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Deliverable D2.1: Analysis of green niche-innovations and their momentum in the two pathways

Country report 6: Green niche-innovations in the UK mobility system

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Executive summary

This report analyses eight green transport niche innovations in the UK and assesses their momentum. The findings of the report are structured in four sections.

First, the report’s introduction situates niche innovations in relation to the existing socio-technical transport system and the main debates, issues and actors in the UK.

Second, the process of case selection is summarised and eight transport niche innovations are selected.

Third, analysis of the momentum of each of these niche innovations is summarised in respect of three considerations: innovation and market trajectory; actors and social networks; and governance and policy.

Fourth, the conclusion highlights the main drivers of momentum and an overall assessment and relative ranking of the momentum of each of the niches is set-out. The overall assessment suggests that each of the eight niches involves some substitution and also some reconfiguration. Whether each of these eight niches are more oriented to pathway A (substitution) or B (reconfiguration) can be summarised as follows:

<table>
<thead>
<tr>
<th>Niche and ranking</th>
<th>Main drivers of momentum</th>
<th>Transition pathway</th>
<th>Momentum</th>
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</thead>
<tbody>
<tr>
<td>1) (Plug-in- )Hybrid Electric Vehicles:</td>
<td>Ongoing growth in the numbers licensed since the early 2000s and momentum in the UK. The automotive industry is the main actor. In the UK governance is a response rather than agenda-setting. The aim is to attract the production of new models to safeguard economic activity, to address carbon emissions reduction and to use tax and fiscal measures to stimulate uptake. HEVs can be used in similar ways to conventional ICE vehicles and therefore require little reconfiguration of infrastructure or user practices. For use in plug-in mode there is an emergent plug-in infrastructure in the UK and changes in user practices are needed. • Moderate momentum for market trajectory of HEVs • Moderate socio-cognitive momentum • Moderate governance and policy momentum</td>
<td>A</td>
<td>Moderate</td>
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<tr>
<td>2. Battery Electric Vehicles:</td>
<td>A new cycle of hype in the UK since 2005. Social, organisation and technological networks are being developed. Yet, BEVs remain a highly marginal part of UK</td>
<td>A</td>
<td>Moderate</td>
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mobility. In the production and use of BEVs there are many similarities with ICE. There are also numerous differences including an emerging, policy-driven plug-in infrastructure and new production and R&D facilities in the North-east of England. There is a key role for incumbent actors. The main inhibitors to greater momentum are issues of vehicle range and cost. UK policy on BEVs aims to address decarbonisation and economic development.

- Low momentum in terms of market trajectory
- Moderate socio-cognitive momentum
- Moderate governance and policy momentum

### 3. Inter-modal Ticketing (Smart Cards):

Long-term growth in London and limited development elsewhere in the UK. The challenge of building an interoperable smartcard specification was underestimated. The policy narrative is of the ‘inevitability’ of smartcards but this has met the reality of the need for new business processes and commercial agreements. Smartcards aim to integrate sub-regimes of the public transport regime; this involves both existing interests and new interests in configuring new business processes and user patterns.

- Momentum of market trajectory is high in London and low elsewhere
- Socio-cognitive momentum is low to moderate
- Governance and policy momentum is low to moderate

### 4. Car-sharing/Clubs

‘Haphazard’ development from 2000, with rapid growth in membership from 2007 (geographically concentrated in London). Car clubs remain highly marginal. The sector has undergone and continues to undergo rapid change. Local authorities are key actors whose role is subject to experimentation. This requires significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors.

- Momentum of market trajectory is moderate in London and low

<table>
<thead>
<tr>
<th></th>
<th>A/B</th>
<th>Low</th>
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<tr>
<td>3. Inter-modal Ticketing (Smart Cards):</td>
<td>Long-term growth in London and limited development elsewhere in the UK. The challenge of building an interoperable smartcard specification was underestimated. The policy narrative is of the ‘inevitability’ of smartcards but this has met the reality of the need for new business processes and commercial agreements. Smartcards aim to integrate sub-regimes of the public transport regime; this involves both existing interests and new interests in configuring new business processes and user patterns.</td>
<td>B</td>
</tr>
<tr>
<td>5. Biofuels</td>
<td>Shift from optimism around 2003 that biofuels could provide a viable (if partial) substitute for UK liquid transport fuels to a flatlining of supply towards the end of the decade. Biofuels are currently more expensive than fossil fuels. It is difficult to characterise a UK-specific trajectory of biofuel technology development. The UK governance style at present appears unlikely to provide the required push to reach targets set at the European level. Can be viewed as substitute for liquid transport fuels. Though a wider framing sees the reconfiguration of land-use systems from production for food to production for fuel.</td>
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</table>
|  | • Market trajectory momentum is low to moderate  
  • Socio-cognitive momentum is low  
  • Governance and policy momentum is low |
| 6. Hydrogen Fuel Cell Vehicles | Were the subject of much hype from the late 1990s, that stalled around 2005 in the face of technical and cost difficulties and the ‘re-emergence’ of BEVs. Since 2012 there have been the beginnings of a much more modest momentum in the UK. In order to be able to support hydrogen fuel cell vehicles, the existing road infrastructure and some manufacturing capacity can be used. A new hydrogen production, distribution, storage and fuelling infrastructure needs to be configured around the vehicle - elements of which have been the subject of demonstrations in the UK. |
|  | • Market trajectory momentum is low  
  • Socio-cognitive momentum is low to moderate  
  • Governance and policy momentum is low |

7. Urban Cycling/Sharing Schemes: The UK’s largest scheme commenced operation in 2010. There have been limited responses in the rest of the UK. Other interventions alongside bike-sharing may be important in reducing congestion, such as...
congestion charging. An effective public transport system and governance capacity may be a pre-requisite. Reconfiguration of many elements around the bicycle - requires a new conception of users, new business models, new actors, tracking, monitoring and payments technologies and the strategic development of infrastructure.

- Market trajectory momentum is very low, except in London where it is moderate to high
- Socio-cognitive momentum is low outside of London
- Governance and policy momentum is very low

8. Compact Cities

The idea of a compact city has been promoted by national and sub-national policymakers and architects. There are many contemporary visions of new and ‘retrofitted’ cities which have limited realisation. By far the most well-developed is in London. In other cities in the UK this is much more piecemeal. This is not surprising given the weaker governance powers and capability relative to London and the less well-developed public transport systems. Involves a fundamental reconfiguration of a city through designing in public transport and designing out car use.

- Market trajectory momentum is very low
- Socio-cognitive momentum is very low
- Governance and policy momentum is low to moderate
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References
1. Introduction

The purpose of this report is to identify, analyse and assess the momentum of green niche innovations in relation to land-based transport in the UK. The structure of the report reflects this and begins with an introduction which situates niche innovations in relation to the existing socio-technical transport system and the main debates, issues and actors in the UK.

a) Transport Modes

The UK land-based transport domain consists of various mobility modes, which is dominated by cars (Figure 1.1). Each mode can be studied as a relatively separate socio-technical system (with some overlaps). The bus system has some overlap (in terms of infrastructure, petrol fuel, internal combustion engines) with the car-system. The train system is largely separate (its own companies, infrastructure, policies). The tram system is also largely separate, but interacts with cars in cities (overlapping infrastructures), and cycling/walking also interact with cars.

Figure 1.1: Different modes in the land-based transport system/domain

The contribution of different modes in the UK is remarkably similar to different European countries, with cars accounting for about 87% of passenger kilometres (Figure 1.2).
Because of its dominance, special attention will be paid to car-based automobility, although interaction with other modes will also be important. Figure 1.3 presents a schematic representation of the socio-technical system in auto-mobility.

**Figure 1.3: Schematic representation of socio-technical system in auto-mobility**

![Diagram showing the socio-technical system in auto-mobility]
In the UK car transport is the dominant mode of land-based passenger transport as a proportion of overall passenger kilometres travelled (Figure 1.4). The proportion of passenger kilometres attributed to automobility (cars, but figures also include vans and taxis) has been growing since the 1950s, from just over a quarter of passenger kilometres then to 87% by the 1990s, with signs of stabilisation.

**Figure 1.4: Passenger transport per passenger kilometres**

![Graph showing passenger transport per passenger kilometres](image)

Source: Transport Statistics Great Britain 2013

b) **User Practices**

The reasons for undertaking car journeys are multiple: these include commuting to work and for business purposes, to access education, for shopping, to access leisure activities or as a leisure practice itself (see Figure 1.5). The overwhelming majority of car journeys are under 50 miles (98%). By 2012 this still meant that trips by car contributed 64% of all trips and 78% of distance travelled (National Travel Survey, 2012).

**Figure 1.5: Trips by main mode and purpose 2012**

![Bar chart showing trips by main mode and purpose](image)

Source: Transport Statistics Great Britain 2013
c) Infrastructure

The road network in Britain consists of approximately 245,000 miles of roads (Transport Statistics Great Britain, 2013). This network is made up of different ‘types’ of roads from major roads (motorways, ‘A’ roads) to minor roads (‘B’ and ‘C’ roads). Responsibility for maintenance of road infrastructure lies with UK national government, devolved government in Scotland and Wales and local authorities.

The vast majority of the more than 28 million registered cars in Britain in 2012 are fuelled by petrol (66.7%) or diesel (32.7%). There has been a significant shift from petrol (92.6% in 1994) to diesel (7.4% in 1994) through the 1990s and 2000s. These vehicles are fuelled via a roadside infrastructure of filling stations that are estimated to have reduced in number from around 37,500 in 1970 to around 9,000 in 2011.

d) Production

The production of automobiles remains a significant part of Britain’s economy. This includes both mass production and assembly capability, including Nissan, Toyota, General Motors and Honda and more specialist producers such as Aston Martin, Jaguar and Rolls Royce – but with only one manufacturer building complete cars. This means that there are manufacturing, process and powertrain design and manufacture capabilities as well as specialist capabilities in motor sports. There is, though, recognition that there are gaps in capabilities and capacity in the UK automotive sector given that there is limited building of complete cars in the UK.

e) Policy and Governance

From the early 1950s onwards a supportive policy context contributed to a rapidly expansionary automobility system. The emergence of problems facing the system – congestion, air pollution, road building protests, noise – by the 1990s resulted in policymakers at different scales reaching for regulatory levers, the search for technological responses and to a lesser extent questioning the sustainability of the dominant automobility system and opening up the possibility of modal shifts in mobility. On the first of these, emissions standards at EU level have become progressively stronger. The European Commission has established binding emission targets for new car and van fleets. Specifically for cars, manufacturers must meet emission targets of no more than an average of 130 grams of CO\textsubscript{2} per kilometre (g CO\textsubscript{2}/Km) by 2015 and 95g by 2021, compared with an average of almost 160g in 2007 and 132.2g in 2012.

On the second of these the UK government and other national bodies have promoted the ‘inevitability’ of and possibilities for green cars (OLEV, 2013). CO2 emissions from road transport accounted for around 22% of UK emissions in 2005 (King Review, 2007, p.12). The Stern Review of 2006 developed a powerful argument that brought carbon and climate change together with the economic costs of inaction and the economic possibilities of action (Stern Review, 2006). This view became influential across government. What followed from this was the King Review of low carbon cars in 2007 and 2008 (King Review, 2007; 2008).

On the third of these, some modal shift away from car use is promoted through public transportation and associated sustainability initiatives. A 10 year national sustainable transport plan was launched at the start of the new millennium (DETR, 2000). The plan: took an ‘integrated’ view of transport; based on public-private partnerships working together;

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delivering a suite of new projects across the transport network. The plan promoted capacity
development over demand management, drawing on technological responses with
responsibilities for delivering the approach passed down to sub-national authorities (Docherty
and Shaw, 2008). In the intervening period from the 1990s there has been a gap between
visions of sustainable transport set out nationally and what has happened in action. Where
outside of London: ‘Sustainable transport remains talked about rather than acted upon’
(Docherty and Shaw, 2008, p.7). This has resulted in a form of pragmatic muddling through
(Shaw and Docherty, 2014). This is the context within which many potential green-niche
innovations in Britain have or have not and will or will not develop momentum.

There is a helpful distinction to be made between seeing transport, on the one hand, in
national terms as a larger-scale inter-urban system across longer distances and, on the other,
addressing urban transport systems of various modes. On the first of these, subsequent to the
10 year plan, there is no national vision for transport. Though in general terms a key statutory
underpinning of UK policy is largescale reduction in greenhouse gas emissions, there are no
concrete targets for CO2 emissions reductions from transport. The grey shaded area of the
left hand column (Figure 1.6) sets out the contribution of ‘surface transport’ (i.e road and rail)
to overall greenhouse gas emissions – of which cars accounted for the majority.

**Figure 1.6: CO2 emissions and reduction target**

Aviation (GHG) - (37); Shipping (GHG) - (13); Agriculture and LULUCF (GHG) (48); Waste (GHG) - (17);
Other non-CO2 - (28); Industry (CO2) - (114); Buildings (CO2) - (82); Surface transport (CO2) - (110); Power
(CO2) - (144); 2050 target - (160)

Between 1990 and 2011 total transport GHG emissions fell in absolute terms but increased as
a proportion of total UK GHG emissions (Transport Statistics Great Britain, 2013).
2. Case selection

2.1. Initial list of Potential Green Niche-Innovations
This section sets out a list of potential green-niche innovations in the UK context. The list was generated through an initial search of key UK policy documents and academic literature. The list is as follows:

1. Battery electric vehicles
2. ICE/electric hybrid vehicles
3. H2 fuel cell vehicles
4. Biofuels
5. Inter-modal transport and innovations to facilitate this (e.g. intermodal ticketing / smart cards, park-and-ride, coordination of bus/train schedules)
6. Light rail/tram schemes
7. New forms of ‘on demand’ car rental; Car sharing
8. Cycling and various innovations to support/expand this market niche (e.g. urban bike hire schemes; Cycling groups; cycle hubs at employment destinations/public transport interchange; cycle route investment; cycle storage at public transport points)
9. Radical changes in urban space, e.g. transit-oriented development, smart/compact cities, car-free cities

2.2. Selection of 8 Main Niche-Innovations
Different niches are grouped under four themes on the basis of the dominant purpose of the niche. The momentum that they have generated is discussed. These themes build on a ‘sustainable mobility approach’ (Banister, 2008) (pp.75-6) and four sets of actions underpinning such an approach. These are:

1. Reducing the need to travel
This approach focuses on reducing travel and not making trips – for example, through teleworking, teleconferencing or via internet shopping. Similarly new practices of car sharing, such as car clubs, can contribute to alternative ways of undertaking a journey and reduced aggregate travel (e.g. through a shared commute). On the other hand new forms of ownership through convenience (on demand rental) may promote more travel. There appears to have been growth of car clubs and on-demand rental since the second half of the 2000s.

2. Encouraging modal shift
This is intended to be a contribution to reducing car use through shifts to alternative modes of mobility such as walking, cycling, tram and light rail. Urban bike hire schemes have begun to generate interest since the second half of the 2000s. London has a city-wide bike hire network. Other UK cities are beginning to try and build similar networks. A significant element of this theme is not only provision of modal alternatives to automobility but also building inter-modal connections. Efforts to address this have focussed on urban centres. The experience of this in the UK has been variable over the last 15 years. Inter-modal ticketing, for example, exhibits momentum in London and limited momentum outside of the capital.

3. Reducing trip lengths
This approach aims to reduce the lengths of trips through integrating the planning of urban centres, with a reduction in the physical distance between everyday activities and the
organisation of green modes of transport. There are various long-term visions that integrate sustainable mobility with plans to re-think and re-design cities. These include, for example, as compact cities, smart cities and even traffic-free cities. This is a long-standing idea dating back to the 1960s and 1970s but has been re-vitalised since the 1990s. These are often highly visionary and there has been limited realisation to date.

4. Encouraging greater efficiency in the transport system

This involves promoting the use of new engine and fuel technologies, and standards and obligations on manufacturers, to build greater transport efficiencies. This includes battery electric vehicles, ICE/electric hybrid vehicles, hydrogen fuel cell vehicles and also biofuels. There is variable momentum of each of these niches with each over the last 15 years exhibiting momentum. The important reason for including them under this theme is that each remains a potential option even if at this point in time some generate less momentum (H2 FCV) than others (BEV). They are also included as the policy context in the UK has developed a strategic vision for ultra-low emissions vehicles (see OLEV, 2013).

The discussion of the recent history of transport in the UK, and the variable momentum of the different niches above illustrate that there is a lack of coherence in the approach to transport in the UK. There has been the promotion of particular green niches at different times over recent years. Some of these niches had begun to be symbolically promoted before stalling (e.g. light rail), others have recently been strategically prioritised (ultra-low emissions vehicles) and others still are picking up momentum elsewhere following their exemplification in London (urban cycling, inter-modal transport).

The four themes above currently represent the nine potential niches that are set out in the list above. Eight are chosen from the initial list. Each of these niches can be understood as efforts to address one of the four themes set out above. They are a mix of niches that are technology-focused, addressing behavioural change and demand management and changing the form of cities. The eight are:

<table>
<thead>
<tr>
<th>Niche</th>
<th>Approach</th>
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<tbody>
<tr>
<td>1) Battery electric vehicles</td>
<td>[4] Greening of cars (and/or buses) to improve efficiencies</td>
</tr>
<tr>
<td>2) ICE/electric hybrid vehicles</td>
<td>[4] Greening of cars (and/or buses) to improve efficiencies</td>
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<tr>
<td>3) H2 fuel cell vehicles</td>
<td>[4] Greening of cars (and/or buses) to improve efficiencies</td>
</tr>
<tr>
<td>4) Biofuels</td>
<td>[4] Greening of cars (and/or buses) to improve efficiencies</td>
</tr>
<tr>
<td>5) New forms of car rental/sharing</td>
<td>[1] Reducing or stimulating the need to travel through new social organisation of existing technologies</td>
</tr>
<tr>
<td>6) Urban cycling</td>
<td>[2] Encouraging modal shift through new configuration of old technology in new urban cycling system</td>
</tr>
<tr>
<td>7) Inter-modal transport</td>
<td>[2] Encouraging modal shift through integration – improving linkages between transport modes. Conceptually it is integration that is the signifier of modal shift – and that is populated by a variety of initiatives.</td>
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</table>
3. Analysis of the Momentum of 8 Niche-Innovations

Section 3 contains analysis of these eight niche innovations in UK context, using the case-study protocol described in chapter 1.

3.1. Battery Electric Vehicles

3.1.1 Innovation and Market Trajectory (Techno-Economic)
Battery electric vehicles (BEVs) have seen significant symbolic promotion since around 2005. Yet, they remain a highly marginal part of UK mobility. This is the case in both overall numbers of BEVs on UK roads and in percentage terms (see Figure 3.1).

Figure 3.1: Pure Electric and Plug-In Car Grant Eligible Vehicles Licensed in Great Britain

Though there are small numbers of BEVs on the streets of the UK, there is an emergent plug-in-infrastructure, there have been efforts to secure or retain inward investment and various vehicle and infrastructure demonstration projects have been undertaken or are in progress. This contrast between the hype of BEVs and limited diffusion in the UK should be set in a context where transition to ultra-low emission vehicles is seen as ‘inevitable’ (OLEV, 2013).

Limited diffusion contrasts with the UK Committee on Climate Change’s high EV uptake pathway. This set out a 16 per cent market share for Plug-In Hybrid Electric Vehicles and Zero Emission Vehicles (BEVs and Fuel Cell Vehicles) by 2020 – revised down to 9 per cent in 2013 - a 60 per cent market share by 2030, and a 100 per cent market share for ZEVs by 2040 (Committee on Climate Change, 2013a, p.23; Element Energy, 2013, p.viii).

The main perceived inhibitor to diffusion is anxiety about the range - generally around 100 miles - of BEVs. It has been pointed out that for widespread adoption battery storage will need to increase fourfold and costs will need to drop by 70% over the next decade (Tran et al, 2012, p.330-1).
Assessing price and performance aspects of BEVs is fraught with difficulty. With that in mind, the costs of electric vehicles, particularly without support, are expected to remain high between now and 2030 (Element Energy, 2013). Recognizing difficulties of direct comparison, it is estimated that there is a premium on the costs of BEVs of around 50 per cent in relation to ICE comparators (Element Energy, 2013, p.25). Projections for the costs of BEVs vis-à-vis ICE vehicles show a significantly longer payback period where lower running costs of BEVs do not offset higher capital costs. There remains a wider debate as to the business model appropriate for the BEV and whether it is sold as a single product, one consisting of various bought and hired elements, or through various hire and rental schemes (Tran et al, 2012).

Often assessment of CO2 emissions is framed in relation to tailpipe emissions. In the case of BEVs this would result in zero emissions. A more helpful comparison of the CO2 emissions of BEVs vis-à-vis competitors and ICE technologies would involve full lifecycle assessment of CO2 emissions from production to disposal and including the source of electricity (Tran et al, 2012).

3.1.2 Actors and Social Networks (Socio-Cognitive)

A complex network of regulators, industry, users, both incumbent and new actors, has been behind the development of BEVs in the UK. The UK government set up a dedicated coordination body – the Office for Low Emission Vehicles (OLEV) – in 2009. It also manages the provision of £400m of public funds to 2015 and £500m between 2015 and 2020. Funding provides grant support to the purchasers of eligible electric vehicles, to stimulate the development of charging points (through the Plugged-in Places scheme) and to develop an R&D programme (see Figure 3.2).

Figure 3.2: OLEV Relationships

![OLEV Relationships Diagram](Source: OLEV, 2013)
R&D funding of £82m (between 2010 and 2015) in Ultra Low Emission Vehicles (ULEVs) generally has been committed by OLEV and managed through the national innovation agency the Technology Strategy Board (TSB). There has also been the development of an advanced propulsion centre, announced in 2013, which is claimed to be supported by a joint government-industry investment of £1bn over 10 years.

Nissan sited European production for its LEAF electric vehicle in the North East of England since 2013. The European Investment Bank provided €220m, the UK government allocated grants of more than £20m and a new battery plant was built alongside the Nissan plant in Sunderland. This is part of a wider trend internationally of car manufacturers seeking alliances with battery companies (Orsato et al, 2012; Dijk et al, 2013).

In terms of users there is much work to be done on whether EVs are substitutional for existing ICE vehicles. Are they just another car? Or do issues of range, charging and connections to the grid link to forms of use that are significantly different from ICE practices? The role of incumbents in defending the existing ICE regime is critical here. With their sunk costs and responses to regulation there is incremental innovation. The limited growth of BEVs can be contrasted with the growth of hybrids (see Dijk et al, 2013). Fleets are seen as an effective way of stimulating uptake of BEVs.

When users will plug-in is uncertain and related to work, leisure, convenience and pricing tariffs amongst other issues (Tran et al, 2012). This also reflects the uncertainties of levels of diffusion with estimates of future market shares ranging from 20% to 70% between 2030 and 2050 meaning that potentially between 2GW and 18GW of installed capacity may be required (Tran et al, 2012). There is a need to bring electricity generators and distributors into the emergent BEV niche. But a business model that works between these sectors has yet to be effectively developed; including mechanisms and levels of payments between electricity suppliers and vehicle operators (Steinhilber et al, 2013).

The vision for BEVs in the UK weaves together a response to ambitious carbon emissions reduction targets with economic, industrial development concerns, energy generation and distribution and also, to a lesser extent, local air quality and noise. In addressing this BEVs are seen as one element of a wide ranging response that cuts across mobility/transport and electricity. Indeed, electric mobility requires a fundamental shift in the supply of energy, local distribution to users and the provision of charging infrastructure networks (Leurent and Windisch, 2011).

3.1.3 Governance and Policy
Since around 2005 there has been a new policy momentum for BEVs driven by concerns around climate change and peak oil. Regulatory instruments have been key at both EU and UK levels. The EU has stringent CO2 regulations that have become incrementally tougher since they were adopted in 2007 and created pressures on manufacturers to reduce CO2 emissions for new cars.

The European Commission’s 2009 roadmap for the electrification of road transport set out development to this end in phases (Demonstration and field tests to 2012; an intermediate phase until 2016 where 1 million EVs/PHEVs are deployed with urban and regional infrastructure development; and 2018 onwards mass production of new vehicles, with battery developments and the removal of subsidy). In 2010 the Commission set out its strategy for
the development and uptake of clean and energy efficient vehicles. Alongside this the EU FP7 stimulates powertrain technology through R&D (Leurent and Windisch, 2011).

In 2009 OLEV was established, a three phase approach to beyond 2020 was set out (Leurent and Windisch, 2011) and grants and incentives for BEVs and low emission vehicles followed as part of a wider green stimulus package. These include the Plug-in Car (introduced 2011 and to pay 25% of an eligible car up to £5,000) and Plug-in Van grants (introduced 2012 and to pay up to 20% of an eligible van up to £8,000); direct grants to support manufacturers (Nissan); whilst at the same time stimulating plug-in infrastructure. BEVs are exempt from a number of duties and taxes (Fuel Duty, Vehicle Excise Duty, Company Car Tax). There is also a ‘Low Carbon Vehicle Procurement Program’ where £50 million is used to stimulate introduction of lower carbon vehicle technologies through public fleets. In 2013 a further development of strategy for ultra-low emission vehicles was set out (OLEV, 2013). This would seem to suggest that there is widespread recognition that diffusion of BEVs requires systemic innovation and strategic protection to achieve this (see Pinkse et al, 2014).

Cities find themselves anticipating or responding to national priorities but also have plans in relation to BEVs. The most ambitious and well developed is in London where there is a target of 100,000 BEVs (5 per cent of GLA fleet) as ‘soon as possible’ and 25,000 charging points by 2015 (Mayor of London, 2009).

Though we appear to be in a period of renewed enthusiasm, BEVs have not broken out of their niche. One view is that contemporary attempts to enact a transition to BEVs have manifestly failed (Steinhilber et al, 2013, p.532). An only slightly more optimistic view suggests that even on the basis of ambitious assumptions that ‘BEVs may only provide a niche market over the next 20 years’; one that will continue to require support (Tran et al, 2012, p.332).
3.2 (Plug-in-)Hybrid Electric Vehicles

3.2.1 The Innovation

The term hybrid electric vehicle (HEV) covers a number of developments that bring together conventional ICE and electric powertrains. Since the first sales of its Prius in 1997 it is estimated that Toyota alone has sold over five million hybrid vehicles (OLEV, 2013). In the UK there has been ongoing growth in the numbers of HEVs licensed since the early 2000s (see Figure 3.3 as indicative of this in relation to petrol HEVs).

Figure 3.3: Petrol Hybrid Electric Vehicles’ Market Share in European Car Sales, By Member State

Hitherto HEVs have largely referred to vehicles with a support electric engine, powered by battery, that is charged by the ICE. There have been generational developments in technology. In 2012 Toyota made available a plug-in production version of the Prius (PHEV). PHEVs are a combination of ICE and battery and additionally charged through plug-in infrastructure. The balance between ICE and electric is important with HEVs dominant on conventional fuels with limited electric. PHEVs continue an incremental shift towards full plug-in electric. The size of the ICE in PHEVs is smaller than in HEVs; and PHEVs have a larger battery and a longer electric range than HEVs. PHEVs have a limited electric-drive range of between 20 and 60 miles (Egbue and Long, 2013). Yet it has been suggested that range anxiety may also be understood in terms of a disconnection between expectations of range and actual practices, where those surveyed typically drove around 80km per day (Tran et al, 2012).

Through a review of 14 studies, the range of predicted market share varies significantly but is expected by 2020 to be between 5% and 20% for HEVs and between 1% and 5% for PHEVs.
and by 2030 to be between 20% and 50% for HEVs and 15% to 30% for PHEVs (Kay et al, 2013, pxvi). The UK had a target for combined BEVs and PHEV to achieve 16% of new sales for both cars and vans by 2020, subsequently reduced to 9% of new car sales and 12% of new van sales. This is in a wider scenario of 60% of new vehicle purchases being BEVs, PHEVs or FCVs by 2030 (Committee on Climate Change, 2013a).

It has been suggested that Toyota produced early Prius’s at a loss of more than $20,000 a vehicle (Pinkse et al, 2014). Even by the early 2000s it was estimated that HEVs cost between $2,500 and $14,500 more than similar conventional vehicles and that by 2005 the premium for existing hybrids averaged around $4,000 (Sovacool and Hirsh, 2009). Latterly, cost premiums on full HEVs versus conventional ICE comparators were estimated at around £2,400, much of which was due to battery costs, and which is claimed will reduce by half in cost by around 2020. PHEVs have a premium from manufacturing of around £7,800 above the costs of conventional ICEs. This is claimed to be reducible to around £3,000 by 2020 (Kay et al, 2013, pp. 70-71).

In terms of CO2 emissions reduction it has been estimated that HEVs can reduce emissions by around 25%. The potential for PHEVs has been estimated at around 33% net lifecycle emissions reduction which could be 37% by 2020 (Kay et al, 2013, pp.70-71).

As of 2012 there was one PHEV model available in the UK, which was a plug-in version of the Toyota Prius and also two range-extended models, the Chevrolet Volt and the Vauxhall Ampera. From 2013 and into 2014 it was expected that there would be a further 10 PHEVs and three range-extended PHEVs available on the market in the UK (Committee on Climate Change, 2013b).

### 3.2.2 Actors and Social Networks

The automotive industry is the main core actor in developing HEVs and PHEVs but there are different strategies of response. At the forefront of developments has been Toyota, where other producers have belatedly sought to join them long after Toyota established itself as a leader (see Pinkse et al, 2014; Dijk et al, 2013). The success in sales of the Prius and other Toyota hybrids brought a shift in the strategies of some manufacturers, from around 2005, who had hitherto been sceptical about hybrids. Toyota has sought to position itself at the forefront of PHEVs, launching a plug-in version of the Prius in 2012. Other automobile producers also have commercial PHEVs priorities, including Mitsubishi, Volvo, Volkswagen and Honda.

Hybrids are associated with existing producers and the role of government, which particularly post the 2007/8 economic and financial crisis has been bound up with a defence of the automobile industry as key employers and economic actors. The coordination of government and producers in the UK can be seen through OLEV. Through the Green Bus Fund local authorities and bus operators have competed for low emission vehicles, through multiple rounds of funding, that has resulted in more than 1200 low carbon buses in England, particularly in major cities. This is not solely focused on HEVs, as it includes BEVs and other low emission options but it includes significant numbers of diesel-hybrid buses.

Production of hybrids in the UK can be seen at Toyota’s plant in Derby where the Auris hybrid is manufactured. Hybrid trucks have also been manufactured in the UK, by Leyland DAF, since the end of 2010 allowing for stop-start functioning and up to 2km of electric driving (OLEV, 2013).
Users of hybrids in broad terms are conceived of as users of conventional vehicles. That said, there has been research which sets out a range of motivating factors in adopting hybrids from a perceived financial gain to links to environmental value and the symbolism and image of driving a hybrid (Tran et al, 2012).

Often discussion is of hybrids as a product. But it is more helpful to talk about hybridisation as a process, which is embodied in products (HEVs and PHEVs). The vision is one of evolution that seeks to strategically adapt the dominant position of incumbents to the regulatory and technical challenges presented by carbon and air quality regulation. Though competitors have entered the game not all manufacturers have and there remain competitor technologies from full BEVs to H2 FCVs and increased efficiencies of conventional ICEs. Policymakers recognise a role for HEVs, and PHEVs. Yet what that role is is subject to a wide range of expectations – see for example the wide variety of expectations of potential market share of PHEVs. Often even in the way in which PHEVs are characterised there is a conflation in terms of targets with BEVs. Such a view is one which is consistent with a processual view of hybridisation where the processual ‘end’ is full BEVs.

Though there has been generational developments, where there has arguably been less development is in understanding the social context of use and the business models that may mediate that. This is not surprising given that the strategy for HEVs and PHEVs is primarily constructed by dominant incumbents whose interests are arguably served by fewer changes and more certainty in user practices.

3.2.3 Governance and Policy
In the UK the institutional context and governance of HEVs and PHEVs is a response rather than agenda-setting. The UK is a home to but not the home of largescale automobile producers. On the one hand governance and regulation of HEVs and PHEVs in a UK context is concerned with defending the jobs and economic activity associated with automobile production in the UK. This has involved promoting the production of a hybrid model by Toyota, the Auris, at their Derby plant. It also means ‘not picking winners’ where alongside hybrids the production of a full BEV, the Nissan Leaf, has been supported with loans and R&D support for Nissan’s Sunderland plant.

The UK government is bound by its own statutory carbon emissions reduction targets of 80% by 2050 with interim targets in between then and now. There are also CO2 regulations at EU levels on manufacturers and the pressures for CO2 emissions reductions on new cars. As a governance response the aim is to retain existing producers and to attract the production of new models to safeguard economic activity and to address carbon emissions reduction. There is limited control over the private interests who will deliver these responses. There is therefore a combination of grants, subsidies and the provision of supporting infrastructure with coordination mechanisms, such as OLEV to try and voluntarily bring together different elements of the innovation system. That said, this operates at the level of a range of possibilities rather than specifically in terms of hybrids. This network governance approach is intended to create favourable conditions for private sector activity.

There is a different relationship at the level of the public sector where national government arguably exerts more control on the responses that emerge. There has been some incorporation of HEVs in to bus fleets across the UK. This has been part of a Green Bus Fund established by national government and where UK local authorities compete for funding for
greener buses. There is also a ‘Low Carbon Vehicle Procurement Program’ to stimulate public fleet demonstration, particularly public bodies such as government departments and local authorities, and uptake of lower carbon vehicle technologies. At the level of individuals ultra-low emission vehicles are not subject to a number of duties and taxes (Fuel Duty, Vehicle Excise Duty, Company Car Tax).
3.3 Hydrogen Fuel Cell Vehicles

3.3.1 The Innovation
Between 1998 and 2005 major car manufacturers contributed to the production of 33 prototype hydrogen fuel cell vehicles (H2 FCV). By 2004 this led to predictions from Opel that within a decade 10% of their vehicles sold would be FCVs with similar pronouncements from other leading manufacturers (Bakker et al, 2012). These projections have not been met. Although the period after 2005 saw a shift from hype to disappointment, H2 FCVs remained seen as a long-term option even given a new hype around BEVs. Since around 2010 there has been a reassessment and a move towards keeping the option of H2 FCVs open (hedging) but a re-framing away from a single technology winner to a portfolio of possibilities (complimentarity). As H2 FCVs remain largely in a demonstration phase it is ‘not possible to extrapolate diffusion patterns on this basis’ (Zubaryeva and Thiel, 2013). UK H2 Mobility suggests sales of approximately 10,000 vehicles per annum by 2020, taken up by early adopters. And by 2030 the claim is that there will be 1.6 million H2 FCVs in the UK with annual sales of over 300,000, as relative costs of FCVs decrease and the hydrogen refuelling network expands (see Figure 3.4) (UK H2 Mobility, 2013, p.ii).

Figure 3.4: Consumer Demand for FCVs, Cost, and Fuel Network Expansion

By contrast with BEVs, the issue of vehicle range is less of a problem, with FCVs demonstrators having ranges of over 400 miles (Thomas, 2012). H2 FCVs can be fuelled in minutes at refuelling stations. There is the need for the development of a fuelling infrastructure to provide sufficient coverage to stimulate demand yet widespread uptake will require a pre-existing fuelling infrastructure. This is the so-called chicken and egg problem. Producing hydrogen relies on more or less carbon intensive methods. Currently the majority of hydrogen is a product of industrial processes generated by natural gas or other
hydrocarbons. Distribution may be through trucks, pipelines or local production. The issue of storage on the vehicle has remained an ongoing issue for H2 FCVs and there has been a significant amount of research on storage, where solid-state, or metal hydrides storage is seen as a key technology to be developed. It is broadly expected that proton exchange membrane (PEM) fuel cells will be used for H2 FCVs. There are systemic challenges for connecting and configuring elements of H2 FCV systems (see Figure 3.5).

**Figure 3.5: Connecting the Hydrogen Mobility Chain**

![Hydrogen Energy System for Mobility](Image)

Source: Anandarajah et al, 2013

A review at the end of the hype period in 2005 suggested that FCVs were about three times more expensive than conventional vehicles and four times more if the supply chain was factored in (Veziroglu and Macario, 2011). A number of different sources have projected steep cuts in price to 2020 (McDowall and Dodds, 2012) – although intuitively, and with the benefit of only a few years passing since they were made, these projections would appear to be optimistic. This said, there has been steady progress with bringing down the cost curve for H2 FCVs (Veziroglu and Macario, 2011).

It is hardly surprising with these levels of uncertainties that depending on the study it is anticipated that H2 FCV penetration may range from 5% to 50% (Zubaryeva and Thiel, 2013). Widespread diffusion of FCVs is still not expected to take place until the 2040s.

### 3.3.2 Actors and Social Networks

In the early 2000s there was policy concern about the UK’s absence from the international race for hydrogen. This informed the development of the UK strategic framework for hydrogen in 2004. The role of government is in setting conditions rather than a strong role in delivering. The delivery was to be done by others – either private interests, quangos or sub-national government. In this hype period notions such as independence, progress, democratization and inevitability were attached to hydrogen developments (Sovacool and Brossmann, 2010; Eames et al, 2006). These rhetorical visions were often weakly connected to implementation.

H2 FCV diffusion and infrastructure development will depend on strategic interactions between government and business (McDowall, 2012). It is important to understand collaborations between them and also with fuel providers, regime actors and some actors
external to the regime such as hydrogen distribution companies (van Bree et al, 2010, p.535). From 2005, significant efforts to stimulate collaboration didn’t take place until 2012 when UK H2Mobility was established to bring together industrial gas companies, automobile producers, fuel cell companies and their representatives, energy utilities, government departments, power technology and infrastructure companies, supermarkets and wider EU interests. Incumbent fuel providers are not advocates of hydrogen and are not part of the major UK collaboration on hydrogen (McDowall, 2012).

H2 FCVs have also been seen as potential answers to problems at urban levels, in particular around issues of air quality and emissions reduction. Developing a hydrogen agenda in London has been promoted through the London Hydrogen Partnership since 2002 and which, on the face of it, has been subject to a similar hype cycle to that nationally. There were also the development of visions in other UK cities and regions (Hodson and Marvin, 2006; Hodson, 2008).

In visions the role of the users are often treated as rational economic actors and consumer preference type surveys are undertaken. Many government and business responses conceive of H2 FCVs either explicitly or implicitly as substitutional with limited shift in user practices and mobility patterns. The business model for H2 FCVs is uncertain (McDowall, 2012). There is also a question of infrastructure development and whether keeping options open and hedging is a sustainable approach given that two sets of infrastructures with their capital costs need to be developed (Bakker et al, 2012).

3.3.3 Governance and Policy
There have been all manner of efforts to build platforms, consortia, frameworks, roadmaps and plans and (temporary) governance frameworks. At the EU level the hype cycle can be seen as relatively synchronised with EU policy pronouncements and funding programmes in the early 2000s. Indeed, in 2002 the then Commission President, Romano Prodi promoted the ‘hydrogen revolution’. In the US, President Bush promoted the role of hydrogen ‘so that America can lead the world in developing clean, hydrogen-powered automobiles’3. There was the creation of a competitive race around hydrogen and FCVs. Yet this stalled from around 2005 and momentum picked up for BEVs.

An EC High Level Group for Hydrogen and Fuel Cell Technologies was established in 2002 to develop a vision for the transition to a future sustainable hydrogen-oriented economy. A European Hydrogen and Fuel Cell Technology Partnership was set-up in 2003 and a European Hydrogen and Fuel Cell Technology Platform launched in 2004. A European Hydrogen Roadmap was also set out and the Joint Understanding / Joint Technology Initiative established in in 2008. Not only was a strategic framework and funding for hydrogen and fuel cells established but also a green vehicles strategy in 2010 and a ‘technology neutral’ transport white paper in 2011 created targets to halve the use of ‘conventionally fuelled’ cars in urban transport by 2030 and to phase them out in cities by 2050. The earlier documents are emblematic of the hype while the latter documents represent the move from hype and disappointment towards hedging and complimentarity.

In the UK, the 2003 Energy White Paper outlined a role for hydrogen and fuel cells as part of a future ‘fuel mix’ to meet what was at the time a 60% carbon emissions reduction target by 2050. In 2004 the development of a strategic framework for hydrogen suggested that

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hydrogen had the potential to make a significant contribution to the UK’s priorities in transport (E4Tech et al, 2004). UK visions were strong on rhetoric in this period but funding and financial resources were not particularly significant. After 2005 this became much more under-stated in the UK.

At a UK level - in addition to the establishment of Cenex in 2005 - the UK Sustainable Hydrogen Energy Consortium, involving a number of UK universities ran from 2003-2011. The King Review (2007; 2008) saw a long-term role for H2 FCVs but pointed out that they were unlikely to be a significant contributor to CO2 emissions reduction in the short to medium term. This though began a process of re-framing H2 FCVs as one option rather than the option. The institutionalisation of CO2 emissions reduction through statutory targets and the role of the Committee on Climate Change meant that rather than specific advocacy of H2 FCVs (or other technologies) that a suite of possibilities were assessed in relation to CO2 emissions. From 2012 there has been a modest re-emergence of interest in H2 FCVs. This does not have the enthusiasm of the previous hype phase but still assumes that by 2030 that around 10% of new vehicle sales will be H2 FCVs and that in the longer-term H2 FCVs could complement BEVs.
3.4 Biofuels

3.4.1 The Innovation
After earlier optimism that biofuels could provide a viable (if partial) substitute for UK liquid transport fuels, supply has flat-lined. Figure 3.6 shows biofuel supply emerging in the UK in 2003, increasing sharply towards the end of the decade, before plateauing. Current volumes equate to approximately 3% of UK liquid fuel consumption. These levels are low within the European context and even lower compared to Brazil and the USA.

Figure 3.6: UK Biofuel Supply Volumes

![UK Biofuel Supply Volumes Graph](source: DfT, 2013a, p. 17)

UK biofuel production capability is negligible. Over the period of the Renewable Transport Fuel Obligation (which has been the UK government’s main policy instrument to incentivise biofuels, see below), the proportion of UK domestic supply compared to imports has increased from 9% to 21% between 2008 and 2013. The UK differs from other European countries in terms of the relative importance of petrol and diesel and this provides important market context for biofuel substitution. Over the RTFO period the ratio of biofuels supply has shifted significantly from biodiesel to bioethanol (Figure 3.7), which also reflects the higher price of the former compared to the latter.

Given the significant reliance of UK biofuel supply on imports, it is difficult to characterise a UK-specific trajectory of biofuel technology development. Analysis of global developments in biofuel technologies is typically framed in terms of generations. First generation biofuels, based on long known technological principles, currently dominate UK supply of biodiesel (made through transesterification of vegetable oils and animal fats) and bioethanol (made through fermentation of wheat and sugar for example). Of currently available first generation biofuels, only sugar cane bioethanol is viewed as being a viable component of the fuel mix in the longer-term future. The search for advanced biofuels has been spurred by emerging evidence concerning greenhouse gas emissions from biofuels (see discussion of ILUC later) and the effects of energy and food crops competing for land.
Second generation or advanced biofuels refer to a wide range of potential innovations, ranging from different feedstocks, cultivation techniques and biorefining technologies. The UK’s public research base is quite active in crop research and in microbial science and has links to a relatively small group of dedicated biotechnology companies and large agri-food (e.g. Syngenta) companies working in the field.

In the UK there has been significant flux in the feedstocks used for biofuel supply. Figures 3.8 and 3.9 illustrate these changes for biodiesel and bioethanol respectively. The fluctuations reflect modifications to regulatory frameworks and to changes in the economic competitiveness of biofuels sourced from different global regions.
Biofuels are currently more expensive than fossil fuels. Projections about future price competition are strongly effected by uncertainties in oil prices and efficiency / scale factors in biofuel production. The IEA (2011) produced two scenarios (Figure 3.10) based on different assumptions for these uncertainties. These figures for global biofuel supply show that for the low cost scenario, most biofuels reach price parity with fossil fuels by 2030, with only advanced or cane biofuel doing so for the high cost scenario.

Source: Ecofys, 2013
3.4.2 Actors and Social Networks

UK biofuel production was initially dominated by new entrants, starting first with biodiesel and then shifting towards bioethanol (see Figure 3.11 for main production facilities in the UK). Production capacity has increased steadily over the period, but actual biofuel volumes produced remain significantly below this capacity (around 20-30%). This is largely down to the availability of cheaper biofuel imports (especially US and Brazilian bioethanol) and through some temporary plant closures. Beyond these larger facilities, there were approximately 60 smaller firms operating small-scale biodiesel production plants. There has been significant shake-out and consolidation in the number of these biodiesel producing companies over the past several years (Ecofys, 2013).

Apart from some recent involvement of BP, major UK fuel suppliers have not been involved in biofuel production in the UK. More notable has been their involvement in R&D projects globally, mostly oriented towards next generation biofuel technologies. As such, fuel giant BP has a major investment ($500 million) in the US-based Energy Biosciences Institute and has formed a joint venture with a Brazilian sugarcane company.

Figure 3.11: UK Biofuel Production – major plants

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Year of operation</th>
<th>Investment (£ million)</th>
<th>Owners</th>
<th>Jobs</th>
<th>Capacity (million litres)</th>
<th>Fuel type</th>
<th>Feedstock mix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Argent Energy</td>
<td>Motherwell, Scotland</td>
<td>2005</td>
<td>£18.8</td>
<td>Swire &amp; Son</td>
<td>70</td>
<td>60</td>
<td>Biodiesel</td>
<td>UCO, tallow, sewage grease</td>
</tr>
<tr>
<td>British Sugar</td>
<td>Wissington, Norfolk</td>
<td>2007</td>
<td>-</td>
<td>British Sugar</td>
<td>30</td>
<td>70</td>
<td>Bioethanol</td>
<td>Sugar beet</td>
</tr>
<tr>
<td>Convert 2 Green</td>
<td>Middlewich, Cheshire</td>
<td>2007</td>
<td>-</td>
<td>Various</td>
<td>60</td>
<td>20</td>
<td>Biodiesel</td>
<td>UCO</td>
</tr>
<tr>
<td>Greenery</td>
<td>Immingham, Hull</td>
<td>2007</td>
<td>£50</td>
<td>-</td>
<td>56</td>
<td>220</td>
<td>Biodiesel</td>
<td>Waste oils</td>
</tr>
<tr>
<td>Gasrec</td>
<td>Aldbury, Surrey</td>
<td>2008</td>
<td>-</td>
<td>MEZ Energy main investor</td>
<td>21</td>
<td>5</td>
<td>Bio-LBM(^1)</td>
<td>Municipal Solid Waste</td>
</tr>
<tr>
<td>Ensus</td>
<td>Wilton, Teesside</td>
<td>2010</td>
<td>£310</td>
<td>Crop Energies AG</td>
<td>100</td>
<td>400</td>
<td>Bioethanol</td>
<td>Wheat</td>
</tr>
<tr>
<td>Olleco (formerly Agri Energy)</td>
<td>Bootle, Merseyside</td>
<td>2012</td>
<td>-</td>
<td>Olleco</td>
<td>450(^2)</td>
<td>16</td>
<td>Biodiesel</td>
<td>UCO</td>
</tr>
<tr>
<td>Vivergo</td>
<td>Immingham, Hull</td>
<td>2013</td>
<td>£350</td>
<td>AB Sugar, BP, DuPont</td>
<td>80</td>
<td>420</td>
<td>Bioethanol</td>
<td>Wheat</td>
</tr>
<tr>
<td>Planned plants</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>INEOS Bio</td>
<td>Seal Sands, Teesside</td>
<td>2016</td>
<td>-</td>
<td>INEOS Bio</td>
<td>-</td>
<td>30</td>
<td>Bioethanol</td>
<td>Municipal Solid Waste</td>
</tr>
<tr>
<td>Vireol</td>
<td>Grimsby</td>
<td>2016</td>
<td>-</td>
<td>Vireol</td>
<td>-</td>
<td>200</td>
<td>Bioethanol</td>
<td>Wheat</td>
</tr>
</tbody>
</table>

Source: Ecofys

A highly vocal protest was launched against biofuels in Europe and especially in the UK
from around 2007. Environmental NGOs reacted strongly to emerging concerns about the potential impacts of large scale biofuel expansion, the sustainability credentials of biofuels themselves and also about pressure that biofuel expansion would place on food cultivation and therefore food prices (Harvey and Pilgrim, 2010). The publication of two studies in particular sparked a scientific controversy that is still largely unresolved. This relates to the GHG emission effects of Indirect Land Use Change (ILUC) in addition to those relating to Direct Land Use Change (Searchinger et al., 2008 Fargione et al., 2008). ILUC refers to the idea that diversion of crops from food to fuel use would increase demand for food crops to be cultivated elsewhere and this shift would lead to conversion of uncultivated land for food crops which would release previously sequestered CO2. A second area of controversy also emerged in 2008, partly sparked by spike in prices for commodity food crops. This was presented by NGOs in global terms as a societal choice for using land for fuel or for food. In a 12-month period, between 2007-2008, NGOs published major critiques of biofuel technology (WWF, 2007; Greenpeace, 2007; FOE, 2008; Oxfam, 2008). Harvey and Pilgrim argue that NGO campaigns had a tangible impact on biofuel policy in Europe and especially in the UK (Harvey and Pilgrim, 2010).

Visions and expectations for the use of biofuels in the UK are generally cautious and in some cases hostile. The outcome of the Gallagher Review in 2008, advocating a pull back from original targets, appears to remain. The Committee on Climate Change, in its projections for potential future expansions in the use of biofuels offers the following view: ‘There is scope for some use of biofuels in surface transport but, given continued uncertainty over sustainability issues and technologies for advanced biofuels, we continue to limit the take-up of biofuels in the 2020s to a level indicated by the Gallagher Review of between 5-8% by energy in 2020’ (Committee on Climate Change, 2013a, p.111). The UK biofuel industry and associated science base, especially in crop and microbial research, hold alternative visions for the future of biofuels, which are optimistic in principle, but pessimistic in the current context of limited political support.

It is debateable whether biofuel innovation is best conceptualised as a regime development or as a new niche. This partly concerns the extent to which biofuels are viewed as deviant and disrupting to the current mobility sociotechnical system / regime.

### 3.4.3 Governance and Policy

UK biofuel policy has been strongly shaped by the shifting wider discourse, high pressure from NGOs and by European legislation. The policy move in the early to mid-2000s to stimulate biofuel adoption was based on concerns about climate change, energy security and to a lesser extent prospects for stimulating rural development. The overall governance orientation for biofuels can be summarised as a shift over the period from gentle economic incentivising, to strongly interventionist, to the current situation of pulling back and finding ways to circumvent the previously strong commitments.

The European Commission established in 2003 long term and mandated targets for the uptake of biofuels, a strongly interventionist policy approach. The RTFO (see below) has been the UK’s instantiation of EC targets. During 2007-2008, the UK government adopted the most antagonistic stance towards the EC targets and continues to do so on both the rate and ultimate target level of increase in biofuels in the fuel mix. The UK Gallagher Review was highly influential in shaping the EC’s revisions of its biofuel targets to include stringent sustainability criteria for biofuels to be counted against the targets. Overall, the UK
governance style at present appears unlikely to provide the required push for biofuels to reach targets set at the European level (Harvey and Pilgrim, 2013).

The pathway of UK biofuel policy is depicted in Figure 3.12. During the early 2000s the UK government used fiscal incentives to stimulate the growth of biofuels, initially focusing on biodiesel. The key switch in UK instruments followed the European Biofuels Directive (2003/30/EC, EC, 2003), which required that “biofuels or other renewable fuels” constitute 5.75% of the energy content of petrol and diesel sold for transport in member states by 2010. The UK’s response to this was to institute a much more radical (compared to fiscal measures) mandate for the supply of biofuels. The Renewable Transport Fuel Obligation (RTFO) applies to any road transport fuel supplier supplying more than 450,000 l of fossil fuel per year to the UK market, or to discharge their obligation through purchase of certificates. In terms of settings for this instrument, it was originally established to start at 2.5% of total road transport fuel sales in 2008/9, rising to 3.75% in 2009/10 and 5% in 2010–11 and beyond.

Figure 3.12: UK Biofuel Policy Timeline

However, following the recommendations made by the Renewable Fuels Agency (RFA) to the Government in the Gallagher review on the potential indirect land use effects of biofuels policy, the RTFO (Amendment) Order was made on 1 April 2009, reducing the rate of increase of the targets for biofuel supply by volume under the RTFO to 3.25% for 2009–10, 3.5% for 2010–11, 4% for 2011–12, 4.5% for 2012–13 and 5% for 2013 onwards (Renewable Fuels Agency, 2009).

In December 2008, the European Parliament agreed that in order to count toward the EU target, biofuels must deliver life-cycle CO2 savings of initially 35%, then 50% from 2017, rising to 60% when produced from new refineries that come on-stream from 2017 onwards (European Parliament, 2008). These changes were implemented in the 2009 EC Renewable Energy Directive (RED), which also set new targets for 10% renewable transport fuels by 2020. The UK does not as yet have a policy to meet these 2020 targets.

A key modification to the RTFO in light of the European RED has been to allow for ‘double
counting’ (effectively 2 certificates for 1 quantity of biofuel) for some more sustainable biofuels. This partly explains why the actual volume of biofuel in the UK fuel mix is much lower than targets (Figure 3.13).

Figure 3.13: Volumes of Biofuels against Obligation

Source: DfT, 2013, p. 52
3.5 Car-sharing/Clubs

3.5.1 The Innovation

There is a long history to organised car sharing stretching back to the 1940s (Ornetzeder and Rohracher, 2013) and as a response to the oil crisis in the 1970s. The history of modern car clubs can be traced to developments in Switzerland in the 1980s (Truffer, 2010). Since the 1990s the integration of an existing artefact (the car) with various reservation and accounting systems, onboard computers for tracking and billing journeys (Truffer, 2010) have been part of the ongoing development of car clubs. These technological innovations have enabled new forms of service delivery (Le Vine, 2012). Car clubs range from those that allow members/subscribers to make a one-way journey, through station to station journeys, to peer-to-peer car clubs where the club serves as an ‘intermediary’ between car owners and car renters (Finrkorn and Mueller, 2011).

The difference between the conventional automobility paradigm and car clubs is a shift from ownership to access (Katzev, 2003). In station to station clubs there are costs of membership and then, through reservation, the cost of using the vehicle, usually in terms of 30 minute blocks (Hockerts, 2003). In one-way clubs users can pay by the minute and have more spontaneous, on-demand, access (Le Vine, 2012). Whether costs are less or more than ownership of conventional vehicles is complex and relates to variables that include mileage undertaken, age of the existing vehicle and the tariff for using the club’s car. Claims have been made, for occasional and short-term requirements, that car sharing was cheaper than rental and ownership (Hockerts, 2003); or that car club use is generally cheaper than driving a new vehicle where this involves annual distances of less than 10,000km-12,000km per year (Loose, 2010).

The Edinburgh City Car Club, established in 1999, is seen as signalling the birth of modern car clubs in the UK (Loose, 2010). By the early 2000s there were fewer than a dozen car clubs in the UK and development was ‘haphazard’ (UKERC, 2007). In 2006 Carplus, the national coordination point for car clubs, set out a national plan for growth to 180,000 car club participants using 8,000 vehicles, within four years at a public cost of £12.8m (Loose, 2010).

Car club membership in the UK rose from 32,000 in 2007 to almost 160,000, with around 3,000 vehicles, in December 2013, of which about 75% were in London (Carplus, 2014). There are differences between a piecemeal approach (the rest of England and Wales) and efforts to politically and strategically promote a car club network (Greater London and Scotland) to, in London’s case, develop a leadership position in the global car club market (Ball et al, 2014). A 2010 report highlighted that the percentage of the UK population participating in car clubs was under 0.2%. The UK was neither a first mover nor a laggard. (Figure 3.14).

Projections are that car clubs could have one million subscribers in the UK by 2020 (Carplus in Le Vine, 2012). Methodologically there are issues with the reliability of such figures; even with this in mind, car clubs have grown rapidly in recent years and there have been numerous forms of experimentation with how these operate on the ground. Yet despite these levels of growth and hype they remain a marginal part of daily life.
3.5.2 Actors and Social Networks

Early car clubs in Switzerland were user innovations (Truffer, 2010). In the UK from 1999, by contrast, many developments were promoted by coalitions of providers and public authorities (UKERC, 2007). Nationally there was the establishment of the Community Car Share Network (CCSN) (subsequently named Carplus), to support car clubs, in 2000. Carplus has played numerous roles from developing a sector-wide accreditation scheme, setting up an annual survey of car clubs and providing advice to local authorities\(^4\). The sector has undergone and continues to undergo rapid change. In 1999 City Car Club was established, followed by Streetcar and WhizzGo in 2004 and the US operator Zipcar moved into the UK in the middle period of the decade (Bioregional, 2007). By 2009 in the UK there were four large commercial providers (Streetcar, City Car Club, Zipcar and Connect by Hertz) and 12 smaller providers in 43 locations (Loose, 2010). In 2010 Zipcar bought Streetcar, which at the time had the largest car club fleet in the UK. In 2013, Zipcar was bought by Avis Budget group. Car2Go signalled at the end of May 2014 that it intended to pull out of the UK, where it had operated since 2012\(^5\).

There are competing visions of car clubs. The early vision was as response to environmental concerns, where shared usage, sometimes involving cooperative ownership was seen as a way of reducing individual use of cars. A second vision sets out the ways in which ICTs have the potential to create new markets for consuming automobility in convenient, flexible portions.

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\(^4\) [http://www.carplus.org.uk/] [accessed 05/06/2014]

\(^5\) [https://www.car2go.com/en/london/] [accessed 05/06/2014]
Inevitably these two positions are often combined in the different ways of organising car clubs.

Charging and monitoring technologies have generally been retrofitted to standard production vehicles. One likely consequence of this is the evolution of vehicle design to integrate the requirements of car club use (Le Vine, 2012). Studies have highlighted the predominance of male, middle-to-upper income educated customers (Le Vine, 2012). Others highlight that car club subscribers are generally between 25 and 34 (TfL, 2008). Car clubs’ contribution to reducing CO2 emissions are framed and calculated differently; whether emissions relate to end of tailpipe or include full lifecycle for example (Le Vine, 2012). Car club vehicles have been claimed to typically emit significantly less CO2 per km travelled than the ‘average’ car disposed of by members (Myers and Cairns, 2009). Car-Sharing fleets have been reported to emit between 15-20% less CO2 emissions than ‘personal cars nationally’ (Loose, 2010).

Whether car clubs result in reduced or increased numbers of journeys is not well understood (Le Vine, 2012). It has been suggested that ‘traditional’ car clubs are primarily used for excursions, weekends away or shopping but not for commuting (TfL, 2008). By contrast, another survey suggests that one-way car clubs are used primarily as commuter vehicles (see Figure 3.15, Le Vine, 2012). Questions remain about whether the efforts of car clubs to address congestion results in a new form of virtual congestion where congestion is experienced in a different way (Le Vine, 2012).

**Figure 3.15: Respondents’ Usage of Cars by Type of Car Access**

Some studies of the impact of car clubs have been subjected to methodological criticism where evaluation studies and the methods that are used in them are not well developed (Le Vine, 2012).
3.5.3 Governance and Policy
What an appropriate role for government and policy is in relation to car clubs is not clear. A range of support measures for car clubs at a national level have been trumpeted. These include: financial start-up support; establishing a national co-ordination point; car-sharing parking in public streets; political commitment to car sharing (see Loose, 2010). In the UK, there was the establishment of Carplus in 2000. The UK government discussed car clubs in its 1998 White Paper. The limited discussion that there was about car clubs by government at this time largely referred to its role in relation to rural communities, isolation and exclusion. Small additional amounts of funding (£4.2m a year) for car clubs were outlined (DETR, 1998). By the time of the 2011 transport White Paper, car clubs were set out as one of a number of initiatives that could form local sustainable transport responses (Department for Transport, 2011). Funding was through the Local Sustainable Transport Fund (LSTF), which was intended to chime with the government’s ‘localism’ agenda. The funding was available for a wide range of bus, cycling, school travel and other schemes locally, including car clubs. This was available to local authorities to bid to.

The role of local authorities is key in car clubs (Bonsall, 2002; Le Vine, 2012). They can be understood as potentially funders, promoters, partners and demonstrators of car clubs. Local authorities can make land under their control available for parking, raise awareness, provide financial support to projects, include car clubs in local plans and as partners with providers and through designated car club vehicles as allowable in congestion or low emissions zones (Loose, 2010). The precise nature of this is subject to negotiation and experimentation, particularly given the different models of car clubs and also the various local settings in which they are to be developed. This can involve authorities working with incumbents and/or new entrants. Other public sector organisations, such as universities, are increasingly developing car clubs. Businesses have also sought to shape the use of car clubs through using them instead of and alongside their fleets of company vehicles. Not knowing how the field is going to unfold means that flexibility of approach for public authorities and other interests is important. What is interesting is the limited role of national government. Into this space are emerging governance experiments of local authorities and providers, other public-sector bodies and providers, and also private sector business and providers.
3.6 Urban Cycling/Sharing Schemes

3.6.1 The Innovation

There has been significant growth in the numbers of bicycle-sharing schemes and fleets worldwide since 2000 and particularly since 2007 (see Midgley, 2011). In 2000 it is claimed there were five schemes, in five countries, amounting to 4,000 bikes in total. By 2013 it was estimated that the fleet had reached 500,000 in 500 cities in 49 countries (Larsen, 2013). In Greater London, the UK’s largest scheme commenced operation in 2010. This is a large scheme by international standards (see Figure 3.16). There were around 8,000 bikes and 500 docking stations by 2014 with plans for further expansion\(^6\). The scheme is operated by the outsourcing company, SERCO, for Transport for London\(^7\) and sponsored by Barclays\(^8\). The scheme was expected to cost £140m over six years\(^9\).

![Figure 3.16: London in Relation to the World’s Largest Bike-sharing Schemes](source: Larsen, 2013)

In the UK, with the exception of Greater London, there have been limited responses to developing bike-sharing. There are a number of smaller schemes launching in 2014 or planned for 2015 in Glasgow (400 bikes)\(^10\), Liverpool (500 bikes)\(^11\), Belfast (300 bikes)\(^12\).

First generation schemes, such as that in Amsterdam in 1965, were established as a radical alternative form of transport where bicycles could be borrowed for free from a location and left at any location. Many of these schemes suffered from theft and vandalism and were closed (Midgley, 2011). A second generation, established in the 1990s, utilised identifiable, robust bikes, multiple rental and return points and bikes were often secured and released.

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\(^6\) [https://www.tfl.gov.uk/corporate/about-tfl/what-we-do/cycling](https://www.tfl.gov.uk/corporate/about-tfl/what-we-do/cycling) [01/07/2014]

\(^7\) [http://www.serco.com/about/servicetolife/transportcasestudy.asp](http://www.serco.com/about/servicetolife/transportcasestudy.asp) [accessed 01/07/2014]

\(^8\) [http://www.bbc.co.uk/news/10182833](http://www.bbc.co.uk/news/10182833) [accessed 01/07/2014]


\(^10\) [http://www.bbc.co.uk/news/uk-scotland-glasgow-west-27984471](http://www.bbc.co.uk/news/uk-scotland-glasgow-west-27984471) [accessed 01/07/2014]


\(^12\) [http://www.belfastcity.gov.uk/leisure/outdoorleisurefacilities/bikesharescheme.aspx](http://www.belfastcity.gov.uk/leisure/outdoorleisurefacilities/bikesharescheme.aspx) [accessed 01/07/2014]
through coin payments at docking stations (Shaheen and Guzman, 2011). The coin payments system meant that users were still anonymous in the system. Third generation systems: (1) enhanced elements of existing systems, such as bicycle design, docking station technology, and locking systems; and (2) fused together bike-share systems with smartcard technology, electronic payments systems and self-service bicycle stations that link with a central computer and technology to monitor the location of bicycles in the system. Websites also offer real-time data on availability of bikes at particular stations (Midgley, 2011).

Bicycles have been designed for frequent use in a variety of conditions, are standardised and identifiable and difficult to vandalise or steal. Most bicycles have a GPS capability and other tracking mechanisms (Midgley, 2011; Boullier and Crepel, 2014). There are mainly two locking technologies. In the first, bicycles are checked out from an automated bicycle rack with the use of a smartcard or magnetic stripe card. The second technology provides an automated lock on the bicycle itself and relies on the user to communicate via mobile or pay phone for the entry code. Fourth generation systems may include a stronger integration with existing public transport systems through single smartcard payment systems and the location of more docking stations at rail and bus stations (Midgley, 2011).

System costs are more than the cost of a bike and include docking stations, user registration, system status information systems, maintenance programmes and bicycle redistribution mechanisms. Capital costs have been suggested to be between $3,000 and $4,500 per bicycle (Midgley, 2011). There are also capital costs of maintenance and redistribution vehicles, docking stations, licensing of IT systems. Operating costs include those for staff, maintenance, storage, website hosting, electricity for the docking stations and have been estimated at between $1,200 and $1,700 per bicycle (Midgley, 2011). As accreting systems there is likely to be a reduction of costs from learning and upscaling of technologies but additional costs through the ongoing layering of information systems and new technologies over the system. Pricing for most bike-sharing initiatives seeks to configure short-term usage with, often, the first 30 minutes of use free and then increasing prices for each additional 30 minutes. Some systems require membership.

3.6.2 Actors and Social Networks

Visions for urban bicycle-sharing schemes have developed from anti-establishment roots in First Generation schemes to large-scale, corporate-sponsored Third Generation schemes.

Urban decision-makers are prioritising bike-sharing to contribute to enhancing mobility, addressing congestion, reducing air pollution and promoting health benefits through reducing car use. The aspirations of urban decisionmakers are that bike-sharing schemes allow the extension of and are integrated into wider urban transportation systems as part of multi-modal mobility systems (Midgley, 2011; Lin and Yang, 2011). This means that new capacity needs to be built when many urban authorities - in the UK - have limited resources to be able to develop systemic capacity.

Corporate actors (Barclays in London) have become involved in defining and/or operating systems. There has been some opposition from Greens as to the private sector promotion of such schemes (Tironi, 2014). Bike-sharing schemes are usually a public-private partnership, driven by municipalities or occasionally by new companies. The most prolific mode of bike-sharing systems operate via some version of an advertising model (DeMaio, 2009). Within this there is a role for policymakers in providing supporting infrastructure including cycle
lanes and other wider supporting infrastructures. Yet, it has been pointed out that there are relatively few studies that address the strategic design of these systems (Lin and Yang, 2011).

The claim that bike-sharing can extend the system for the last and first mile is difficult to substantiate in that there is very little meaningful data on the benefits and impacts of bike-sharing. That said, there is some evidence that suggests that there is some limited effect from bike-sharing on reducing car use (between 2% and 10% of trips) with the shift being mainly from other forms of public transport to bike sharing (Midgley, 2011) where bikes may increase trips on other modes of public transport and where users may use schemes as part of longer trips (Wang et al, 2010).

Other interventions in concert with bike-sharing may be important in reducing congestion, such as congestion charging (Pucher et al, 2010). What this does highlight is that bike-sharing requires both an effective public transport system and also forms of demand management policy (Midgley, 2011). It has been suggested that successful bike-sharing requires the development by cities of comprehensive bike-sharing strategies (Shaheen and Guzman, 2011) and also that bike-sharing is often part of wider sustainable urban transport strategies. Climate, topography and location of stations/racks all influence use patterns (Wang et al, 2010; Lin and Yang, 2011). Also important is understanding the habits and routines of those moving through the city rather than analysis based on rational intention (Middleton, 2011).

There is a huge amount of hidden work that repairs and maintains the system (Tironi, 2011). This includes maintenance and redistribution of the bikes within the system, where there are imbalances between pick-up and drop-off, through electronic monitoring and the physical relocation of bikes (Boullier and Crepel, 2014; Midgley, 2011). There is limited understanding of the effects of bike-sharing and a call for research into the social and environmental benefits of bike-sharing and of different business models (Shaheen and Guzman, 2011).

3.6.3 Governance and Policy
At a national level in the UK, the Department for Transport is responsible for cycling policy, with the Scottish Executive responsible in Scotland, the Welsh Assembly Government in Wales and the Department for Regional Development (DRDNI) in Northern Ireland. Implementation of policy is largely a local concern. The 1990s were marked by ‘slow and patchy’ local responses to often unclear national frameworks, multiple documents, and limited funding. There was ‘partial institutionalisation’ of cycling policy in the UK from the mid-1990s through planning policy and guidance for local authorities promoting the reduction of car use and the promotion of alternatives, the development of a national blueprint on cycling and, in 1996, a national cycling strategy with targets of doubling cycling trips by the end of 2002 and quadrupling them by the end of 2012 (Golbuff and Aldred, n/d, p.10).

Importantly by the end of the 1990s there was the extension of local transport planning horizons from one year to five years which required an explicit commitment to produce a cycling strategy, and subsequently cycling trips was made a mandatory indicator. Yet, by 2010 cycling in Great Britain accounted, as it had done since 1968, for around 1% of all distance travelled (Golbuff and Aldred, n/d) and ‘for a number of years’ has remained at 2% of all journeys travelled (Department for Transport, 2013b).
There had been significant growth in cycling in Greater London with trips by bike increasing 79% between 2001 and 2011, with this amounting to a 173% increase in central and inner London (Department for Transport, 2013b, p.5). A comparison of people driving into London and cycling showed a sharp shift between 1998 and 2008 where the ratio changed from being 15:1 in favour of driving in 1998 to 3:1 in 2008 (Golbluff and Aldred, n/d). A strategy for cycling was set out in 2001 (Mayor of London, 2001), there was the establishment of a Congestion Charge scheme for the urban core of London in 2003 and its extension in 2007, and designated bus lanes were available to cyclists. By 2008/9 the mayor of London had pledged £62m for walking and cycling which was five times higher than five years previously and set out plans for a bike-sharing scheme\textsuperscript{13}. There were thus a set of pre-conditions to the establishment of a bike-sharing scheme. A change of mayor in 2008 didn’t slow momentum and the new mayor championed a ‘cycling revolution’ (Mayor of London, 2010b). There had been a feasibility study in 2008 to introduce a bike-sharing scheme. This launched in July 2010 to registered users and in December to unregistered users.

Bike-sharing developments in other parts of the UK aside from Greater London have been rather limited. The dominant national-local paradigm involves centralised setting of priorities, funding and the parameters within which local responses must be made. This has so far produced limited results in UK cities outside of Greater London. Greater London by contrast has a privileged relationship vis-à-vis national government. It has a large and relatively well integrated public transport system and has political institutions which allow strategic development and relatively greater resources to achieve these than other areas of the UK.

\textsuperscript{13} http://london.gov.uk/media/mayor-press-releases/2008/01/mayor-sets-out-budget-to-continue-london's-green-revolution [01/07/2014]
3.7 Inter-modal ticketing (smartcards)

3.7.1 The Innovation
Integration and coordination of public transport modes is promoted to create more seamless travel between origin and destination to encourage a shift from car use towards greater use of public transport. Various means are used to promote this including new forms of inter-modal ticketing such as smartcards. Inter-modal ticketing allows a passenger to make journeys utilising more than one mode of transport, where a journey may mean more than one trip, or where a ticket may also be used for a number of independent journeys. A ticket may also be utilised across multiple operators, usually within a defined travel area. The concept of inter-operability (of media, application and products) is central (AECOM, 2011). There are four generations of inter-modal ticketing: (1) systems of tokens or paper tickets; (2) magnetic ticketing systems introduced in the 1970s; (3) from the 1990s, contactless ticketing; and (4) ticketing systems using the customer’s mobile phone (Mezghani, 2008). These systems co-exist and processes of transformation can often be based on historical processes of picking and mixing rather than straight substitution.

Smartcards for public transport grew from there being probably less than 50,000 smart cards across the UK in the 1990s (Blyth, 2004) to there being over 3.7 billion public transport journeys made by smartcard in 2013. There is a London-centric bias to the use of smartcards in the UK with only 700 million of these journeys made outside of London (Slavin, 2014). Since 2003 the Oyster card has become the ‘dominant fare medium’ for public transport in London with over 80% of all public transport journeys using it. More than 43 million cards have been issued since initiation and there are over 10 million journey transactions daily by Oyster card (Ortega-Tong, 2013). A future narrative trumpets the ‘inevitability’ of widespread smartcard transport systems where ‘smart card fare collection systems will become the mostly widely used method of payment in transit networks’ (Pelletier et al, 2011, p.567) and where they will ‘play a significant role in public transport ticketing for years to come’ (Blythe, 2004, p.53).

Smartcards are credit-card sized cards that use a microchip to store, process and write data. There are two broad varieties: memory-only chips which store data and microprocessor chips which as well as storage can process data and which also carries small programs to undertake programmed activities (Blythe, 2004; Pelletier et al, 2011). It is not a new technology with patents dating back to the late 1960s and in to the 1970s (Pelletier et al, 2011). Growth in interest in smartcards in the 1990s came in conjunction with the development of the internet and with information and communications technologies more generally (Blythe, 2004; Pelletier et al, 2011). The technology, as well as the card, and the microchip it contains also involves interfaces that can be contactless - where the card and the reader ‘talk’ via radio frequency identification (RFID).

There is a challenge in estimating whole lifecycle costs of the system (Mezghani, 2008). The costs of producing cards are claimed to be reducing with the scale of production - though there remain limits related to the cost of silicon - and the reliability of cards is increasing (Blythe, 2004). Levels of funding are not always easily identifiable for contractual and commercial reasons with one estimate putting the figure at between around £170,000 and £150m (AECOM, 2011). It has been suggested that the business case for operators using smartcards in transport alone is ‘fairly marginal’ (Blythe, 2004).
3.7.2 Actors and Social Networks

In the UK: ‘The Government's vision is for smart and integrated ticketing across public transport in England, with the ITSO specification allowing for seamless travel, potentially across the country, using the same smartcard. As technology develops, it may be possible to use mobile phones instead of smartcards, while contactless bank cards may remove the need for a ticket for some journeys’ (Department for Transport, 2009, p.3). This vision of a national network required the development of urban ‘islands’ of smart ticketing by 2015. Where: ‘Over time, we envisage that the local ticketing schemes will be linked by corridors of intercity transport’ and that what will result is ‘a network across the country that provides for the seamless travel at a national level without the need for a single national ticketing scheme’ (Department for Transport, 2013a, p.34). The key issues raised by this are: 1) whether smartcards are seen as an end point or as a stepping stone technology; 2) where the boundaries of smartcards lie, whether that is solely as a transport card or encompassing other services; and 3) the scale at which these are organised and whether their application is universal or limited to particular places.

The Integrated Transport Smartcard Organisation (ITSO) was established in 1999 ‘to build an interoperable smartcard specification and supporting environment for the UK transport environment’. The challenge of this was underestimated given the ‘sheer complexity’ of the scheme, the contractual arrangements between multiple actors, and the time that it took to persuade actors to be part of the scheme (Blythe, 2004, p.51). There are numerous potential but underdeveloped business models for the implementation of smartcard systems in public transport. This has often either involved the system being under the control of the transport authority, it being outsourced to ICT companies or a form of hybrid public-private organisation that involves transport authority, operators, system suppliers, banks and so on (AECOM, 2011).

The specific social and technical organisation of each scheme can vary in terms of both the front-end and back-end of systems. The operation of London’s Oyster card system, for example, is undertaken by TranSys, a consortium involving Cubic Transportation Systems and EDS. The distribution of revenue generated from the Oyster card between different modes and also between non-transport authority operators is managed and accounted for by the public transport authority, Transport for London (Mezghani, 2008). TfL has also access to and has begun to use the data generated to understand journey patterns (Ortega-Tong, 2013). These systems generate large amounts of data that can potentially be used to plan and control public transport systems (Pelletier et al, 2011). There is a huge challenge in translating this data into intelligence (AECOM, 2011). This includes: difficulties in operators cooperating under UK competition law (Department for Transport, 2011, p.59); privacy and data protection problems of using data generated through smartcards (AECOM, 2011); and moving beyond individualistic views of travel choices (Nyblom, 2014).

There is a view that financial service providers - with their contactless systems, at scale in a European context and where there are contactless payment standards - should or will become aligned with the domain of smartcards. Barclaycard’s One Pulse credit card combines a credit card and a London Oyster card on to a single card (AECOM, 2011). Various benefits of smartcards have been characterised for authorities, operators and passengers (Mezghani, 2008). Smart cards may realise these benefits but that is not inevitable. The organisational and implementation context matters.
3.7.3 Governance and Policy

Governance and policy of transport in the UK, from 1979 to 1997, was dominated by a laissez-faire approach. Though the Labour government of 1997 to 2010 was much more pro-intermodal, ‘the decisions of the administration not to make significant changes to the basis of public transport regulation meant that the ability to deliver intermodality as a matter of public policy was limited’ (Parkhurst et al, 2012, p.319).

Application of smartcard technology in the UK transport sector was limited in the 1990s with early trials seeing ‘a number of spectacular (and costly) failures’ (Blythe, 2004). Renewed interest in the benefits of smartcards for transport was recognised in the 1998 UK transport White Paper (Blythe, 2004; DETR, 1998). In 1999 ITSO was established. This resonated with the aspirations of the European Commission transport White Paper 2001 which stated: ‘To facilitate transfers from one network or mode to another, encouragement needs to be given to the introduction of ticketing systems which are integrated (and thus ensure transparency of fares) between rail companies or between modes of transport (air - coach - ferry - public transport - car parks) (EC, 2001, p.80).

The most recognisable smartcard development in the UK is at a metropolitan level where Transport for London established the Oyster Card in 2003. Initially launched as a £1.2 billion private finance initiative (PFI) scheme (Blythe, 2004), this covered London’s public transport infrastructure including buses, tube, overground trains and trams and river modes. This was not ITSO compatible. Developments in other UK cities have largely been piecemeal. A 2009 national government strategy document recognised that: ‘Smart ticketing is currently not widespread outside of London, but there are a number of schemes about to begin roll out or in development’ (Department for Transport, 2009, p.2). Outside London to this point, national government had sought all concessionary travel passes to be ITSO smartcards (Department for Transport, 2009, p.4). National government also sought post-2009 to promote ITSO-compliant smartcard development by 2015 in the nine largest urban areas in England (not including London; Scotland and Wales had developed their own ITSO plans) with funding of up to £20m. These ‘islands’ of development were seen as steps in building a national network of smart ticketing under the ITSO standard. It was recognised that the largest existing smartcard scheme, the Oyster card in London, was not aligned with ITSO. So, at the same time national government promoted a £60m initiative to support the integration of Oyster with ITSO standards. This level of funding in London was three times that of the other nine urban areas.

Though national government promoted smartcards and the provision of a regulatory framework their delivery in urban contexts was for Local Transport Authorities, as the coordinating bodies between operators and requiring widespread local partnership working. Yet: ‘in the United Kingdom the whole ethos of promoting intermodality did not fit well with the dominant political hegemony of “allowing the market to decide”, and even after 1997 rhetoric was more common than specifically targeted funding measures. As a result, both rail and bus-related initiatives have generally remained piecemeal, tentative (with a number of trials ultimately ended) and over-dependent on local factors, such as the presence of policy entrepreneurs or particular coalitions of actors’ (Parkhurst, 2012, p.328). The Department for Transport’s 2011 white paper promoted the view that the majority of public transport journeys to be made by using smart ticketing by the end of 2014 (Department for Transport, 2011). Yet the scale of the task seemed to be recognised and in particular the need for ‘new
business processes and commercial agreements. These may be complex and difficult to negotiate’ (Department for Transport, 2013b, p.27).
3.8 Compact Cities

3.8.1 The Innovation
The compact city resonates with utopian models of development of Garden Cities in the early part of the 20th Century and New Towns after the Second World War (Raco, 2007). Even in more recent times the idea of a compact city can be traced back to the 1970s (Dantzig and Saaty, 1973) and overlapped with conceptions of sustainable cities in the 1990s (Raco, 2007). This ‘opened up the possibility for the new idealization of urban form on environmental grounds’ (Brand with Thomas, 2005, p.41). There is no accepted definition of a compact city (Neuman, 2005; OECD, 2012). Compaction is often seen as counter to problems created by urban sprawl and processes of suburbanisation (Burton, 2000; Neuman, 2005) and seeks to build more sustainable ways of organising cities. The power of compact cities is in visions which present the city as a product but where realisation is limited.

In the UK, in 2007, the UK government set out a competition to build up to 10 eco-towns with populations of between 5,000 and 20,000.14 Principles of promoting cycling and walking, reducing car usage, and providing access to public transport led to a ‘menu’ of sustainable transport options (DCLG, 2009). By 2011 only one of these was still planned to be built to the original standards. Development on the site commenced in 2014. Strategies in Greater London aspire to increase compaction. Efforts in other cities and towns in the UK have been much less strategic and more piecemeal (Hodson and Marvin, 2010; Hodson et al 2013).

The emphasis is on building new cities or ‘retrofitting’ existing cities in ways that reconfigure the metabolic flows (of resources and people) through the city and where notions of ‘self-sufficiency’ are sometimes mobilised (UNEP 2013; Girardet, 1999; Heynen et al, 2006; Hodson and Marvin, 2010). Practically, in relation to transport, this usually means combinations of: integrating cycling infrastructure in to the design of the city (stands, bike rental, cycle routes), and improved walking infrastructure (footbridges, lighting); encouraging reduced car usage through, for example, car-free sites, car parking restrictions, setting up car clubs, car sharing, incentivising small and clean cars; accessible and reliable public transport, including trains (and the linking of cycle paths and footpaths to train stations, as well integration with bus services); provisioning of buses as part of the design of the city (bus lanes or bus-only roads, bus priority at traffic lights, real-time information at bus-stops to facilitate intermodal travel, alternative fuel buses, community transport alternatives to buses). Depending on the scale of the development compact cities may also develop light rail systems. In many ways, compact cities have become the scale at which sustainable transport initiatives are experimented with in practice (OECD, 2012).

There is no simple answer to the question of what a compact city costs. The Masdar eco-city in the United Arab Emirates was estimated to cost US$22bn in 2006 when it was initiated, revised after the 2007 financial crisis to US$18.7bn-$19.8bn (UNEP, 2013). State funding for the four planned UK Eco-Towns was claimed to be around £60m,15 with other funding needing to be generated. One of the difficulties in attributing price and performance is that while the visions indicate a fixed point the achievement of compact cities is an ongoing

14 [http://news.bbc.co.uk/1/hi/uk/7311548.stm](http://news.bbc.co.uk/1/hi/uk/7311548.stm) [accessed 13/06/2014]
15 [http://news.bbc.co.uk/1/hi/uk_politics/8504050.stm](http://news.bbc.co.uk/1/hi/uk_politics/8504050.stm) [accessed 13/06/2014]
process of many elements. These elements are funded through a range of public and private funding streams.

3.8.2 Actors and Social Networks
The idea of a compact city (even if some do not use this label) has achieved momentum amongst policymakers at national and sub-national levels (Howley, 2009) and amongst architects and has become something of a ‘conventional wisdom’ of urban futures (Breheny, 1997). Rationales for compaction have differed over time (OECD, 2012). There are many contemporary visions of compact cities that may (but do not always) include national governments, urban authorities, development companies, engineering consultancies, planners and architects, utilities and infrastructure providers, corporate and energy companies (Hodson and Marvin, 2010). Visions are important at holding together economic and ecological priorities of cities and become a means for attracting funding and for constructing missing capacity. Underpinning the idea of compaction in relation to transport is academic work which demonstrates a relationship between population density and per capita petrol consumption, where higher density results in fuel consumption falling significantly (Newman and Kenworthy, 1989) (see Figure 3.17).

Figure 3.17: Urban Density and Transport-Related Energy

![Figure 3.17: Urban Density and Transport-Related Energy](http://sapiens.revues.org/docannexe/image/914/img-1.jpg)


The fundamental premise that density results in significantly reduced petrol consumption has been questioned (Breheny, 1995); where the relationship between urban form and mobility is not a direct one with issues such as income influencing mobility patterns (Dieleman et al,
It is thus the causality in the relationship which is disputed (Melia et al, 2011). That said, it is claimed that increasing densification does result in reduced per capita vehicle miles travelled (Melia et al, 2011) and that generally the literature demonstrates there is enough evidence to suggest land use influences travel behaviour (Howley, 2009).

How compact cities are characterised is not always commonly agreed. Indicators for assessing the relationship of density to travel are numerous. These include: passenger kilometres travelled; percentage of commuters using public transport; percentage of commuters walking to work; and others (OECD, 2012). These kinds of indicators don’t effectively capture patterns of and motivations for urban mobility. Indicators that begin to piece this together include: distance from a station; connection of transport routes to shops, employment centres and entertainment and other leisure pursuits; trip distance. In relation to transport and more broadly mobility compact cities often involve an emphasis on: shorter inter-urban travel distances; less automobile dependency; better access to local jobs and services. These are intended to reduce carbon emissions, to result in better accessibility, higher mobility for non-car owners, improvements in health due to more walking and cycling and lower transport costs and to achieve economic benefits through a green growth agenda, the developments of local skills and capacities.

The compact city paradox suggests compaction requires concentration of functions and populations but that liveable cities require lower density populations and functions (Neuman, 2005). The claim is that individual components of compactness are likely to be associated with widely differing effects (Burton, 2000). Density patterns have become more complex over the last fifty years (Gordon, 2008) where urban form can be understood not only as monocentric but also as polycentric metropolitan regions (Dieleman, et al, 1999). This has implications for the scale at which compaction happens and also whether this can be governed by public policy and planners or whether this is a consequence of market forces and a large number of personal and commercial choices (Gordon, 2008). The implementation of compact cities is also made difficult by the administrative fragmentation of urban regions (Dieleman et al, 1999). In short, compact cities may be sustainable in some areas and not so in others with sustainability gains, losses and trade-offs (Westerink et al, 2012). Though there is a substantial literature, empirical evidence on compact cities is mixed and often contradictory (Howley, 2009). Compact cities have many forms that often remain visions and unrealised.

3.8.3 Governance and Policy

There is a broad consensus among global and national actors in favour of compact cities (Gaigne et al, 2012). This includes the OECD and UNEP who have each produced reports on compact cities (OECD, 2012; UNEP, 2013). At a policy level, compact cities in the UK can be understood as a means of addressing sustainable development concerns from the 1990s. These have primarily been through planning policy and the ways in which national government has sought to discipline local authorities: the UK strategy for sustainable development in 1994 (Department of the Environment, 1994) and an updated strategy in 2005 (DEFRA, 2005) and also through Planning Policy Guidance - specifically PPG13, which promoted reducing transport demand, encouraging development that minimises the need for travel, and promoting the use of public transport, walking and cycling. These documents promote the reduction of transport CO2 emissions through a range of planning measures via guidance for local authorities. Subsequent to these documents there have been various Planning Policy Statements and Planning Guidance Statements which have shaped local planning around transport, housing, climate change and the creation of communities.
The lack of clear indicators and even agreement on the configuration of compact cities highlights the tension between, on the one hand, generalizable visions of compact cities, even more locally specific visions of what a compact city might look like and tangible efforts to realise those visions. The sorts of governance capabilities that are necessary to achieve these require new structures, new capacity and agreed ways of monitoring and assessing the progress of compact city development; in short, it needs a governance and knowledge infrastructure for developing a compact city. There have been responses in cities and local authorities across the UK. By far the most well-developed is in London. London has a spatial plan where the concept of sustainable development ‘runs through it’ providing ‘an integrated economic, environmental, transport and social framework for the development of London over the next 20–25 years’ (Mayor of London, 2011a, p.10). This in a period where growth is prioritised but where there is a CO2 emissions reduction target of 60% by 2025. Relatedly there is also a suite of strategies for transport (Mayor of London, 2010a), climate change adaptation (Mayor of London, 2011b), climate change mitigation and energy (2011c), water (2011d) and waste (2011e). There has been the implementation of a Congestion Charging scheme in 2003, the establishment of an urban cycling hire scheme that began operation in 2010, the development of a multi-modal Oyster card system that commenced in 2003 and numerous other initiatives. In other cities in the UK this is much more piecemeal. This is not surprising given the weaker governance powers and capability relative to London and the less well-developed public transport systems.
4. Conclusion

4.1 Overall Assessment of Momentum

The conclusion highlights the main drivers of momentum and an overall assessment and relative ranking of the momentum of each of the niches is set-out:

<table>
<thead>
<tr>
<th>Niche and ranking</th>
<th>Main drivers of momentum</th>
<th>Transition pathway</th>
<th>Momentum</th>
</tr>
</thead>
</table>
| 1) (Plug-in-)Hybrid Electric Vehicles: | Ongoing growth in the numbers licensed since the early 2000s and momentum in the UK. The automotive industry is the main actor. In the UK governance is a response rather than agenda-setting. The aim is to attract the production of new models to safeguard economic activity, to address carbon emissions reduction and to use tax and fiscal measures to stimulate uptake. HEVs can be used in similar ways to conventional ICE vehicles and therefore require little reconfiguration of infrastructure or user practices. For use in plug-in mode there is an emergent plug-in infrastructure in the UK and changes in user practices are needed.  
• Moderate momentum for market trajectory of HEVs  
• Moderate socio-cognitive momentum  
• Moderate governance and policy momentum | A | Moderate |
| 2. Battery Electric Vehicles: | A new cycle of hype in the UK since 2005. Social, organisation and technological networks are being developed. Yet, BEVs remain a highly marginal part of UK mobility. In the production and use of BEVs there are many similarities with ICE. There are also numerous differences including an emerging, policy-driven plug-in infrastructure and new production and R&D facilities in the North-east of England. There is a key role for incumbent actors. The main inhibitors to greater momentum are issues of vehicle range and cost. UK policy on BEVs aims to address decarbonisation and economic development.  
• Low momentum in terms of market trajectory  
• Moderate socio-cognitive momentum  
• Moderate governance and policy momentum | A | Moderate |
<p>| 3. Inter-modal Ticketing (Smart Cards): | Long-term growth in London and limited development elsewhere in the UK. The challenge of building an interoperable smartcard specification was underestimated. The policy narrative is of the ‘inevitability’ of smartcards but this has met the reality of the need for new business processes and commercial agreements. Smartcards aim to integrate sub-regimes of the public transport regime; this involves both existing interests and new interests in configuring new business processes and user patterns. | A/B | Low |</p>
<table>
<thead>
<tr>
<th>4. Car-sharing/Clubs</th>
<th>‘Haphazard’ development from 2000, with rapid growth in membership from 2007 (geographically concentrated in London). Car clubs remain highly marginal. The sector has undergone and continues to undergo rapid change. Local authorities are key actors whose role is subject to experimentation. This requires significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Momentum of market trajectory</strong></td>
<td>moderate</td>
</tr>
<tr>
<td><strong>Socio-cognitive momentum</strong></td>
<td>low to moderate</td>
</tr>
<tr>
<td><strong>Governance and policy momentum</strong></td>
<td>low to moderate</td>
</tr>
<tr>
<td><strong>4. Car-sharing/Clubs</strong></td>
<td>B</td>
</tr>
</tbody>
</table>

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<tr>
<th>5. Biofuels</th>
<th>Shift from optimism around 2003 that biofuels could provide a viable (if partial) substitute for UK liquid transport fuels to a flatlining of supply towards the end of the decade. Biofuels are currently more expensive than fossil fuels. It is difficult to characterise a UK-specific trajectory of biofuel technology development. The UK governance style at present appears unlikely to provide the required push to reach targets set at the European level. Can be viewed as substitute for liquid transport fuels. Though a wider framing sees the reconfiguration of land-use systems from production for food to production for fuel.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Momentum of market trajectory</strong></td>
<td>low to moderate</td>
</tr>
<tr>
<td><strong>Socio-cognitive momentum</strong></td>
<td>low</td>
</tr>
<tr>
<td><strong>Governance and policy momentum</strong></td>
<td>low</td>
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<tr>
<td><strong>5. Biofuels</strong></td>
<td>A</td>
</tr>
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<table>
<thead>
<tr>
<th>6. Hydrogen Fuel Cell Vehicles</th>
<th>Were the subject of much hype from the late 1990s, that stalled around 2005 in the face of technical and cost difficulties and the ‘re-emergence’ of BEVs. Since 2012 there have been the beginnings of a much more modest momentum in the UK. In order to be able to support hydrogen fuel cell vehicles, the existing road infrastructure and some manufacturing capacity can be used. A new hydrogen production, distribution, storage and fuelling infrastructure needs to be configured around the vehicle - elements of which have been the subject of demonstrations in the UK.</th>
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</thead>
<tbody>
<tr>
<td><strong>Momentum of market trajectory</strong></td>
<td>low</td>
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<td>low</td>
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<tr>
<td><strong>6. Hydrogen Fuel Cell Vehicles</strong></td>
<td>A/B</td>
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</tbody>
</table>
### 7. Urban Cycling/Sharing Schemes:

The UK’s largest scheme commenced operation in 2010. There have been limited responses in the rest of the UK. Other interventions alongside bike-sharing may be important in reducing congestion, such as congestion charging. An effective public transport system and governance capacity may be a pre-requisite. Reconfiguration of many elements around the bicycle - requires a new conception of users, new business models, new actors, tracking, monitoring and payments technologies and the strategic development of infrastructure.

- **Governance and policy momentum is low**
- **Market trajectory momentum is very low, except in London where it is moderate to high**
- **Socio-cognitive momentum is low outside of London**
- **Governance and policy momentum is very low**

### 8. Compact Cities

The idea of a compact city has been promoted by national and sub-national policymakers and architects. There are many contemporary visions of new and ‘retrofitted’ cities which have limited realisation. By far the most well-developed is in London. In other cities in the UK this is much more piecemeal. This is not surprising given the weaker governance powers and capability relative to London and the less well-developed public transport systems. Involves a fundamental reconfiguration of a city through designing in public transport and designing out car use.

- **Governance and policy momentum is low to moderate**
- **Market trajectory momentum is very low**
- **Socio-cognitive momentum is very low**

### 4.2. Conclusion about Transition Pathways

Each of the eight niches involves some substitution and also some reconfiguration. Whether each of these eight niches are more oriented to pathway A or B can be summarised as follows:

1. **Battery Electric Vehicles:** In the production and use of BEVs there are many similarities with ICE. There are also numerous differences including an emerging, national policy-driven plug-in infrastructure and new production and R&D facilities in the North-east of England. The main inhibitors to greater momentum are issues of vehicle range and cost. Pathway A.

2. **(Plug-in-)Hybrid Electric Vehicles:** HEVs can be used in similar ways to conventional ICE vehicles and therefore require little reconfiguration of infrastructure or user practices. For use in plug-in mode there is an emergent plug-in infrastructure in the UK and some changes in user practices are required. Pathway A.
3. Hydrogen Fuel Cell Vehicles: In order to be able to support hydrogen fuel cell vehicles, the existing road infrastructure and some manufacturing capacity can be used. A new hydrogen production, distribution, storage and fuelling infrastructure needs to be configured around the vehicle - elements of which have been the subject of demonstrations in the UK. Pathway A/B.

4. Biofuels: Can be viewed as substitute for liquid transport fuels. Though a wider framing sees the reconfiguration of land-use systems from production for food to production for fuel. Pathway A.

5. Car-sharing/Clubs: This requires significant reconfiguration in conceptions of users, business model, tracking, monitoring and payment infrastructure and a mix of new and incumbent actors. Pathway B.

6. Urban Cycling/Sharing Schemes: Reconfiguration of many elements around the bicycle - requires a new conception of users, new business models, new actors, tracking, monitoring and payments technologies and the strategic development of infrastructure. Pathway B.

7. Inter-modal Ticketing (Smart Cards): Smartcards aim to integrate sub-regimes of the public transport regime; this involves both existing interests and new interests in configuring new business processes and user patterns. Pathway A/B.

8. Compact Cities: Involves a fundamental reconfiguration of a city through designing in public transport and designing out car use. Pathway B.
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