was estimated at US$ 5,000 per car by Keith and Ferrell (2003). Few fuel cell vehicles would be sold in the absence of a fuelling infrastructure, while no commercial organisation would build an infrastructure without some guarantee of demand. Shell has been relatively pro-active in this respect, investing in H2 supply in Iceland, as well as along the Pacific Coast of North America, including the show-case facility on Santa Monica Boulevard in Los Angeles.

A range of automotive fuels is offered in markets around the world. Petrol or gasoline is almost universally available, closely followed by diesel, used by trucks worldwide and by cars in Europe. Many individual markets offer LPG, CNG, bio-diesel, ethanol and methanol. Adding hydrogen as an additional fuel is challenging on a crowded forecourt with a fixed number of storage tanks. With only five percent of new car sales being hydrogen powered, this is also difficult to justify. However, from British Columbia to California there is a
fledgling ‘hydrogen highway’ – a corridor where hydrogen availability is guaranteed at regular intervals.

Hydrogen supply infrastructures already exist for industrial purposes in various locations, with the Europoort area of Rotterdam an example, while further hydrogen highways are under construction or proposed in various locations including Scandinavia and Germany. Hydrogen’s volatility often prevents its distribution over longer distances; the closer it can be used to the location and time of manufacture, the less is lost. Hydrogen systems in vehicles need exceptional tightness and even so, H2 often still find its way out into the atmosphere. For this reason, pipeline systems are used only in local areas, while tankers transport hydrogen over relatively short distances. Extending existing H2 pipeline systems, or even upgrading existing pipelines for oil or gas, would be prohibitively expensive.

Depot-based vehicle can often avoid the need for a fuller dedicated infrastructure and this has been behind the schemes for fuel cell buses in several cities, as well as new initiatives such as the use of fuel cell handling equipment in Walmart’s new warehouse in Alberta, Canada. The US, however has enough hydrogen production capacity already to power around a quarter of its fleet, although this hydrogen is used for other purposes today (Green 2005). Alternatively, we could turn to methanol. Romm (2001, 92) points out that “Gasoline and methanol are very potent ways of storing hydrogen”. Although gasoline is a fossil fuel, methanol can be made from a range of different feedstocks, including renewables. This idea has also been promoted by others, notably Nichols (2003), and Olah et al. (2006), as well as Turner and Pearson of Lotus Engineering (2008).

In practice, these fuel cell vehicles would probably not be equally distributed among world markets. Instead there are likely to be pockets of higher fuel cell car densities. One can imagine areas such as the state of California, Iceland, and the Canadian province of British Columbia enjoying a significantly higher density than Texas, Bahrain or Romania, for example. This is probably a more effective approach in any case as it encourages local infrastructures and markets to develop, perhaps as ‘strategic niches’ which can be used to test the technology in a real world context before exposure to the market (Hoogma 1999, 2000).

However, it is also quite clear that – with the possible exception of Iceland – much of this hydrogen would be derived from conventional fossil fuels. Though not perhaps the most efficient use of hydrocarbon fuels, it would allow the kick-starting of a hydrogen system in preparation for more sustainable hydrogen production (Verdugo-Peralta, 2007). At the same time, oil-derived fuels are likely to increase further in cost. Supply of oil is now estimated to peak at the latest around 2010-15 (Hirsch et al. 2007, Aleklett 2007), while demand – from newly motorising nations such as China, India, Brazil, Indonesia and Russia – will continue to increase. This cost increase in conventional fuels could increase the demand for alternative powertrain technologies such as the hydrogen fuel cell. Alternatively, the car industry may decide – in a bid to preserve the tried and trusted
internal combustion engine – to go for petrol- or diesel-hybrid solutions instead, with the plug-in hybrid particularly promising. Their fuels can also be derived from natural gas, coal or biomass even when oil itself became too costly.

**Electricity infrastructures**

Electricity infrastructures and value chains are quite different in nature from what we have discussed thus far. They can also take various different forms. The conventional model is based on fossil fuel supply from wells, or mines, sometimes over considerable distances. Alternative models already have a considerable track record, such as nuclear power, which does not need fossil fuel, but does need a secure supply of uranium, which although not bulky, still often needs to be transported over long distances with specialised handling. Another well-established alternative is hydro power. Here the power generation is integrated with the source of the power, the ‘feedstock’ of water + gravity. Now, increasingly with the advent of small-scale wind and solar power, we are moving to a highly dispersed supply network.

The advantage here is that all these different generating modes can feed into existing electricity grids, which are well established in most countries. Unlike with liquid fuels, these can take electricity from any source without modification, as the actual ‘product’ is the same, an energy carrier, whatever its source. It is also this fact that makes EVs particularly attractive – the vehicles are no longer feedstock-dependent, and therefore over time radical changes in feedstock can be implemented without the need to change vehicle technology.

The final phase, the distribution to end user, is also exceptionally dispersed, or even fragmented in electricity systems, in that in developed countries, at least, all houses and industrial buildings enjoy a direct electricity supply. The electricity grid is thus far more dispersed than any of the other vehicle fuel delivery systems, allowing many people to charge their EV at home; this is an attraction for many people who dislike visits to fuel stations.

This dispersed nature, however, has also become a new expectation unique to EVs. So, while there are only 10 conventional fuel stations within the area inside the Avenue Periferique in Paris, by 2007, so even before Autolib existed, there were already 84 EV charging stations in this area (Whatgas.com; Treehugger.com). Unlike with petrol stations, end users of EVs expect a significantly denser charging infrastructure. One of the main drivers of this is that unlike liquid fuel vehicles which may spend 5 or 10 minutes refuelling, an EV, even when using a fast charger would spend at least 30-40mins charging up, with 5-8 hours for a slow charge more typical. Fortunately with electricity readily available in urban and suburban areas, it is possible to install a charging point anywhere where a car can be parked, at lower cost than installing a petrol or diesel pump.
One area where different business models are anticipated to make a difference is in the realm of electricity generation and distribution. NPC (2012) reports the findings of a study by the Israel Electric Company that found that with uncontrolled charging the electricity generator would have to add 2,345MW of capacity, and the distributor would have to add a switching station, substations and transformers to cope with 2 million electric cars. The full findings are shown in Table 6.2.

Table 6.2 Electricity and generation costs of different charging regimes for 2 million EVs (Israel)

<table>
<thead>
<tr>
<th>Item</th>
<th>Ad Hoc charging</th>
<th>Off peak incentive</th>
<th>Managed EV network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generation</td>
<td>Add 2,345MW</td>
<td>Add 1,770MW</td>
<td>No additional capacity</td>
</tr>
<tr>
<td>Transmission</td>
<td>Add 1 switching station, 10 substations and 18 transformers</td>
<td>Add 1 switching station, 7 substations and 13 transformers</td>
<td>No additional transmission required</td>
</tr>
<tr>
<td>Distribution</td>
<td>Add 2,158km medium voltage cables</td>
<td>Add 1,581 km of cables</td>
<td>Add 287 km of cables</td>
</tr>
<tr>
<td>Total cost</td>
<td>US $4,586 million</td>
<td>US $3.414 million</td>
<td>US $471 million</td>
</tr>
</tbody>
</table>

(Source: NPC, 2012)

Average car battery price is in the region of US$12,000 for a 24kWh battery, on top of a typical average new car price (USA) of US$28,400. Allied to this high purchase cost, consumers are concerned about the rate of battery deterioration (anticipated life 10 years), possible battery failure, and product obsolescence. Looking at a whole battery pack, Element Energy considered that contemporary costs were in the region of US$800/kWh for a 300kg pack required for a standard pure BEV, but weight would be reduced by 30% and cost 50% by 2020 and by 45% and 70% respectively by 2030 – albeit with new technologies like those employing Lithium-air configurations.

It is in this context that many participants in the emergent EV market consider that alternative business models are needed, both to create propositions that customers will find compelling and to ensure profitability for the companies themselves – as is explored in the next chapter.
7. The need for different business models

Business Models

Business model innovation and technological innovation are closely linked, but do not necessarily presuppose each other. For any industry at a given point in time there are therefore broadly four possible options regarding innovation in these two areas. These options are summarised in Diagram 7.3 below. Inevitably, this type of categorisation is open to debate, particularly in terms of what constitutes radical innovation against incremental change or an extension of existing practices. However, the framework is provided as a means of thinking about the future for alternative fuel infrastructures without necessarily being definitive.

The Existing Automotive Business Model

The existing automotive business model is outlined in figure 7.1. Different parties capture different parts of the value chain and have been able to derive a profit out of these activities.

Fig. 7.1 Current Automotive Business Models

current business model – different parties capture different parts of the VC
Car manufacturers still see their activity primarily as making and selling cars with the IC engine and the all-steel body as core technologies. Their primary expertise beyond that is in systems integrations. However, the key activity essentially stops at the factory gate. In lifecycle value terms this is clearly untrue. In reality, manufacturers only capture a limited slice of the total automotive value chain. New business models for the future would need to capture more of that value chain by integrating assembly, distribution and aftercare. This kind of thinking could also ultimately lead to a more sustainable car industry in economic, social and environmental terms. Figure 7.2 demonstrates the relative share of total lifetime earnings generated by a vehicle being manufactured and used (not including fuel).

Fig. 7.2: Car Lifetime Earnings Contributions

(Nieuwenhuis and Wells, 2009, 98)

This pattern is likely to change under the combined impacts of shifts in automotive technology, the economics of the industry, and the strategies of the major players involved. Car making in the conventional sense is increasingly unprofitable, prompting occasional forays of manufacturers into the aftermarket. If current trends continue then, at least in the developed markets such as those prevailing in the UK, Europe, North America, Australia, Japan, and similar countries then the aftermarket is going to become more competitive and probably of reduced real value.

Conversely in the fuel supply side of the current value chain, some players, such as Shell, or Total, are able in many cases to capture all, or virtually all of the value chain, whereby some less profitable activities can be supported by more profitable activities. Both of these can be
linked, as less profitable forecourt activities, for example, are a crucial market information tool to support other aspects of the business and ensure their continuing profitability (Fig. 7.3).

Figure 7.3 Existing Fuel Value Chain

![Oil infrastructure (simplified)](image)

Some firms operate a business model that captures all of this.

What is beginning to change is the way in which other areas impinge on this traditional model. With a potential change in core technologies from IC to increasingly electrified powertrains and from all-steel to increasingly multi-material and lightweight structures, the core technologies are under attack. In addition, car manufacturers are increasingly having to take an interest in infrastructure matters, from the simple interfacing with biofuel suppliers to ascertain that their vehicles can handle these fuels, to questions about the CO2 reduction potential of different electricity and hydrogen generating sources for their battery electric and proposed hydrogen fuel cell powertrain vehicles.

The picture is complicated further by recent findings on ‘embedded carbon’ which indicate that the carbon reduction potential of alternative vehicles in use is less straight-forward than has often been assumed. For biofuels, for example, sugar cane yields 7,500 litres of ethanol per hectare of production compared with corn in the USA that yields 3,000 litres per hectare, making Brazilian bioethanol significantly more efficient in CO2 reduction terms, often justifying shipping it into certain locations, instead of producing it locally.
Table 7.1: CO2 cost (in kg) for 1,000 litres of Brazilian cane sugar ethanol

<table>
<thead>
<tr>
<th>Item</th>
<th>Emissions</th>
<th>Absorption</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farming of cane</td>
<td>173</td>
<td>7,464</td>
</tr>
<tr>
<td>Cane growth</td>
<td></td>
<td>2,940</td>
</tr>
<tr>
<td>Burning and transport</td>
<td></td>
<td>3,140</td>
</tr>
<tr>
<td>Production of ethanol</td>
<td></td>
<td>1520</td>
</tr>
<tr>
<td>Use in car engine</td>
<td></td>
<td>309</td>
</tr>
<tr>
<td>Net</td>
<td></td>
<td>3,368</td>
</tr>
<tr>
<td>Gasoline</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

(Source: Veja, 19th March 2008, p106-7)

EU Member States have to comply with the existing EU Biofuels Directive, which guarantees a biofuels content of 5.75% by 2010 and sets various targets beyond this. The US also has biofuel target. In addition, the EU is making real efforts to stop imports of unsustainable biofuels. Some manufacturers have put considerable investments into the biofuels area, notably Ford and Saab. The reasons for this are much to do with incentives in certain key markets for these manufacturers, notably Sweden and Germany. In addition, Saab and Sweden are hoping to transfer from current imports of Brazilian bioethanol to future domestic supplies of second-generation bioethanol from wood by-products in Sweden. In the meantime, Sweden is introducing ethical sourcing standards for biofuel. While biofuels may have some role to play in reducing carbon, in reality their role is likely to remain small for some time. Demand will be driven by the EU Directive and the growing public momentum. However, it is likely to settle at a level determined by the regulation and mixed with fossil fuels (max. 10%-15%) for use in mainstream IC engines.

While biofuels have a clear CO2 reduction benefits, as the growing crops extract CO2 from the atmosphere, the picture for other alternative fuels and alternative powertrain is rather less clear. Recent work by Ricardo on behalf of the UK Carbon Trust (2011), supported more recently by the findings of Hawkins et al. (2012) suggest that one effect of the move toward electric powertrain is that the ratio of ‘embedded’ carbon in a vehicle resulting from the production process, to carbon emissions in-use is set to change with the degree to which a
vehicle is driven by grid-derived electricity. Also, the ‘greener’ that electricity the greater the proportion of life-cycle emissions attributable to production rather than use.

**Fig. 7.4: Well-to-wheel vs Embedded carbon in different powertrain vehicles**

(adapted from Ricardo/Carbon Trust, 2011)

Traditionally, the proportion has been between 20/80 production/use and 30/70 production use, depending on the expected useful life of the car and whether ELV phases are included (cf. Nieuwenhuis 1994). At these ratios, the production impacts are significant, but small, in relation to the use phase. Under these circumstances emphasising emissions reduction in the use phase is the higher priority.

However, as shown in Fig. 7.4 above, as the CO2 emissions in use are reduced from a typical IC ratio of 20/80 at 160 g/km of CO2, the proportion of in-use emissions shrinks in relation to the ’embedded’ carbon in production of vehicle, battery and powertrain. For a battery electric car with CO2 emissions equivalent to 45 g/km, in fact the proportion of embedded carbon exceeds that from in-use emissions. However, even low CO2 IC vehicles meeting forthcoming CO2 standards in the EU (120-130 g/km) and existing hybrid and plug-in hybrid vehicles (78-98 g/km), already show a significant shift, as evident from Fig. 7.2.

The implications are clear. A new emphasis on reducing embedded carbon in vehicle and powertrain production is expected, while there is also a strong case to be made for moving to much longer vehicle lifespans, thereby using to the full the carbon embedded in the vehicle. Fortunately, EVs are already less maintenance-intensive than IC vehicles, so a significant extension of vehicle lifespans is possible. Ironically, this could also lead vehicle manufacturers to concentrate more on the manufacturing phase – their core area – at the expense of the newly emerging agenda of engagement with energy and infrastructure.
providers.

In summary, then, we have a number of drivers that put pressure on the existing business model and may prompt the adoption of different business models. These are as follows:

- The existing business model does not capture the full value of the value chain for vehicle manufacturers.

- Car markets are increasingly regulation-driven and CO2 reduction is fundamentally different from previous regulation – it has the potential to fundamentally change the nature of the product in terms of its core technologies (= powertrain and body/chassis structure)

- Alternative fuels and alternative powertrain technologies force vehicle manufacturers, infrastructure providers and energy providers to engage with each other.

- The relative proportions in vehicle life cycles of manufacturing/use is changing as a result of increasing electrification in relation to both the value chain and environmental impacts; this can lead to much longer vehicle life spans.

- The desire to use telematics to link cars with their environment for enhanced customer experience, also forces car makers into closer cooperation with infrastructure providers.

- All this will change the nature of the car industry and car markets – the automobility paradigm.

**New Business Models**

In the long run, one factor that could profoundly influence the structure and membership of the aftermarket sector is the adoption of new strategies by the vehicle manufacturers. There is always a tension here. On the one hand, there is much to be said for the incremental development of the existing generic strategy and structure. This approach offers lower risk in what is a capital-intensive industry that has long product cycles. Year-on-year productivity gains and reductions in costs from suppliers might only result in low profit margins, but do result in continued survival. On the other hand there is evidence as shown above that the industry collectively is running out of options with these measures. Yes there are always cases of companies that are profitable and of course observers will point to companies such as Toyota. The trouble is, not all vehicle manufacturers can be Toyota.
With these thoughts in mind, it is worth considering what alternative strategic shapes might be possible. Six thumbnail sketches are presented below. It will be readily appreciated that each will have different consequences for the nature of the aftermarket.

Fig. 7.3:

The business model and technology innovation matrix

**Business as usual**

In the business as usual situation there is no substantive technological innovation and no business model innovation either, although evolutionary developments may occur. In this case, competition depends upon having a better strategy and / or a better operational execution of existing practice. Cost leadership is essential to profitability in this business model, because no company is able to dominate or distort the market. This case is typical of large, mature industries with established economies of scale, product and production technologies, industrial structures and relationships, and management practices. The Toyota Production System is an example of the sort of innovation that can still occur without radical challenge to either the overall business model or the technologies of the industry.
Competing Better:

The competing better option introduces technological innovation but without radical business model innovation. That is to say, this case relies upon product/process innovation to provide a competitive edge such that the business is better but not different to the competition. In many respects this case appears to be the preferred option of established industrial sectors if pressure for change is being exerted on the sector. An example is Toyota with Prius hybrid in which there is a conventional car design apart from the hybrid powertrain, along with the use of a conventional sales channel, support, etc. Typically, this approach to competition provides a ‘window’ of competitive advantage, the duration of which varies according to the product development times of the sector concerned. In the case of the automotive sector, Toyota gained an established early leadership in hybrid technologies and market acceptance, along with a broader public recognition for ‘green’ leadership, but arguably competitors have now caught up or surpassed Toyota.

Competing differently:

In this option there is no technological innovation but there is business model innovation which allows the business to redefine the relationship to the customer with a qualitatively different offer or value proposition in the market. Interestingly, it may be difficult for others to rewrite their rules of behaviour and organisation and so this case may provide a competitive advantage that is as enduring as that given by technological innovation alone. Technology may enable this case but is not core to it. The automotive industry has not shown much evidence for this to date, where the best examples come from the ‘budget’ airlines. It could be argued that the car sharing business model of a company like Zipcar offers a potential reinvention of the business model via a new intermediary, but certainly vehicle manufacturers have thus far avoided entry directly into this sort of business.

Beyond Competition

In this case there is a combination of technological innovation and business model innovation which in theory has the potential to open up a new market space for which there are no direct competitors or for which a market did not previously exist. As such, this case generates ‘first mover’ advantages. While a business model cannot be patented it may be difficult to emulate because of company-specific competencies. Interestingly, the alternative fuel vehicle infrastructure business offers just such a combination of technology
and business model innovation. Better Place is one interesting example; the Paris Autolib scheme is another (see case study, below). The combination of business model and technology innovation in a new market space of course also brings higher risks. There is potentially, in the case of vehicle infrastructures, the high investment cost in the infrastructure, alongside the need to co-operate of vehicle makers and electricity suppliers while also winning customer acceptance. On the other hand, once established, it may be difficult to replicate or compete with an established infrastructure.

The EV ‘ecosystem’ as many term it (Rishi et al., 2008; E&Y, 2011) is interesting in part because it is possible to reconfigure the participants and their roles in a great many ways, theoretically giving the consumer a much wider choice extending, for example, to choosing who generates their electricity and how. This factor, along with the potential incompatibility of networks mentioned above, may undermine the return on investment calculations offered by e.g. Langezaal and Bouman (2011) who claim a 45% return on capital employed for a network of 200 stations. Investment costs for commercial charging stations vary widely according to the scale and speed at which they charge, but €30,000 is typical for a DC system offering rapid charge whereas a small domestic unit costs under €3,000.

The implication of the ‘ecosystem’ way of understanding change in and around the automotive industry is that previously distinct systems can no longer maintain boundaries or barriers against other systems. Rishi et al. (2008) define these ecosystems as being automotive, energy, consumer electronics, communities, geographies, social networks, other industries (software, telecommunications, financial services) and government.

Dammenhain and Ulmer (2012) take a view that is narrower, but more detailed. In their framework, the e-mobility ecosystem comprises vehicle manufacturers, suppliers to them, the electric vehicles, the IT provider, the e-mobility technology supplier, the e-mobility provider, the public sector, the utility, the distributor, and the charging / changing operator.

No matter what precise definition is used, it is this merging of complexity and the spontaneous eruption of new possibilities between and across previously distinct ecosystems that means that ‘stand-alone’ business models cannot really be understood in isolation any more.

Much ecosystem thinking focuses on the concept of resilience vs efficiency (Walker and Salt, 2006), whereby we tend to make our systems more and more efficient over time within a narrow set of operating conditions. When these conditions change, the hitherto efficient system lacks resilience, a threshold is reached, beyond which a rapid change to a new system results – often with undesirable characteristics. At times of impending or on-going change, it is prudent to favour resilience over efficiency, but resilience often comes at a cost – ‘redundancy’ – that existing players are reluctant to accept. It could be argued that the
existing automotive industry is a classic example of such an efficient human system, lacking in resilience – as the recent near-collapse and hurried bail-out of the Detroit 3 illustrates.\(^1\)

Langezaal and Bouman (2011) identify a series of problems that need to be resolved to bring AFVs to market, many of which have a business model or regulatory component. The challenges included:

- Market models and regulatory frameworks, including the division of responsibility by participants in the market
- Standardisation and inter-operability, including issues of software security across and within networks, and payment systems
- Core vehicle technology development including bringing down the cost of battery packs to below US$300 / kWh; and installing an appropriate charging infrastructure
- Enabling technologies including for example communication systems between charge points, vehicles, electricity suppliers, and vehicle suppliers; and the development of key back-office systems to provide seamless integration of the customer experience
- Detailed understanding of the impact of charging on grid performance
- Greater understanding of consumer behaviour and practice with AFVs.

\(^1\) Although Ford did not receive direct tax payers money, it is now agreed that the collapse of GM and Chrysler would have been enough to cause a major collapse of the supply sector, which would have made Ford no longer viable – 60%-80% of the value of a car is outsourced.
8. AFV Business Models

Biofuels are in many ways the least radical of AFV solutions, yet even here new players enter the scene, most obvious of these are farmers and the farming lobby, while new risk elements such as climate and weather make an appearance. Dealing with farmers also means dealing with many more suppliers than in the conventional oil sector, even though the vehicle side of the value chain sees few if any significant changes (Figs. 8.1 and 8.2).

Fig. 8.1 Simplified Biofuel Value Chain

One additional aspect here is the role of informal supply networks of private individuals and SMEs making biofuel from feedstocks such as vegetable oil, used fats from the fast food industry, etc. This is either for use in their own vehicles, or for sale in localised markets, either formal or informal.
According to Langezaal and Bouman (2011) electric vehicle recharging offers the space for business model innovation but that space is constrained by the following four factors: A driver needs to recharge every 150km; charging can be made possible by almost anyone almost anywhere; the cost of charging is about €3 per full battery; and the faster the charger the more expensive it is. The initial infrastructure investment costs are high, but the marginal costs of increasing the consumer base is low – meaning that the key to commercial success is in signing up a large number of consumers – probably by a proliferation of consumer propositions. Unfortunately, the potential social cost of this strategy is that different networks may be ‘closed’ to varying degrees to non-subscribers, particularly in those countries where a pure market approach is taken to bringing infrastructure forward.

NPC (2012) indentify four key questions with respect to infrastructure provision: who owns and pays for the initial investment in the charge point; who installs, operates and maintains that point; who provides the charging and billing from that point to the customer; and how does the customer pay for access to the point and the electricity consumed? Equally, May and Mattila (2009) identify four distinct scenarios in which they examine the cost structures, revenue streams and profitability of EV charging infrastructures, but it is precisely here that the main problems emerge. While it is entirely possible to describe and enumerate a given
scenario under which investments make good sense and offer competitive rates of return, investors still have no real way of knowing which out of countless possible scenarios will actually come to pass. In other words, all of these forecasts suffer from the same fundamental problem in that the error margin is not known.

Figure 8.3 shows the BEV value chain and the various elements that can be used to extract value from it and that can therefore form the basis for a business model. As with biofuels, certain informal local supplies can compete with the more conventional mainstream generators.

Figure 8.3 The BEV Value Chain

BEV business model?

In figure 8.4, then the range of feedstocks for the EV is highlighted. It is this aspect that is crucial to the EV’s competitive advantage, as it has the potential to reduce, or even eliminate our reliance on fossil fuels.
Charging infrastructure points

The EV ‘ecosystem’ as many term it is interesting in part because it is possible to reconfigure the participants and their roles in a great many ways, theoretically giving the consumer a much wider choice extending, for example, to choosing who generates their electricity and how (as with the BMWi linkage with Naturstrom). This factor, along with the potential incompatibility of networks mentioned above, may undermine the return on investment calculations offered by e.g. Langezaal and Bouman (2011). The eVGo model is thought to require up to 20,000 subscribers to be profitable in a given metropolitan area (NPC, 2012). Government investment has underpinned much of the initial infrastructure deployment as in the Netherlands, the UK and elsewhere. As the UK OLEV (2011) argues, in order to ensure government funds are not wasted the public infrastructure is often seen as providing a secondary role behind domestic and workplace charging; but the lack of public infrastructure is often cited as a key component of so-called range anxiety.
Different business models will attempt varying degrees of bundling or integration. For example the NRG eVGo model (initiated in Houston, Texas) offers a high level of integration including the installation and upkeep of charge points as well as unlimited charging (subject to fair use) in a public infrastructure subject to a suitable monthly fee. There are three tiers to the eVgo model as shown in Table 8.1 below. The eVgo approach is able to be offered at the point of sale (i.e. a vehicle manufacturer franchised dealer) alongside finance, service packages and other mobility features.

Table 8.1 Subscription tiers in the eVgo business model

<table>
<thead>
<tr>
<th>Home</th>
<th>Complete</th>
<th>Mobile</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 year service agreement</td>
<td>3 year service agreement</td>
<td>3 year service agreement</td>
</tr>
<tr>
<td>Installation of home charging dock and equipment</td>
<td>Installation of home charging dock and equipment</td>
<td>Installation of home charging dock and equipment</td>
</tr>
<tr>
<td>Pay for electricity use at home station</td>
<td>Unlimited charging at eVGo stations</td>
<td>Unlimited charging at eVGo stations</td>
</tr>
<tr>
<td>US$49 per month</td>
<td>Unlimited charging at home with no additional electricity cost during off peak use</td>
<td>Pay for electricity use at home station</td>
</tr>
<tr>
<td></td>
<td>US$89 per month</td>
<td>US$79 per month</td>
</tr>
</tbody>
</table>

(Source: NPC, 2012).

In the event of market failure, public authorities may justify intervention on wider social, economic or environmental grounds as in the case of the Paris Autolib scheme. As initially defined (Jeffery, 2010) this scheme envisaged 1,000 stations (700 in central Paris, 300 in the suburbs) with an average capacity of 6 cars, resulting in 6,000 parking lots for about 3,000 cars. The business model is based on a €15 monthly subscription plus €4 per 30 minutes of driving. The Paris scheme is in effect a large car sharing scheme that embraces the entire urban area (see below). Both this scheme and private initiatives such as that run by Zipcar depend upon robust real-time information to link drivers with available cars: in the case of Zipcar many of the added value services can be accessed by iPhone.
One problematic issue is how the business models will evolve over time given the uncertainty surrounding issues of market scale. For example, while EVs in general are not expected to exert a heavy load on the grid, growth in numbers and clustering effects may very well result in ‘hot spots’ and peaks of electricity demand that should not ideally be met simply by increasing capacity. In this case the infrastructure management model may migrate from a simple subscriber orientation to one that integrates electricity supply management.

A second problematic issue is the legal and regulatory environment in which third party infrastructure management businesses might seek to develop. The provision and billing of electricity is already a contentious and regulated area in many countries, with a wide range of approaches evident. This lack of cohesion alone may be a significant hurdle to the provision of integrated services across jurisdictions when electricity is being provided as a fuel to vehicles. In an attempt to alleviate concerns in this area, there has been a focus on ‘roaming’ agreements to enable users to charge their vehicles on other networks or indeed in other countries; for example in October, Renault, PSA and others announced a MoU to allow roaming. In Portugal the MOBI.E system has been designed from the outset to support all electric vehicles (including bicycles and vans), to be inter-operable, and to offer users seamless billing on a pan-European basis (rather in the manner that bank clearing houses process VISA transactions or like mobile telephones with a roaming account).

A third consideration is that broadly speaking the different types of charging point become more expensive as they become faster at delivering a charge (Chang et al., 2012). Domestic (Level 1) chargers use 110V or 220V (AC) and typically deliver 1.9kW, charging a pure BEV with a 24kWH battery such as the Nissan Leaf in about 8 to 14 hours. Level 2 chargers also operate at 220V (AC) but can deliver up to 6.6kW, and hence charge a Nissan Leaf in 3 to 5 hours. Finally, a level 3 charger uses 480V DC and can charge a Leaf in less than 1 hour – though care must be taken not to damage the battery. However, while the equipment and installation cost of a Level 1 charger is less than US$1,000; a Level 2 charger less than US$2,000 to over US$10,000 (depending somewhat on location); and a Level 3 charger in excess of US$40,000. Given that electricity prices are low relative to the charge required, the sale of electricity alone does not readily justify the investment in public infrastructure. It is notable that Chang et al. (2012:31) conclude that:

‘From a revenue perspective, site owners are reliant on consumers for high turnover, high utilization, and a willingness to pay a premium, or mark-up for the electricity used. Given that electric vehicles are so new and such a large proportion of owners tend to charge predominately in their own homes, a lot of the revenue related variables are currently quite low, and
growth is somewhat uncertain since many public locations currently offer free charging.’

In their report, the NPC (2012) identified two broad types of infrastructure provision: that of charging the battery still in the car via suitable points; and that involving battery swaps. The battery swap model offers a more comprehensive solution to the issues of speed of recharge, battery purchase cost for consumers, and grid loading issues but equally requires a higher level of commitment from vehicle manufacturers to design vehicles to be suitable, and from consumers to accept that the swapped battery concept is suitable.

**Battery swap model**

The Better Place model is not exclusively reliant on battery swap: home and public charging facilities are also envisaged. Even fast-charging takes 35-40 minutes, whereas the battery swap approach offers times comparable to a conventional petrol or diesel refill. In Israel, Better Place anticipated a ratio of 30,000 charge spots against only 70 battery swap stations (Lache et al., 2010), although there is possibly an argument that by being given an effective monopoly over infrastructure deployment Better Place in Israel could plan and deploy a larger infrastructure more quickly. Israel is particularly favourable to Better Place for several reasons, including the significance of solar power electricity generation, the small size and isolated nature of the market, and the importance of fleet sales. Lache et al. (2010) estimate the following investment profile for Better Place (Table 8.2)

<table>
<thead>
<tr>
<th>Item</th>
<th>2015 end</th>
<th>2016 end</th>
<th>Investment (US$m) at 2020 battery price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Switch stations</td>
<td>25</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Charge spots</td>
<td>107</td>
<td>137</td>
<td>136</td>
</tr>
<tr>
<td>Batteries</td>
<td>914</td>
<td>1,160</td>
<td>770</td>
</tr>
<tr>
<td>Other fixed assets</td>
<td>12</td>
<td>13</td>
<td>12</td>
</tr>
</tbody>
</table>

| Total investment | 1,058    | 1,339    | 948                                    |

(Source: Lache et al. 2010. Note assumes 2020 battery price of US$325 per kWh)
The profitability of the Better Place business model is crucially dependent upon gaining a sufficient number of subscribers across which to amortise the approximately US$1 billion investment required in Israel. Lache et al. (2010) estimate that at a revenue of about US$4,550 per annum and a subscription base of 110,000 by the end of 2016 Better Place would be significantly profitable, generating revenues of about US$500 million and an operating margin of 40%. The major proviso, however, is that the infrastructure investments have to proceed ahead of the revenue generation, so it is necessary for the financial backers to sustain a long-term view of the market opportunity. It may be significant that in October 2012 the founder of Better Place was removed as Chairman while the business continued to accumulate debts faster than was anticipated.

An alternative is to use battery swapping on public bus fleets (Kaschub et al., 2012). There are advantages in terms of the known and regular routes public transport travels, and the ‘back to base’ character of the fleet, such that an investment of this type can make sense in net present value terms and as a significant contribution to improved air quality in urban areas. The main problem lies in having appropriate vehicles designed.

**Intersecting business models**

Partnerships, alliances, cross-shareholdings and outright mergers and acquisitions will all feature as multiple parties seek to position themselves in the emergent AFV market. One consequence is that the intersection of mutually supportive business models will probably become more important. The Better Place model is actually reliant upon intersecting with the business models of the power generation and distribution sectors because of the beneficial impact it has on load levelling with renewable energy sources, and with vehicle manufacturers whose business model allows for the removal of battery packs. In this regard it is interesting that Renault has, independent of its relationship with Better Place, brought BEVs to market with a business model that separates out the ownership and funding of the battery pack from the vehicle – an approach that is not possible if the battery pack is deeply integrated into the vehicle structure. It also has – in spite of its relationship with BetterPlace – only designed one of its EVs for easy battery swap. In a related but different manner, the forthcoming BMWi models will be made available to customers with ‘green’ electricity sourced via Naturstrom.

Similarly, the Autolib case in Paris is interesting because the vehicle manufacturer does not require a traditional distribution and retailing structure to bring vehicles to the market. Neither does the manufacturer have the direct relationship with the customer. The result is a business model distinctly different to the mainstream automotive industry, but also one
that is closely tied to the specific character of state intervention in this case. In that respect the Autolib case illustrates the intersection of the business model with state policy.

Case Study: Autolib

Autolib is run by the Bollore Group, a family owned business, founded in 1822. Bollore is in the top 500 companies in the world with 8bn euro net sales in 2011, and 34,500 employees in 110 countries. Their main interest derives from their battery expertise: lithium metal polymer (LMP) technology. This is a unique technology, for which they hold all the patents. It has no liquid electrolyte and with an operating temp of between 60-80 degrees C it means it operates at a stable temperature, as a result of which no cooling system is needed and it works at all ambient temperatures. The full operating temperature range of the battery is 60-180C, but little heat is lost, so very little energy is lost. 100 Wh/kg is the energy density. They now have 2000 batteries running and have used them in real life from -15 to +30 degrees ambient temperature.

Having decided that the LMP technology was very suitable for EV applications, Bollore first approached car manufacturers, but they all agreed battery cars had no future, preferring to develop diesel further and then to manage a transition to the fuel cell.

Bluecar

Bollore decided to go ahead anyway, so they had to find a partner to develop a vehicle. This was CeComp in Italy, who developed the car, which was designed and is built by Pininfarina as a subcontractor to CeComp. The Bluecar has a 250km range (urban cycle), 150km on mixed cycle, it is a 4 seater and takes 8 hours for a full charge. The chassis is a combination of steel and aluminium, the body panels are aluminium, with some plastic panels (e.g. bumpers). Pininfarina finalised the car in 2009 and it was type approved in June 2011; 4 months after Bollore won the Autolib tender.

Autolib

Bollore won the Autolib tender on 8/2/11 with this vehicle, the Bluecar. It was able to combine the vehicle with its in-house data management and automated interface terminal maker IER, which is world leader in terminals for public services (e.g. automated check-in at airports). It was also able to use Polyconseil – a telecoms consultant. Autolib covers 47 communities in the Ile de France, with Paris at the centre. By 1/6/12 it had 1740 Bluecars in use, 500 charging stations and 600 employees. By full roll-out it will have 3000 cars and 1200 people. Each Autolib station has 4-6 spaces, and a terminal for signing in. 250 sites also have charging for other EVs. There are about 2000 non-Autolib EVs in the Paris region. According to research by ADEM, one Autolib replaces 9 cars.
The average rental is 40 mins and 10 km for Premium annual subscribers. Monthly subscribers tend to use them about 3 hours each rental. The IT solution will find a parking/charging space either automatically or via the call centre. 1 central control/call centre at Vaucresson works 24 hrs/day. An annual subscription (Premium option) is 144 Euro, alternative tariffs for shorter periods are: 30 per month, 15 per week and 10 per day + 5-7 c per km, 17-23 cent/min depending on length of subscription. They have 680 stations now, but are aiming for over 1000. Autolib now has 13000+ annual subscribers (at current growth rate up to 20k by year end), and 37000 overall. They have achieved 584,665 rentals since the start (5/12/11) and an estimated 701,599 kg CO2 saved. Total car trips in Ile de France are normally 23 million/day; with Autolib they hope to replace 22500 private vehicles. Paris is not a car-friendly city, which helps people shift from their own car to Autolib, which guarantees a parking space, for example. They have also found that because 18-21 year olds have little access to a car, but can rent Autolib, they have become early adopters. In fact, 70% of Autolib users are in the 18-34 age group. Contrary to expectations, not a lot of tourists use Autolib. Most people book in the kiosk next to the charging station, not by phone – the direct contact with people at the control/call centre (visible on screen) is appreciated – the human touch is very important and customer care has been a high priority for Autolib from the start to help overcome some of the psychological barriers to EVs.

The 47 municipalities pay 47000 euro per station as a subsidy, but Autolib pay back a fee for the parking spaces, which will pay back this subsidy by 2014 – 4 years ahead of plan. Once it is profitable, profit will be shared with the local authorities. The total investment in the whole project so far is 1.7 billion Euros, including cars, batteries and infrastructure. This has largely come from Bollore. Private individuals can now lease the Bluecars at 500 euros per month. For this they also get a charging point. These cars feature a blue coloured ‘wrap’ (2 shades of blue available), rather than the bare aluminium finish of the Autolib version.

The Autolib business model is particularly interesting, as Bollore has been able to combine the battery technology, the vehicle technology and the infrastructure in one business model, which looks set to become profitable within a few years of its introduction. It therefore captures a significant part of the value chain. What it did need is support from local authorities, who themselves have become key stakeholders within this business model, although clearly the system can survive without their financial involvement, it could not survive without the dedicated urban space in the form of parking spaces allocated to the scheme by these local authorities.

Electricity generation and / or distribution companies may also desire to integrate directly downstream operations in infrastructure installation and management, as in the case of
Alliander in the Netherlands (Langezaal and Bouman, 2011). Silver Spring (2010) present the case that for an electricity utility downstream integration into the control and management of an EV infrastructure offers the highest investment and degree of risk, but also the highest returns.

The Autolib case outlined above is of particular value. In an environment where it is as yet unclear where value can be captured along the EV value chain such as to create a viable business model, Groupe Boloré has been able to capture a very large part of the potential value chain. This is a relatively low risk strategy in a high risk environment in the sense that if any value can be captured from the EV value chain, this firm is sure to control some of it. As the project matures, it may become clear where most of the value can be captured by the firm, and other activities can gradually be devolved to third parties who may be better placed to capture value from those activities than Boloré itself.

**Hydrogen fuel cell infrastructures**

The picture for hydrogen is again different, although there is a considerable degree of technological overlap between BEV and hydrogen fuel cell vehicles, notably in areas such as motors, controllers, etc. However, in terms of energy supply there are differences in that rather than using electricity direct, a conversion step to liquid hydrogen is needed, either from a fossil feedstock or from renewables, whereby electricity can be part of the conversion process.

**Figure 8.5 Hydrogen Value Chain**

H2 business model?
– many different ‘feedstocks’; can be made on-site
In terms of hydrogen fuel cell infrastructures the overall level of development is well behind that for electric vehicles, with major collaborative R&D programmes underway in the foundation technologies (NEW, 2011). Even where the concept is relatively advanced, such as California, a new pragmatism acknowledges that ‘early commercialisation’ is unlikely before 2015 at best (CaFCP, 2012). To a degree that is even more pronounced than with EVs, the deployment of a fuel cell vehicle infrastructure is dependent upon government acting to overcome market failure and essentially subsidise the initial phases to achieve wider policy goals. There is also still uncertainty as to the viability of pipelines, as against distribution by truck, or local hydrogen generation at the refuelling site. All options currently exist (Fig 8.6).

**Figure 8.6 Hydrogen Infrastructures**

![H2 infrastructure (simplified)](image)

In Germany a government – industry partnership with €20 million funding (partners include Daimler, Linde, Air Products, Air Liquide and Total) aim to establish 50 stations by 2015, and a total of 1,000 by 2025 (FCT, 2012). In California these ‘pre-commercial clusters’ are in the process of being developed. In other words, the CaFCP is adopting a version of ‘predict and provide’ in which uneconomic investments in establishing a hydrogen infrastructure will be made in order to pull forward sales of fuel cell vehicles. In their analysis the CaFCP estimate
that 68 stations would be needed in the target locations by 2015. The overall station deployment plan is shown in Table 8.3

Table 8.3 Deployment of hydrogen stations in California 2012 to 2018

<table>
<thead>
<tr>
<th>Year</th>
<th>Stations</th>
<th>Added stations</th>
<th>FCEVs total</th>
<th>Station design capacity (kg/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>4</td>
<td>4</td>
<td>312</td>
<td>Up to 100</td>
</tr>
<tr>
<td>2013</td>
<td>8</td>
<td>9</td>
<td>430</td>
<td>100</td>
</tr>
<tr>
<td>2014</td>
<td>17</td>
<td>20</td>
<td>1389</td>
<td>100-500</td>
</tr>
<tr>
<td>2015</td>
<td>37</td>
<td>31</td>
<td>5,000 to 15,000</td>
<td>100-500</td>
</tr>
<tr>
<td>2016</td>
<td>68</td>
<td>Market needs</td>
<td>10,000 to 30,000</td>
<td>500</td>
</tr>
<tr>
<td>2017</td>
<td>&gt;84</td>
<td>Market needs</td>
<td>53,000</td>
<td>500</td>
</tr>
<tr>
<td>2018</td>
<td>&gt;100</td>
<td>Market needs</td>
<td>&gt;53,000</td>
<td>&gt;500</td>
</tr>
</tbody>
</table>

(Source: CaFCP, 2012)

Of significance in Table 8.3 are two items. First is the obvious uncertainty in the projected numbers of vehicles and hence of required stations. Second is the anticipated production capacity in kg/day of each station. This is actually a crucial figure because at present the demonstration stations around the world produce up to 100 kg/day, which is sufficient for about 25 cars of moderate size. As a guide, 1kg of hydrogen is good for about 100 km of driving range. So an average car running about 12,000 km per annum would need to fill up at least 2 times per month. This means in turn that a 100 kg/day station operating 7 days per week could at best support only 350 cars in circulation. Apart from the investment cost required to deploy sufficient stations, a secondary concern once the established stock of cars in circulation becomes large is the sheer space that the required number of stations will
consume. Even in the CaFCP calculation 50,000 cars require at least 100 stations; on this basis 20 million cars in circulation would require 40,000 stations.

The interesting feature of the approach in California is the use of the Clean Fuel Outlet regulation, which in effect is a mechanism to establish the cross-subsidisation of hydrogen infrastructures. Under this regulation, where there are at least 20,000 vehicles using a particular fuel (such as hydrogen) in a region the regulation requires that the seven petroleum companies that supply 93% of California’s petrol must build hydrogen outlets in line with the introduction of fuel cell vehicles.

One of the leading suppliers of hydrogen fuel infrastructures is H2Logic, whose analysis of the situation in Denmark makes a useful comparison with the conventional petrol and diesel infrastructure (Slo, 2012). It is estimated that there are 2,000 conventional stations in Denmark serving about 2.1 million cars, or about 1,000 cars per station. At a delivered price of €10/kg for hydrogen and €1.67/litre petrol, assuming a range equivalent of 30km/litre petrol when using hydrogen and 20km/litre petrol the two fuels are broadly comparable in cost per kilometre. The roll out of the infrastructure then depends upon the assumptions shown in Table 8.4.

<table>
<thead>
<tr>
<th>Item</th>
<th>2012-15</th>
<th>2015-25</th>
<th>2025-50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stations</td>
<td>15</td>
<td>185</td>
<td>450-1,000</td>
</tr>
<tr>
<td>Capital cost</td>
<td>€13 million</td>
<td>€240 million</td>
<td>Not stated</td>
</tr>
<tr>
<td>Government support</td>
<td>50% funded by government</td>
<td>30% funded by government + fuel support</td>
<td>Commercial market terms</td>
</tr>
</tbody>
</table>

Given the fleet predictions for Denmark made by H2Logic, this means that the investment in infrastructure per FCEV is €9,212 in 2012, but would fall to €1,565 by 2025 if the fleet share becomes 4.6% of the total in Denmark. It is interesting to note that with government investment support as defined in Table 8.3 and with fuel cost support at €1.1/kg the entire infrastructure would start to be profitable by 2022, although by then the accumulated debt would be substantial. Vehicle tax exemption, investment support and fuel cost support from...
2012 to 2025 would cost €345 million, or H2Logic prefer to put it the equivalent of one bottle of wine per Dane per annum.
9. Why does change not happen?

Many observers expect the industry to change in the face of recent developments, notably tightening environmental standards and the recession. In reality, there is scant evidence thus far that – despite low profitability now being endemic in the industry – the fundamental structure and operating practices of the automotive industry are changing. It is also the case that much of the technological effort of the automotive industry is going into areas other than powertrain or body architecture, but in fact into aspects of occupant comfort, safety, entertainment and communications. Ironically, this may indeed be the start of a transformation of the car, from a device essentially used to deliver personal mobility and freedom of travel, to a device to protect and connect people within an increasingly urbanized and congested spatial environment. The emphasis of much of this new wave of technology is on vehicle – infrastructure interaction, presented to users as enhanced efficiency through route planning, the identification of parking spaces, proximity to recharging points, etc. all of which cocoon the individual further within the shell of the vehicle (Mitchell et al., 2010). This illustrates that there is also an inexorable path dependency within the automobile towards electric powertrain, making the car over time less of a mechanical and more of an electric and electronic device (Nieuwenhuis, 2009).

New technology in product design and manufacturing process that can be traced to the imperative to improve environmental or sustainability performance may create the space for new entrants and / or new business models and these new entrants may presage a genuine transition in automobility from the outside. However, this need not necessarily be so. It is true that smaller, more niche emergent suppliers of electric vehicles have emerged including companies such as Tesla, Miles Electric Vehicles, ZAP (Zero Atmospheric Pollution), ZENN (Zero Emission, No Noise) and Fisker; all of which have developed or are developing their own versions of electric vehicles. On the other hand, history thus far has shown that such companies are often either doomed to obscurity, or in danger of being absorbed by the incumbents. Even more on the fringe are micro-niche socio-technical experiments with innovative companies and social partners offering alternatives to traditional conceptualizations of the automotive industry alongside innovative technology – new business models in other words. Examples such as Riversimple, Local Motors and MDI Air Car can be found, but remain entirely irrelevant within the vastness of the industry.

Equally, small-scale or localized developments in terms of infrastructure to support alternative mobility practices are under way as cities and regions attempt to capture both the economic benefit of the emergent automobility paradigm as well as the more obvious environmental and transport benefits. Hence there has been a multiplication of ‘hydrogen highways’ and electric vehicle re-charging networks across North America, Europe, Japan, and increasingly in emergent markets such as China. Such instances of diverse development trajectories suggest that the monolithic character of the prevailing socio-technical paradigm is also under threat as localities seek specific and place--- appropriate solutions to sustainable mobility (Wells, 2010b).
Giffi et al. (2010) explore in some depth consumer expectations and responses to a range of different EV cost and performance options, though of course statements in public surveys of this type need to be treated with some caution as actual purchase decisions may not follow from stated intentions. The survey showed that the top three reasons for not wanting an EV were price, range, and the size of the vehicle. The latter point is interesting because in a US context larger cars (and light trucks) have tended to dominate more than in other markets. Moreover, the US has low petrol costs compared with say Japan or the EU, which results in a need for lower electricity costs if EVs are to be competitive. Indeed, a key factor in restraining the rate of change could be conservatism among consumers with respect to what is generally regarded as a ‘big ticket’ item. As Giffi et al. show, it does not matter that much to consumers that they drive say 40 miles per day and their EV has a range of 100 miles... they want the comfort and convenience of a 350 mile range, rather than being a ‘prisoner’ of that limited range.
10. Policy recommendations

While various forms of AFV may indeed help to achieve a range of policy goals there remain doubts about the overall case for their introduction with respect to environmental, economic and social issues. Much depends upon the rate of penetration of AFVs and the carbon intensity of electricity generation (Duvall and Knipping, 2007). As a result, the reduction in externalities is perhaps not as great as had been hoped, while the question of how and by whom costs are borne remains one that is difficult to resolve, particularly during the transition phase before such vehicles become widespread. As Thomas and Sidhu (2009) have shown, a broader perspective of the benefits to include social, economic and environmental gains compared with ICEs helps with the justification for intervention. Gordon et al (2012: 1), also writing about the US case, underline that the broader benefits are valid but still felt moved to argue that:

‘...there is still much to do to further the transition to electric-drive vehicles. It will take a sophisticated set of policy tools and local action to spur manufacturers, utilities, localities, and states to fully commercialize PEVs.’

Interestingly, the approach advocated by Gordon et al. (2012) echoes much of what has been proposed in Europe by those working from a technology policy perspective with an interest in socio-technical transitions (Geels et al. 2012) in that they argue that niche applications need to be identified and nurtured to establish a robust ‘pathway’ to further growth in all forms of plug-in electric vehicle.

Generally, industry argues for clear, consistent and long-term regulatory frameworks as an aid to planning and strategy. Equally, standardisation and commonality are often deemed important. The problem with the ‘niche’ approach to policy, and with the devolvement of policy to multiple jurisdictions (which may be entirely justifiable on democratic grounds alone), is that a fragmented and volatile market framework can result. The work of Lindquist and Wendt (2011) for the case of the US provides compelling evidence of the complexity facing participants in the EV market space.

Critics may identify much more cost-effective ways of reducing carbon emissions or improving air quality, or may indeed highlight the lifecycle costs of alternative technologies, the potential scarcity (and hence geo-political risk) that may accompany key materials, or
the inequity of privileging access and mobility for the wealthy that can afford AFVs. The Union of Concerned Scientists (Anair and Mahmassani, 2012) in the US argues that for consumers or indeed policy makes a key problem lies in trying to understand exactly when and where an AFV makes sense: For example in the US the global warming intensity of electricity generation in the worst region is 2.5 times that in the best region because of differences in the energy generating mix. An important policy consideration is therefore that gains in one area are not undermined by reversals in other. A second and rather neglected policy consideration is to ensure that social cohesion is not undermined by inequalities in access or mobility arising from AFV initiatives (Wells, 2012).

It is readily apparent that policy must further be suited to specific contexts and conditions. Significantly, many of the locations that have sought to support the introduction of AFVs through subsidies, public-private partnerships, or outright government investment in infrastructures have done so in part on the basis that doing so will enable those locations to capture a significant share of what is anticipated to be an important emergent sector of the economy. Again, these hopes may be misguided at least in as far as it is unlikely all locations will be winners in the race to capture the economic benefits of AFV production and use (Wells, 2012). Moreover, high-profile state support for nascent AFV companies and related technologies may backfire, as appears to be the case in the US with 123 Systems (battery supplier) and Solyndra (solar power company) where substantial public funds have been invested and the companies have failed.

Policy interventions therefore are both necessitated by the embryonic state of the technologies concerned, and the relative cost-benefit of these technologies compared with traditional ICE vehicles, but simultaneously those interventions carry a significant risk. While it may be politically attractive to be seen to be supporting ‘green’ mobility of one form or another, it is likely that only significant resource investments over a protracted period of time and with complete policy stability will enable AFVs to prosper. In this respect an interesting, if contentious, role model is that of the Olympics. In the Olympic policy framework it is absolutely evident that there is a very real deadline, and then a very large and consistent investment by the state is necessary, partnering with companies with the necessary skills and resources, to bring the entire event forward. To date, no AFV programme has seen anything like that level of concentrated and coherent investment. The very fact that such project carry a higher risk than is entrepreneurially acceptable, is why the state has to intervene in such cases, especially where there are perceived or expected public or social benefits – such as cleaner air, greater energy independence, etc.
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Appendix 1 – EV charging and business models
### Electric vehicle charging and related business models

<table>
<thead>
<tr>
<th>Sector model</th>
<th>Sub-category</th>
<th>Comments and examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Electricity generators</td>
<td>Renewable energy electricity production</td>
<td>1.1 Align tariffs and availability to downstream electricity retailers.</td>
</tr>
<tr>
<td>2. Electricity distributors</td>
<td>Peak pricing and managed supply</td>
<td>2.1 Charge differential (higher) prices for charging at peak times; lower prices for off-peak times. Requires smart grid connection so that the vehicle ‘knows’ when best to recharge. De-regulated electricity market probably aids flexibility in deployment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.2 Reducing charger output to manage demand peaks. Again requires smart grid connection. IT system is vital here.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.3 V2G solutions. Owners of EVs could re-sell electricity back to the grid at peak times. Requires smart grid and suitable regulatory framework, as well as consideration on battery longevity issues.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4 Sell to service provider rather than charge individual customers</td>
</tr>
<tr>
<td>3. Recharging equipment manufacturers</td>
<td>OEM supplier only. Manufacture and supply recharging equipment to third party vendors or infrastructure managers</td>
<td>3.1 Tied supplier e.g. SolarCity solar rechargers supply to Tesla but Tesla CEO Elon Musk also is an investor and the Chairman of SolarCity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2 Manufacture equipment and sell to third parties only. Expected to become a low-margin business</td>
</tr>
<tr>
<td></td>
<td>OEM and infrastructure management. Combined manufacture and installation and management of recharging infrastructure on own</td>
<td>3.3 Design and construct EV charging points. Provide free to businesses. Example: Success Charging (USA). Retain ownership of charge point. <strong>Generate or share revenues with client from charging either PAYG or subscription system.</strong> Use smart phone to offer added services e.g. locator for charging points.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.4 As in 3.3 but <strong>not provided free to</strong></td>
</tr>
<tr>
<td>3.5</td>
<td>3.5 As in 3.3 above but U-Go Stations (USA) is currently acquiring exclusive location rights and installing charging stations in targeted, desirable, high traffic locations. In exchange for <strong>exclusive location rights</strong>, U-Go shares the charging station income with the location owner.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td>---</td>
<td></td>
</tr>
<tr>
<td>3.6</td>
<td>3.6 As in 3.3 above but adding e.g. <strong>aggregating power consumption and matching billing to demand cycles to help optimise grid use</strong>. May involve linkage with electricity generator and / or distributor. May act as a virtual aggregator of demand.</td>
<td></td>
</tr>
<tr>
<td>3.7</td>
<td>3.7 <strong>Buying minutes or miles.</strong> Example: NRG (Houston). Three plans up to US$89 per month. Say 36 month deal. Users essentially pre-pay for the electricity use. Consumers get charging point installed free at home (worth US$2,000), and have free access to public points, but pay (in the plan) for the electricity used.</td>
<td></td>
</tr>
<tr>
<td>3.8</td>
<td>3.8 <strong>Public – private collaboration.</strong> Initial investment costs in charging points supported by public funding to allow critical mass to be attained.</td>
<td></td>
</tr>
<tr>
<td>3.9</td>
<td>3.9 <strong>Third party company leases the equipment and support, and offers free charging to its own customers.</strong> Potential clients could be e.g. a large supermarket chain. The viability of this model depends upon attracting extra customers, a feature that may readily deteriorate over time as competitors follow suit.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>4. Recharging infrastructure managers</strong></th>
<th><strong>Buy in required equipment and installation thereof; manage the network</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.1</td>
<td>4.1 <strong>Battery swap model.</strong> Example: Better Place (Denmark). Owners of the vehicle do not own the battery. Infrastructure manager owns the battery and the recharging equipment; can be run in parallel with normal recharging infrastructure. <strong>Users pay a membership fee and service charge for each rapid swap.</strong> Battery</td>
</tr>
</tbody>
</table>
4.2 Municipal services model. Local government authority manages the infrastructure as part of a wider electric mobility scheme to attain policy targets such as reduced congestion and cleaner air in urban locations. Example: Paris Autolib scheme. **PAYG system once registered.**

4.3 Mainstream charging network management by third party. Example: VitaeMobility produced the equipment in Belgium, with the service being installed, run and maintained by ABB. **For VitaeMobility, the project utilises profitable DC chargers which should provide a quick return on investment.** For ABB, the investment risk has been made by another company, allowing them to focus on sustainable operation and management.

<table>
<thead>
<tr>
<th>5. Vehicle manufacturers</th>
<th>Provide recharging equipment and / or services with the car</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.1 charging with the car. Example: Tesla in California. Tesla will <strong>build and install its own infrastructure for which owners get free access but not free electricity.</strong> Others have to pay an access fee. A form of vertical integration downstream into ‘fuel’ provision.</td>
<td></td>
</tr>
<tr>
<td>5.2 Free home recharger with the car. <strong>Equipment is provided and installed free where circumstances permit. Users pay electricity supplier for energy.</strong> Example: Nissan and the Leaf model.</td>
<td></td>
</tr>
<tr>
<td>5.3 Chassis swap model. Vehicle is designed for rapid swap between running chassis with e.g. fuel cell or battery on board, and independent upper body. Example: GM AUTOnomy concept car. No business model attached to this concept.</td>
<td></td>
</tr>
<tr>
<td>5.4 Chassis swap model with public / private split. As with 5.3 but the lower running chassis is owned by the public transport authority while the upper body is retained under private ownership. Example: RIDEK concept. No</td>
<td></td>
</tr>
<tr>
<td>5.5 Additional mobility offer. The package sold to the consumer who has acquired or leased an EV includes access to one or more alternative vehicles in the product range (not necessarily an EV) for occasional use as the need arises. Example: Peugeot Mu concept, only available via selected Peugeot-owned dealerships.</td>
<td></td>
</tr>
<tr>
<td>---</td>
<td></td>
</tr>
<tr>
<td>Battery management strategies</td>
<td></td>
</tr>
<tr>
<td>5.5 Second life for the battery. Manufacturer takes the battery back after useful life in automotive has ended, and uses in energy storage applications. <strong>This strategy reduces the rate of depreciation on the battery, and hence the cost to consumers.</strong> Example: Nissan 4R programme with Hitachi in Japan.</td>
<td></td>
</tr>
<tr>
<td>5.6 As with 5.5 but the electricity distribution company could own the battery, lease it to a car user, and then recoup the battery after automotive use for applications elsewhere.</td>
<td></td>
</tr>
<tr>
<td>6. Mobility service providers</td>
<td></td>
</tr>
<tr>
<td>Car sharing schemes</td>
<td></td>
</tr>
<tr>
<td>6.1 Back to base recharging by the owner of the vehicle; use of public infrastructure otherwise. Example: May be done by e.g. car rental company (Hertz in NY) or new player like Zipcar (using RFID). <strong>Users pay per distance travelled and/or time taken with the vehicle, and for membership of the scheme.</strong></td>
<td></td>
</tr>
<tr>
<td>7. Hydrogen production suppliers</td>
<td></td>
</tr>
<tr>
<td>Construct, install and manage hydrogen refuel equipment</td>
<td></td>
</tr>
<tr>
<td>7.1 Suppliers of industrial gases diversifying into new areas. Revenues derived from the per kg sale of hydrogen. Example: Air Products (UK) H2 station in Heathrow Airport. Also Linde (Germany). No business model attached to this concept.</td>
<td></td>
</tr>
<tr>
<td>7.2 Suppliers of petroleum products diversifying into new areas. Revenues derived from the per kg sale of hydrogen. Example: Shell; Total. No business model attached to this concept.</td>
<td></td>
</tr>
<tr>
<td>7.3 New suppliers of equipment. Revenues</td>
<td></td>
</tr>
</tbody>
</table>
derived from the per kg sale of hydrogen but also possibly from sale of equipment to third parties. Example: H2 Logic. No business model attached to this concept.

| 8. IT and security services | Manage and support the IT system and customer interfaces | 8.1 Call centre  
8.2 Billing and payment information interchanges between customer (bank), electricity provider, infrastructure manager, vehicle provider.  
8.3 Mapping and related data provision on availability of infrastructure for charging; link to battery management optimisation on the vehicle. |
|----------------------------|----------------------------------------------------------|--------------------------------------------------|
| 9. Mobile charging/fuelling | Provide mobile service for EV rapid charging, or hydrogen refuelling | 9.1 EV mobile rapid charging can be provided to address range anxiety; when the Ev runs out of charge, a mobile service can be called to provide enough charge quickly to get you home  
9.2 A similar service for hydrogen, as long as a full H2 fuel infrastructure is not available; such a service is currently used to support HFCV demonstrators. |