PATHWAYS project
Exploring transition pathways to sustainable, low carbon societies
Grant Agreement number 603942

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

**Country report 7:** Green niche-innovations in the Dutch mobility system

Authors: Bruno Turnheim, Irene Håkansson and Frans Berkhout

November 28, 2014
Executive summary

The purpose of this document is to provide an analysis of promising niche-innovations in the personal mobility domain in the Netherlands, as part of PATHWAYS D2.1.

We first provide an overview of the prevailing mobility domain in the Netherlands, focussing specifically on personal land-based mobility.

We then present a number of niche-innovations in this domain, and justify our choice for selecting 6 of them for analysis:

1. Battery electric vehicles
2. Hybrid electric vehicles
3. Hydrogen fuel cell vehicles
4. Biofuels
5. Carsharing
6. The compact city

The remainder (and bulk) of the document presents the selected niche-innovations, and analyses their socio-technical characteristics (technical and system attributes, actors and organisational field, institutions and governance) before evaluating their potential in the frame of a prospective transition in the Dutch personal land-based mobility domain.

In a concluding section, we present a focussed analysis of the momentum of niche-innovations and how they fit to the PATHWAYS typology. The assessment of momentum for each niche-innovation, based on the consideration of innovation and market trajectory, supporting actors and networks, and policy and governance, is presented in a table, of which we here present highlights:

<table>
<thead>
<tr>
<th>Niche</th>
<th>Momentum</th>
<th>Main drivers of momentum</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hybrid electric vehicles (HEVs)</td>
<td>High</td>
<td>Techno-economic momentum: high (installed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-cognitive momentum: high (accepted)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Governance and policy momentum: stable</td>
</tr>
<tr>
<td>2. Carsharing</td>
<td>High</td>
<td>Techno-economic momentum: high</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-cognitive momentum: high (actors and acceptance)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Governance and policy momentum: high (support)</td>
</tr>
<tr>
<td>3. Battery electric vehicles (BEVs)</td>
<td>Moderate</td>
<td>Techno-economic momentum: moderate (innovation but no dominant design)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-cognitive momentum: high (expectations and visions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Governance and policy momentum: moderate (support for rollout)</td>
</tr>
<tr>
<td>4. Biofuels</td>
<td>Moderate</td>
<td>Techno-economic momentum: high (innovative sector)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-cognitive momentum: low (controversies)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Governance and policy momentum: moderate (obligations)</td>
</tr>
<tr>
<td>5. Compact cities</td>
<td>Moderate (past)</td>
<td>Techno-economic momentum: low</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-cognitive momentum: moderate (consensus – at the time)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Governance and policy momentum: high (strong political will –at the time)</td>
</tr>
<tr>
<td>6. Hydrogen fuel cell vehicles</td>
<td>Very low</td>
<td>Techno-economic momentum: low (early days)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Socio-cognitive momentum: low (not much exposure)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Governance and policy momentum: low</td>
</tr>
</tbody>
</table>

When assessing the degree of fit to current innovation trajectories to the ideal-types transition pathways A and B, ‘technical component substitution’ and ‘broader regime transformation’, we find a dominant leaning towards one of the ideal Pathways, but also some elements of the other.

The Netherlands presents an interesting context for experimentation in the mobility domain, and is positioning itself at the cutting edge of many of the innovation presented in this report, providing a ‘test-bed’ for niche experiments and their development.
# Contents

1 Introduction.......................................................................................................................... 1  
2 Case selection....................................................................................................................... 5  
   2.1 Potential green niche-innovations................................................................................. 5  
   2.2 Niche-innovation selection ....................................................................................... 5  
3 Niche-innovation momentum analysis ................................................................................ 7  
   3.1 Niche 1: Battery electric vehicles ............................................................................. 7  
   3.2 Niche 2: Hybrid electric vehicles.............................................................................. 11  
   3.3 Niche 3: H2 fuel cell vehicles............................................................................... 14  
   3.4 Niche 4: Biofuels .............................................................................................. 19  
   3.5 Niche 5: Carsharing and car clubs ..................................................................... 24  
   3.6 Niche 6: Compact cities ................................................................................ 29  
4 Conclusion ......................................................................................................................... 34  
   4.1 Momentum analysis .......................................................................................... 34  
   4.2 Conclusion about transition pathways ................................................................ 35  
References................................................................................................................................ 37
1 Introduction

The purpose of this document is to provide an analysis of promising niche-innovations in the personal mobility domain in the Netherlands, as part of PATHWAYS D2.1, in accordance to the protocol agreed by all partners. We first provide an overview of the prevailing mobility domain in the Netherlands. We then present a number of niche-innovations in this domain, and justify our choice for selecting 6 of them for analysis. The remainder (and bulk) of this document presents the selected niche-innovations, and analyses their socio-technical characteristics (technical and system attributes, actors and organisational field, institutions and governance) before evaluating their potential in the frame of a prospective transition in the Dutch personal land-based mobility domain.

Personal mobility distinguishes itself from other societal functions for two main reasons: 1) in most cases, mobility is not done for its own sake, but rather as a ‘derived demand’ in order to gain access to places (work, home, shops, city centre, etc.), and 2) personal mobility practices require the active involvement of users (e.g. driving a car or cycle, taking the bus or train, etc.) and hence interaction with transportation devices. Modern transportation modes furthermore rely on large infrastructures (roads, rail networks, etc.) that are shaped by the traffic that they sustain.

Since the advent of the automobile in the twentieth century, personal mobility practices have become dominated by petrol-based cars, shaping and in turn shaping urbanisation modes and supporting infrastructures (streets, roads, highways, etc.) (Geels 2005). The prevailing automobile and the ICE however coexists with other forms of mobility that have existed for a long time (trains, buses, trams, cycling, walking, etc.), and is increasingly being challenged on environmental, convenience, safety, economic and technological grounds. Because of our interest in current and prospective transitions, we start our analysis from the automotive personal mobility regime.\footnote{By focusing on personal land-based mobility, we exclude 1) the transportation of goods, and 2) other forms of mobility (airplanes, ships, etc.).}

![Figure 1: Personal mobility in the Netherlands according to transportation mode 1985-2012, billion passenger-km (KiM 2013)](image)

\footnote{Legend: auto(driver); bus/tram/metro; train; bicycle; auto(passenger); primary road network traffic(volume)}
In the Netherlands more specifically, “automobile dependency and the national passenger automobile trips have increased exponentially between 1960 and 1970” (Alpkokin 2012:543), with a more moderate increase in automobility from the 1980s (KiM 2013). Nonetheless, automobility, the main contributor to land-based personal mobility in the Netherlands, continued to grow at a steady rate throughout the 1980s, and stabilised from 2005 (see Figure 1). Car ownership also continues to grow from 0.40 cars/inhabitants in 1985 to 0.47 cars/inhabitants in 2012 (KiM 2013).

While the automobile is clearly the mode of choice when it comes to overall distance, this picture becomes less clear when looking at individual journeys, their motives, and characteristics (see Figure 2, with the automobile accounting for around 50% of all journeys). In the Netherlands, 70% of all personal journeys are under 7.5km. In this range, the car and the bicycle contribute an equal part of all journeys, with circa 35% (KiM 2013:26). Despite the Netherlands being one of the most densely populated countries in Europe, average commuting time to work is the highest in Europe (Kozluk 2010).

However, journeys over 10km account for 25% of all journeys and for 80% of all personal distance travelled (KiM 2013:26). The major part of land-based personal distance is for two purposes: leisure and recreation (circa 80 billion km) and commuting to work (circa 50 billion km), both figures having risen since the 1980s (KiM 2013).

The prevailing land-based mobility regime is locked in to a configuration based on highly defined core technologies (oil-based, Budd-type chassis, etc.), a mature manufacturing industry constituted of a few powerful actors that has developed around related core competences and economies of scale, and a business model based on the sale of cars to private owners, with more or less diversification and specialisation according to national market differences. The infrastructure (roads, highways, petrol supply and distribution

---

3 It also means that discussing transitions away from automobility in the Netherlands is fundamentally different from other contexts with less intensive land use such as the USA and Australia.

4 Legend: car; train; bus/tram/metro; moped; bicycle; walking; other.
networks, etc.) is deeply embedded in our landscapes, urbanisation patterns, and the structural organisation of everyday life, and sustained by powerful industries (oil, construction, etc.). The car is still seen as the most convenient form of mobility, it is supported by deeply entrenched habits and routines, and supports a number of practices that have emerged along its development trajectory (commuting, weekly supermarket shopping, road tourism, etc.). Land-use and transportation policies have traditionally supported the expansion of the automobile and supporting road infrastructure, although this unconditional support is dwindling in the face of emerging societal problems (climate change, air pollution, safety, congestion, etc.). Culturally, the car remains a powerful symbol of freedom, a marker of social status and identity, aspects that are reinforced by design and marketing objectives dominated by style and elegance in the aspirational higher market models. These highly entrenched technological, industry, and socio-cultural elements jointly contribute and reinforce the stability of the automobility regime and its resistance to change (Geels 2005, Elzen et al 2004, Nykvist and Whitmarsh 2008), despite a number of challenges and contestations.

While automobility is the dominant mode of land-based personal mobility (representing over 70% of personal distance travelled and over 50% of individual journeys in the Netherlands, see Figure 2), it coexists with a number of alternative mobility modes that can be seen as separate, subaltern, socio-technical systems. The Netherlands can be seen as a pioneer in the area of public transport, and a lead market for cycling.

A number of long-term dynamics are affecting the development of mobility regimes, and the current prevalence of the car. Such dynamics can influence established socio-technical trajectories both negatively (destabilise) and positively (stabilise). They will be analysed more fully in D2.2. We here provide an overview:

- Main destabilising pressures include pressures for environmental change (cutting back on GHG emissions and local air pollution), the rising price of oil, increasing congestion, safety, and ICT developments. These issues are challenging the (socio-cultural and policy) legitimacy, practical efficiency and economic viability of established mobility arrangements. They are likely to contribute to shaping the future of mobility.

- On the other hand, a number of landscape developments are contributing to stabilise automobility, as well as to make it more difficult for alternatives to break through. These include: global automobility growth, compatibility with modern culture, and high sunk costs in infrastructure.

- The existing automobility regime is further stabilised by reinforcing initiatives and institutions that contribute to existing lock-in. These include: a powerful industry, continued technical improvements and sophistication, and supporting policies.

- Despite inherent stability, the automobile regime in the Netherlands is also showing some signs of change. Recent trends and developments point to the increasing recognition of external pressures and challenges by the automobile industry itself, with greater attention to environmental and safety issues, innovation strategies geared towards lesser emissions (catalytic converters), fuel efficiency improvements, the

---

5 Historically, many innovations in timetable management, ticketing and traffic signals have emerged in the Netherlands.

6 These subaltern regimes will be considered in the frame of a regime analysis in D2.2.
exploration strategies with different alternative fuels, and the emergence of new business models for mobility. The emission intensity of new cars is steadily decreasing.
2 Case selection

We first compiled an extensive list of potential niche innovations in the land-based personal mobility domain, screening from policy documents and existing literature on emerging (sustainable) transport technology and mobility transitions research (Geels 2012, Nykvist and Whitmarsh 2008, Skinner et al 2004, Farla et al 2011, etc.). We then selected a smaller number of these niche innovations on the basis of criteria tailored to our research objectives.

2.1 Potential green niche-innovations

In line with PATHWAYS analytical focus, we were looking for technologies with a potential to contribute to a prospective transition of mobility within the coming decades. Table 1 presents a structured long list of potential cases.

Table 1: Long list of potential personal mobility cases

<table>
<thead>
<tr>
<th>AUTOMOBILITY</th>
<th>ORGANISATIONAL INNOVATION</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greener automobile (mostly engine innovation)</td>
<td>Behaviour</td>
<td>T-Fuel innovations</td>
</tr>
<tr>
<td>electric car (difference lease vs. ownership)</td>
<td>walking combined with health/diet, etc.</td>
<td>integrated public transport mobility</td>
</tr>
<tr>
<td>bio-fuel car</td>
<td>discouragement of air travel (tourism and business)</td>
<td>smart transport advice (e.g. CityMapper, etc.)</td>
</tr>
<tr>
<td>waste oils and other fuels</td>
<td>virtual tourism, virtual meetings, etc.</td>
<td>multi-modal</td>
</tr>
<tr>
<td>hybrid cars - petrol-electric (Peugeot, etc.)</td>
<td>flexible working / teleworking</td>
<td>rail + bicycle</td>
</tr>
<tr>
<td>hybrid cars - compressed air and gasoline hybrid</td>
<td>fuel-efficient driving (IT assisted)</td>
<td>rail + bicycle rental</td>
</tr>
<tr>
<td>hardware fuel efficiency (lightweight, aerodynamics,...)</td>
<td>personal carbon trading schemes, etc.</td>
<td>rail + taxi</td>
</tr>
<tr>
<td>Automobiles as service</td>
<td>symbolic ‘degrading’ of high-emission air and car travel</td>
<td>Park-and-ride (car + public)</td>
</tr>
<tr>
<td>carpooling (self-organising, bottom up, etc.)</td>
<td>Infrastructure</td>
<td>2-wheeled</td>
</tr>
<tr>
<td>carsharing (short- and long-range)</td>
<td>infrastructural (dis)incentives (road width, bus lanes, etc.)</td>
<td>bicycle replacing other means</td>
</tr>
<tr>
<td>fuel efficient driverless car</td>
<td>congestion changes / limited traffic zones</td>
<td>bicycle sharing</td>
</tr>
<tr>
<td>taxi / dish🎡er membership</td>
<td>urban planning / compact city</td>
<td>electric bicycle / scooter</td>
</tr>
<tr>
<td>improvements in geolocation (taxi, bikesharing, etc.)</td>
<td>‘smart highways’</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Niche-innovation selection

The selection of interesting and relevant green niche-innovations for land-based personal mobility in the Netherlands is based on a preliminary screening according to considerations related to niche development, regime interactions, and transition pathways.

Niche considerations include a preliminary assessment of their transition potential (momentum, growth potential, support, credibility, etc.), the main actors involved, the time horizon and current stage of development, a consideration of development pattern in a transition context, and their decarbonisation potential. Regime considerations include the niche-innovations’ reliance on current regime elements, the involvement of regime actors, and departure from the existing regime.

A smaller number of cases was selected. The result of this selection for the Netherlands is presented in Table 2.

Table 2: Selected niche-innovations and selection considerations

<table>
<thead>
<tr>
<th>Niche</th>
<th>Niche considerations</th>
<th>Regime and pathway considerations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Battery electric vehicles (BEVs)</td>
<td>Some development / marketable Policy support Important role for new players Multiplication of models and market segments Long-term option, available today, High decarbonisation</td>
<td>Most regime elements unchallenged: component substitution Some regime actor involvement Regime departure: - battery technology - new (charging) infrastructure to link with electricity domain - cultural issues with range?</td>
</tr>
</tbody>
</table>
We come back to these considerations in greater detail in the concluding sections following the analysis of each niche-innovation separately.
3 Niche-innovation momentum analysis

3.1 Niche 1: Battery electric vehicles

3.1.1 Innovation and market trajectory

Historical overview. Battery-powered vehicles (BEVs) have existed from the very beginnings of automobility, with practical models produced as early as the 1880s in France, the UK and Germany, and a substantial market share in the US by the 1910s, mainly for short-range urban transport. This market presence was rapidly lost to the ICE engine with the advent of oil, road infrastructure, and the co-constructed preference for long range. After short-lived resurgences following energy crises (1960s and 1970s) and stricter environmental objectives (1990s), BEVs are experiencing a new surge of interest, and seem to be developing fast, as technical, infrastructural and socio-political barriers are gradually overcome.

Technical distinctions. BEVs mainly position themselves as an alternative to the ICE-propulsion of standard vehicles. Within the range of BEVs, a common distinction exists between 1) full electric vehicles (FEVs), and 2) electric hybrids (EHVs), of which (plug-in) hybrids (HEVs/PHEVs) and extend range electric vehicles (eREV/E-REVs) are further distinctions. We here focus on FEVs.

Motivations. The main contemporary claimed benefits of electric mobility are 1) local air pollution (no tail pipe emissions), 2) CO₂ emissions (reduced and concentrated in power generation), 3) its potential synergy with renewable electricity production, and 4) the long-term earning potential of early involvement in a potentially large global industry. Other benefits include noise reduction, and positive side effects from a conscious change in mobility habits (empowerment, energy autonomy, reduced travel, etc.). BEVs interestingly do not (yet?) promise any technical superiority to conventional vehicles (van Bree et al 2010), besides their carbon-intensity. In most current developments, they have lower performance levels on some aspects, and are still more expensive – hence requiring some niche protection.

Technical components. The main technical components of BEVs are the electric motor and the battery, from which all motive and auxiliary power is derived. Other important technical elements include charging inlets (plugs), the power-control unit (electronics), on-board chargers, and regenerative brake systems. While most of these technical elements have been borrowed from other industrial applications, it is their combination, integration, technical performance improvement and miniaturisation (batteries) that are truly innovative. The most critical recent technical development has been in the area of batteries, which achieved remarkable miniaturisation, cost reductions, and charging qualities with consumer electronics, as exemplified with the high performance Tesla Roadster. The above-average price of BEVs however reflects their current level of technical and commercial development, and suggests substantial opportunities for improvement (technical and economies of scale).

---

7 Interesting developments are occurring in the area of smaller and light-weight electric vehicles (e.g. e-bicycles, golf carts, etc.), with potential positive feedback loops generating greater momentum for electric vehicles in general.

8 The Tesla Roadster (a high-end commercial BEV) is considered a landmark in EV development in terms of 1) performance (speed and range), and 2) business style (as newcomer offspring of a Silicon Valley start-up developed by founder of PayPal).
**Infrastructure.** BEVs rely on existing road infrastructure, although their current range limits most of their use to urban and peri-urban roads. The electricity powering the vehicles can be supplied 1) from the current centralised networks, and/or 2) in conjunction with more decentralised power generation options. From a power generation point of view, BEVs offer interesting potential for the balancing of peak loads (e.g. night-time charging, balancing intermittent supply, etc.). Depending on the preferred power generation option, BEVs may be close to carbon neutral in their operation.

The rollout of a charging infrastructure is critical to the commercial development of BEVs. Current early stages involve the multiplication of experiments in terms of technical specification (conventional/rapid charging, battery swapping, induction charging, etc.) and business models (public/private, ‘plug an pay’, etc.). The Netherlands are among European leaders in terms of rollout of a charging infrastructure, along with Denmark, Germany, France, and the UK (ECN 2012).

**Markets.** BEVs in the Netherlands have recently entered the market (see Table 3), in niches where the current limitations of BEVs (e.g. range) is minimised (van Bree et al 2010), such as in small urban cars, bicycles, mopeds, but also increasingly in more conventional passenger cars by experimental users and with the involvement of fleet operators (taxi, carsharing, company cars, etc.). The market is expanding, with a dominance of high-performance and small urban models. FEVs have experienced steady market growth since 2011, with over 4,000 registered FEVS in 2013 (see Table 3), although there are concerns of this levelling off due to changes in tax regimes. These figures, however, are dwarfed by an exponential growth of E-REVs and PHEVs to 24,512 by the end of 2013 (excluding ‘full hybrid vehicles’, such as the non-plug-ins).

**Table 3: Electric vehicles registered in the Netherlands (Data: RVO)**

<table>
<thead>
<tr>
<th></th>
<th>31/12/11</th>
<th>31/12/12</th>
<th>31/12/13</th>
<th>31/01/14</th>
<th>28/02/14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personal car (FEV)</td>
<td>1124</td>
<td>1910</td>
<td>4161</td>
<td>4160</td>
<td>4172</td>
</tr>
<tr>
<td>Personal car (E-REV, PHEV)</td>
<td>17</td>
<td>4348</td>
<td>24512</td>
<td>24734</td>
<td>25880</td>
</tr>
<tr>
<td>Company car &lt; 3.500</td>
<td>158</td>
<td>494</td>
<td>669</td>
<td>676</td>
<td>688</td>
</tr>
<tr>
<td>Company car &gt; 3.500</td>
<td>22</td>
<td>23</td>
<td>39</td>
<td>41</td>
<td>44</td>
</tr>
<tr>
<td>Buses (incl. trolley and hybrid)</td>
<td>68</td>
<td>67</td>
<td>73</td>
<td>74</td>
<td>85</td>
</tr>
<tr>
<td>Quad- and tri-cycles</td>
<td>181</td>
<td>469</td>
<td>632</td>
<td>635</td>
<td>642</td>
</tr>
<tr>
<td>Electric motorbike</td>
<td>88</td>
<td>99</td>
<td>125</td>
<td>120</td>
<td>121</td>
</tr>
<tr>
<td><strong>On-road total</strong></td>
<td><strong>1658</strong></td>
<td><strong>7410</strong></td>
<td><strong>30211</strong></td>
<td><strong>30440</strong></td>
<td><strong>31632</strong></td>
</tr>
<tr>
<td>Moped</td>
<td>2.484</td>
<td>2.853</td>
<td>3.130</td>
<td>3.136</td>
<td>3.133</td>
</tr>
<tr>
<td>Motorised quadricycle</td>
<td>n.a.</td>
<td>107</td>
<td>141</td>
<td>144</td>
<td>145</td>
</tr>
<tr>
<td><strong>Total on-road and limited</strong></td>
<td><strong>18453</strong></td>
<td><strong>28118</strong></td>
<td><strong>53254</strong></td>
<td><strong>53604</strong></td>
<td><strong>54907</strong></td>
</tr>
</tbody>
</table>

**Consumers, legitimacy and credibility.** There are no major legitimation issues, since the “new vehicles comply with current requirements for vehicles for use on public roads […] there are] no large change in the controls, so that consumers are not confronted with an unfamiliar device and do not have to learn a new set of user skills” (Köhler et al 2013:182-3). The main novelty, as far as users are concerned, relates to fuel infrastructure and related range issues. Dijk (2011) has shown that the Dutch consumer was mainly concerned with the

---

9 Technical range limitations of PEVs are being rapidly overcome, with current ranges well over 100km.
range and price of EVs in the late 1990s. Such cultural and preference barriers are however rapidly being overcome.

Consumer education is often seen as an obstacle to the breakthrough of EVs. The consolidating commercial interests behind EVs recognise that a more solid argument has to be made to potential users, emphasising their emotive value (e.g. fun, fuel independence, consumer choice in charging place, time and rate, etc.). There is recognition of the need for articulating a ‘net positive EV value proposition’ in order for consumers to overcome the high initial investment costs of EVs (EY 2013). The main market focus is set where the existing barriers to development are small or easily overcome, such as high-intensity of localised short trips (taxis, deliveries, urban car sharing, etc.), predictable mobility patterns (public transport), high ‘user willingness’ and lower cost barrier (high-performance ground-breaking vehicles, Government procurement, etc.).

3.1.2 Actors and networks

Electric transport, in industry terms, remains a high-risk activity. The main industries involved in FEVs are the automobile industry, the electricity industry, and battery manufacturers. Service providers are proving important for the development of charging infrastructure and new business models for mobility.

Car manufacturers. The EV segment is highly diverse, with dedicated start-ups coming from actors outside the automobile regime (Wells et al 2012), and a race by more traditional automakers, investing to ensure their presence on this emerging markets, developing models such as the Mitsubishi iMiEV (=Peugeot iOn & Citroën C-Zero), the Chevrolet Volt, the Opel Ampera, the Nissan Leaf, etc. Nissan has been an early investor in FEVs, and elaborating more aggressive commercialisation strategies as it partnered with Renault and Better Place (battery swapping) from the mid-2000s (Orsato et al 2012). With substantial support for demonstration projects, the Netherlands is proving to be an interesting location for e-mobility companies to launch their European distribution and assembly, as witnessed by the implantation of ZERO Motorcycles, Nissan Motor Parts Center, and Tesla Motors European headquarters, distribution and assembly centre (RVO 2013).

Component suppliers. While battery manufacture is dominated by Asian firms (NEC, GS Yuasa, BYD, etc.), the Netherlands is home to a number of companies making up a lively industrial and service base for electric mobility, including completely new start-ups, and big industry players in the area of ICT and more traditional vehicle manufacturing:

“more than 200 companies in the Netherlands operating in the arena of electric transport, including some top players such as ACTIA, Mastervolt, Nedap, Philips, Epyon, Alfen, KEMA, TomTom and many enterprising SMEs. In addition, there are several OEMs operating in niche markets (including Spijkstaal, Gemco and VDL Bus) and some companies that convert conventional vehicles into electric ones (AGV, Innosys Delft and Electric Cars Europe)” (RVO 2011:11)

Charging infrastructure and services. Dutch companies are strongly positioned in the area of charging infrastructure and services. ABB, strengthened through the recent acquisition of Epyon, has become a world leader in fast charging batteries and facilities, working with Fastned to supply a network of highway charging stations. A number of organisations are focusing on delivering charging services, including The New Motion, EV-Box B.V, NUON, Essent (owned by RWE AG), The New Motion, Oplaadpalen.nl, etc.

The power supply industry is also involved in e-mobility developments, building on their knowledge of grid operation. E-mobility presents promising business opportunities for grid operators and a variety of power services, especially considering potential synergies from
load management, smart grids, etc. A number of information-intensive innovations in this area can be expected to facilitate the breakthrough of electric mobility, such as Vehicle to grid (V2G), in which batteries may act as storage option from a grid perspective (Orsato et al 2012).

**Fleet operators and mobility service providers.** An interesting development in mobility is the involvement of fleet operators (taxis, buses, company fleets, ‘new’ mobility services, etc.), and their traction on supporting innovation processes. They influence the vehicle market through their size and procurement potential (owing to the sheer size of fleets), but also by imposing new models and purchasing preferences (i.e. short trips, control over refueling, etc.). For instance, a number of new mobility service operators such as Car2Go and MobilityMixx are realizing that the economy of electric vehicles may be more advantageous (from the perspective of costs/km) and are hence investing in urban fleets (Orsato et al 2012). Urban taxi fleets Taxis (RTC, TCA, Taxi Electric, etc.) are also experimenting with electric vehicles.

### 3.1.3 Governance and policy

**Niche support.** The main strategy is to anchor the Netherlands as an attractive early market for electric mobility, on the basis of policy support, the motivation of and federation actors, including in power generation. However, the lack of an indigenous automobile manufacturing industry means that there is a constant need to reaffirm attractiveness of the Netherlands as ‘test-bed’ for e-mobility, in order to attract foreign companies (RVO 2011). The Dutch Organisation for Electric Transport (DOET) is the main dedicated umbrella organisation promoting and lobbying for the development of e-mobility in the Netherlands. Intermediary organisations and businesses promoting electric and other sustainable mobility developments include NL Mobility and Green Mobility. The Dutch Consortium for the Tender of Electric Cars (DC-TEC) supports the deployment of electric cars. Formule E-Team is a public-private partnership set up as a technological platform to support and federate actors for the development of electric vehicles in the Netherlands.

**Policy.** Policy support for electric mobility is fundamental to its potential deployment, as a form of niche protection and development encouragement. Such support concerns chiefly innovation (R&D), incentives for vehicle purchase, and the rollout of a charging infrastructure. In the Action Plan for electric transport 2011-2015, ‘Elektrisch Rijden in de Versnelling’ (RVO 2011), the Government has set ambitious targets for EVs (Table 4). Reaching 200,000 vehicles is seen as demonstrating that the system of electric mobility ‘works’, and will require an adequate charging infrastructure, a market, and safety guarantees.

#### Table 4: National EV targets in the Netherlands

<table>
<thead>
<tr>
<th>Period</th>
<th>Market development</th>
<th>Expected EVs</th>
<th>Program stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2009–2011</td>
<td>Laboratories</td>
<td>&lt;100 to &lt;1000</td>
<td>Program start-up</td>
</tr>
<tr>
<td>2012–2015</td>
<td>Scale-up</td>
<td>15,000 to 20,000</td>
<td>Program implementation</td>
</tr>
<tr>
<td>2015–2020</td>
<td>Continued roll-out</td>
<td>200</td>
<td>Program consolidation</td>
</tr>
<tr>
<td>2020-onwards</td>
<td>Mature market</td>
<td>1,000,000 by 2025</td>
<td>Program scaled down</td>
</tr>
</tbody>
</table>

10 Such opportunities echo with the historical load-balancing synergies of power generation and urban tramways in the early development of electrification.

11 [http://www.samenelektrisch.nl/](http://www.samenelektrisch.nl/)
Electric cars also benefit from a number of fiscal advantages, such as the exemption of registration tax (until 2018), road tax exemption, and tax deductions for investments EVs and charging infrastructure (RVO 2013). Owners of EVs also benefit from free parking in most cities. In more targeted measures, the Government supports the deployment of EVs by encouraging the development of charging and power infrastructure, attracting manufacturers of electric vehicles and components, and supporting a variety of platforms to bring actors together (RVO 2011). Public procurement (government fleets, etc.) at national (ministries) and local levels is intended to further support the development of markets.

A number of ‘electric driving Green Deals’ have been signed with SMEs and local organisations, helping projects pick up steam (RVO 2014). Local (concentration) strategies based on the development of focus areas for roll out and experimentation (e.g. Amsterdam Electric, etc.). A number of regions and municipalities are positioning themselves at the forefront of EV, with the multiplication of field trials and demonstration projects involving private, public/private, or public electric mobility options. The cities of Amsterdan and Rotterdam (seeking a breakthrough of electric mobility), and the region of Brabant (ambitioning to become a leading market, research and industrial pole for electric mobility) are notable efforts in that direction.

3.1.4 Momentum
EVs have followed a bumpy development pattern, with multiple hype/disappointment cycles. Currently EVs are experiencing renewed momentum. The question is whether this is just another hype (Orsato et al 2012). A number of factors seem to indicate that a significant threshold has been passed. Signs of positive momentum include 1) the deployment of commercially viable vehicles, 2) promising steps towards charging infrastructure rollout, 3) the enthusiasm of fleet operators, 4) the deployment of hybrids vehicles acting as a ‘stepping stone’, and 5) increasing public exposure. Among other elements, it appears crucial to achieve high density and interoperability of charging opportunities for the stabilisation of BEV developmental trajectories. Cities and larger metropolitan regions are proving important in this respect.

3.2 Niche 2: Hybrid electric vehicles

3.2.1 Innovation and market trajectory
Historical overview. Hybrid-electric vehicles emerged as a low-carbon alternative to ICE cars and a stepping-stone towards the long-term development of full electric vehicles, as they provide some of the benefits of FEVs without their common drawbacks (dependence on reliable charging infrastructure, range anxiety, etc.). First commercialised in Japan (Prius I, 1997) and in California (Prius II, 2000), the Toyota Prius has been the first successful commercial HEV, with the 3rd version launched worldwide in 2004. HEVs are now entering a new phase, as consumers and producers alike have come to accept it as a common technology, reaching out well beyond over-protected niches and unconventional markets. While the automobile industry was highly reluctant to invest in hybrid cars until 2005 (with the exception of Honda and Toyota), most manufacturers are now offering HEVs (Orsato et al 2012).

Technical specifications. Hybrid-electric vehicles (HEVs) are vehicles combining a traditional petrol engine, as well as an electric motor that provides additional power for purposes such as acceleration or low-speed driving. The electric battery is charged through regenerative braking. Overall, the assistive electric motor can lead to fuel economy improvements, especially in the context of urban driving, although this is highly dependent on individual driving patterns. The scope for technical improvement in this area is that “better
batteries and power management (involving, e.g., the use of fly wheel and supercapacitor-based energy storage) may extend the electric range of HEVs” (Dijk et al 2012:9)

HEVs are to be distinguished from the more recent Plug-in electric vehicles (PHEVs), which can run on electricity alone and can be recharged with electrical outlets and are hence much closer fit to the vision for electric vehicles as well as greater decarbonisation potential:

“With a plug-in hybrid the battery pack can also be charged using the electricity grid so the first tens of kilometres can be driven fully electrically. This is sufficient for most journeys. If a longer range is required, one can continue using the combustion engine.” (ECN 2012:8)

**Technical components.** The technical components assembled in HEVs, in a similar way as for BEVs (as discussed in the previous section), do not divert much from ICE automobiles, with the exception of 1) electric motor, 2) regenerative brakes and controls, and 3) batteries. There are additional architectural and miniaturisation challenges arising from having two engines, as well as increased overall vehicle mass.

**Infrastructure.** HEVs and PHEVs present interesting infrastructure aspects, as they both rely on existing road infrastructure and fuel infrastructure. PHEVs also rely on electricity and hence are a stepping-stone for FEVs, generating demand for the rollout of charging infrastructure:

“Plug-in versions allow people to charge their vehicle at home or at special locations (potentially at work).” (Dijk et al 2012:9)

**Markets.** The mass commercialisation of HEVs was initiated by Japanese car manufacturers, on relatively specialised markets.

“The commercial success of the Toyota Prius, including in the Netherlands where it has been available since 2000, led other OEMs to step into the market. The market has been growing steadily since 2007 (see Table 5):

**Table 5: Hybrid (FHEV, PHEV, EREV) car sales in the Netherlands, Source: RAI (2013)**

<table>
<thead>
<tr>
<th></th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hybrid sales</td>
<td>3123</td>
<td>11835</td>
<td>16281</td>
<td>16112</td>
<td>14872</td>
<td>25509</td>
</tr>
<tr>
<td>Percentage of total sales</td>
<td>0,62%</td>
<td>2,37%</td>
<td>4,20%</td>
<td>3,34%</td>
<td>2,68%</td>
<td>5,08%</td>
</tr>
</tbody>
</table>

In 2009, HEVs sales increased substantially in the Netherlands, “largely as a result of the decrease in the incremental income tax rate (from 25% to 14% of the car sales price) for employees who use company cars.” (IEA 2010:216). These sales were made up almost entirely by Toyota Prius and Honda Civic Hybrid, with respectively around 8300 and 6000 units (IEA 2010:220). By 2013, 91196 hybrid vehicles were circulating in the Netherlands, representing over 1% of all registered vehicles (RAI 2013), of which nearly 25000 were EREVs or PHEVs (RVO 2014). Since 2012, the share of hybrid vehicles sales in the Netherlands is dominated by PHEVs and EREVs – a result that is attributed to generous fiscal incentives for low-emission vehicles.

**Consumers, legitimacy and credibility.** The Dutch public has become quite familiar with hybrid vehicles, which are highly accepted and legitimate since they represent only a minor
departure from conventional vehicles. This is particularly the case for FHEVs, which have become a commonplace vehicle option – albeit a slightly more expensive one. Familiarisation with electric driving with FHEVs is an important form of exposure that contributes to overcoming cultural barriers and gradual forming a positive connotation (Dijk and Yarime 2010).

3.2.2 Actors and networks

Automotive industry. Hybrid cars, because of their very low degree of departure from conventional cars, are being developed by established OEMs. There are however, interesting competitive dynamics at play within the industry, such as a head start of Japanese manufacturers, and consequently a greater development of the knowledge base by Japanese component suppliers – a strong advantage today and in the future move towards greater electrification. Intra-industry imbalances mean that there is some scope for new entrants:

“key European suppliers such as Bosch and Continental are increasing research in this area in an attempt to counterbalance Asian dominance. Existing players (excepting those in Asia) essentially have to start from scratch when it comes to developing the new electrified components and systems – which gives new entrants in the Netherlands some chance to establish positions more easily than they could in the highly mature automotive component market.” (FHA 2010:26)

Following Toyota and Honda’s pioneering market creation for hybrid vehicles, the bulk of the industry is now following the trend and developing hybrid models. The entrance of carmakers in the growing market for hybrid electric vehicles has led to a diversification of vehicles on offer, with 7 PHEVs12 and one EREV13 on offer in the Netherlands in 2013 (RVO 2014).

There is some ambivalence with framing hybrid vehicles, which can be marketed either as conventional cars with improved fuel economy, or as a bridge towards the electric car, especially in the case of PHEVs for short distances. Regardless of the framing, it is apparent that there is an active effort of the automobile industry to present a ‘win-win’ solution, minimising the element of novelty (and related risk-taking) to emotionally reassure potential customers, while at the same time taking full advantage of the technical and environmental performances of such cars to cater for an environmentally conscious and tech-savvy audience. This can be interpreted as a sign that even PHEVs are some sort of technological ‘chimera’ that cannot be expected to stabilise, although their adoption is a crucial step in the electrification of mobility.

Innovation. Technical improvements focus mainly on the performance of batteries, and attending to the challenges from having two engines (weight and volume allocation). There is a clear trend toward developing full hybrid vehicles into PHEVs to reach a greater CO2 reduction potential with limited extra costs (larger battery), in a move towards a greater degree of electrification and reliance on (now more credible) charging infrastructure:

“In the economy segment, the rising popularity of EVs created an opportunity for firms with hybrids to leverage these models by creating plug-in versions, thus trying to ride the wave of electric mobility with fairly minor technological adjustments” (Bohnsack et al 2014:298)

Infrastructure development. FHEVs provide an interesting bridging opportunity towards the development of the charging infrastructure necessary for the deployment of FEVs, with a lesser degree of user commitment and dependence.

12 Chevrolet Volt, Fisker Karma, Mitsubishi Outlander, Opel Ampera, Porsche Panamera S-E-Hybrid, Toyota Prius plug-in, and Volvo V60 plug-in.

13 BMW i3.
3.2.3 Governance and policy

HEVs require very little support to be commercially viable. A number of incentives persist HEVs receive smaller amounts of support than EVs, via tax exemptions for low-emission vehicles. Plug-in hybrids owners can benefit from financial assistance for the installation of charging infrastructure.

3.2.4 Momentum

There are clear indications that hybrid vehicles have moved towards the mainstream, representing a noticeable market share and a relatively stable design. This makes HEVs a very tangible mobility innovation, but one that has already broken out of its niche.

HEVs are interesting insofar as they are an intermediate form of technology, adding some elements of electrification to conventional vehicles. The development of HEVs can be seen as the momentary result of a hybridisation strategy, qualified by the progressive introduction of novelty through technological compromises and overall risk reduction:

**Stepping stone to EVs.** In response to a growing demand for cleaner vehicles, and within a broader vision of ‘electric mobility’, HEVs can be seen as a first step to the mass commercialisation of electric features within conventional cars, in gradual steps from FHEVs (no autonomous electric drive) to EREVs and PHEVs. The development of HEVs continues stimulating the industry in terms of innovation (battery performance and size, frame weight, controllers and electronics), charging infrastructure rollout (for PHEVs and EREVs), the reconfiguration of production networks, and consumer familiarisation, which are contributing to pave the way for EVs, without fully facing some of the major barriers to their development (e.g. range anxiety, uncertain charging infrastructure rollout, etc.). HEVs are hence crucial step towards EVs. With PHEVs, especially in the Netherlands, a new step is being taken towards full electric pathways:

“...The increasing sales of the Toyota hybrids and the recent announcements of the launching EVs in the market suggest that the system may soon move into a growth phase of large scale technology diffusion”
(Köhler et al 2013:185)

**Technological chimera?** However, by seeking the best of both worlds, the development of HEVs has a tendency to combine the inefficiencies of both technologies, with major problems arising from e.g. having two engines (increasing weight, volume, and components), questionable environmental impact reduction (especially for FHEVs), difficulties to open up to radical new designs taking full advantage of electric motors, costs, limited adaptation to changes in mobility patterns, etc. This sub-optimal developmental proposition makes it unlikely that hybrid vehicles will install themselves as a stable mobility proposition in the medium to long term, in a similar way as the ‘horseless carriage’ design was abandoned in favour of ICE-tailored design solutions.

3.3 Niche 3: H2 fuel cell vehicles

3.3.1 Innovation and market trajectory

**Historical overview.** Hydrogen fuel cells were initially developed in high-end niches application such as space programs, and some early experiments with FCVs. The oil shortages of the 1970s triggered a number of large-scale FCVs research and demonstration programs, leading up to a number of demonstration prototypes in the 1990s, gaining interest and enthusiasm within visions of a solar hydrogen economy and sustainable energy futures.

**Technical distinctions.** There are two main ways of using hydrogen for transport application: hydrogen combustion in modified combustion engines and hydrogen fuel cells (our present focus). While most OEMs have focused on hydrogen fuel cells, actors such as
BMW have historically focused on the modification of combustion engines to use hydrogen, a technological area that seems to have now been abandoned in favour of EVs (Budde et al 2012). HFCs are more efficient and cleaner than the ICE run on hydrogen, but still present major disadvantages in terms of costs and weight (Solomon and Banerjee 2006).

**Motivations.** Fuel cells are attracting interest in conjunction with visions of a hydrogen economy, within which there are strong expectations for decarbonisation, namely through the generation of hydrogen from renewable energy sources (e.g. from large solar farms in the desert). In the case of applications in the transportation sector, hydrogen fuel cells present advantages in terms of atmospheric pollution (zero emission in use), refuelling time, and longer-range application (as opposed to current barriers to EV vehicles).

**Technical components.** Hydrogen fuel cells present similarities to batteries – they are made up of an electrolyte, anode and cathode that allow generating electricity from hydrogen (inverted electrolysis of water) to power an electric motor – with the exception that the main energy input is hydrogen (instead of electricity), which presents potential advantages in terms of fuel storage, and atmospheric emissions in the use phase. HFCVs require additional space for the hydrogen tank, and the water exhaust.

FCVs are currently the alternative drivetrain with the furthest time horizon and highest uncertainty. However, while there are many technological challenges, FCV is also one of the options closest to conventional cars in terms of regime and interpretational capacity of user expectations, as it promises long range and short refuelling time, and some complementarities with existing refuelling infrastructure, as opposed to more regime-challenging technologies such as EVs (Budde et al 2012), and is considered the main alternative transportation technology for the longer term (Köhler et al 2013).

**Hydrogen production.** Hydrogen can be produced from a variety of primary sources (and hence contribute to energy independence) and presents advantages in terms of storage (compared to electricity for instance). Two main options are currently being considered for large-scale sustainable hydrogen production: steam-reforming or gasification of hydrocarbons (natural gas) with carbon sequestration, and inverted electrolysis of water using for instance renewable energy sources, both of which are attracting enthusiasm in relation to their potential contribution to net carbon emission balances. Future choices of energy feedstock and conversion technologies are thus crucial to the overall balance of hydrogen fuel cells, as some hydrocarbon-based processes could also lead to increased CO2 emissions (Solomon and Banerjee 2006). The Netherlands already host production facilities in Rotterdam, Groningen and Limburg, totalling around 10bn m3/yr (Maisonnier et al 2007).

**Refuelling infrastructure.** Storage and distribution of hydrogen can be in liquid or gaseous form – involving high-pressure pipelines, but also possibly containers or a combination of both – or in solid form such as in metal hydrides or carbon nanofibres (Ekins and Hughes 2009). Similarly to EVs, FCV experiments run into barriers related to the development of a reliable refuelling infrastructure – the chick-and-egg problem. Local experiments and infrastructure demonstrations for FC buses have been one of the main priorities of European programs, in an attempt to provide means to overcome the infrastructure barriers. In the Netherlands, a number of hydrogen filling stations\(^{14}\) exist or are planned.

\(^{14}\) The two main specifications deployed concern 350-bar stations for buses and 700-bar stations for passenger cars.
Germany is considered to be a lead player in the development of hydrogen mobility and supporting infrastructure,\textsuperscript{15} which provides obvious potential for cross-border cooperation, such as the HyER demonstration programme, which seeks the establishment of a transnational hydrogen corridor between Sweden, Denmark, the Netherlands, Germany, France and the UK. Proximity with Germany is one of the many advantages of the Netherlands in the automotive sector in general.

**Markets.** FCVs are not yet available on commercial markets, “except in selected field test regions” (Zubaryeva and Theil 2013). Given FCVs’ relative immaturity, market penetration can only be evaluated ex-ante, based on projections, which vary significantly from 2-20\% of vehicle stocks by 2030 to 5-50\% by 2050 (Zubaryeva and Theil 2013). Demonstration and prototypes of fuel cell cars have been developed by major OEMs, including GM’s Hy-wire, Toyota’s FCV Concept, Hyundai’s Intrado (SUV), Honda’s Clarity and FCEV Concept.\textsuperscript{16} GVB has been running a pilot project with Mercedes-Benz/EvoBus buses in Amsterdam on two lines since 2004, as part of the CUTE project. The Forze team at Delft University developed record-breaking FC prototypes since 2007. In a new step towards market, Hyundai introduced the first commercial fuel cell vehicle in the Netherlands in 2013, the ix35 Fuel Cell,\textsuperscript{17} in a move to propose a concrete experience to adventurous customers. While the Dutch Government announced expectations of several thousand fuel cell cars worldwide by 2015,\textsuperscript{18} Hyundai brought this figure to between 500,000 and 1milion by 2020.\textsuperscript{19}

**Consumer preferences, related legitimacy and credibility.** Consumers have so far not had much interaction with FCVs, for only few models exists, and marketing is not yet a priority for carmakers. Prototypes and demonstrations are currently mainly reaching a small group of car enthusiasts (but also a more broader public by ways of local experimentations with FC buses). Foreseeable consumer-related issues to be addressed include safety concerns related to hydrogen refuelling and storing, and the availability of refuelling infrastructure (Zubaryeva and Thiel 2013).

### 3.3.2 Actors and networks

Fuel cells are attracting entrepreneurial interest worldwide:

> “[In 2006 there were] over 100 fuel-cell manufacturers worldwide, in addition to many auto and oil companies active in this field. Major ones [were]: UTC Fuel Cells, FuelCell Energy, Gore, DuPont, Ballard, SiemensWestinghouse, IdTech, Acumentrics, MTI Micro, Asahi Kasei, Toshiba, MTU, Sulzer Hexis, ElectroChem and Nuvera.” (Solomon and Banerjee 2006:784-5).

In the Netherlands specifically, a ‘Hydrogen and Fuel cell technology cluster’ is developing in Arnhem, notably with the involvement of Nedstack (PEM fuel cell stack production),


\textsuperscript{16} Dijk and Yarin (2010) however, remind us that prototypes shown in industry events are often presented for PR purposes without intentions of entering production.

\textsuperscript{17}http://www.hyundai.nl/ix35-fcev# accessed May 14, 2014.


HyGear (hydrogen generation), HyET (hydrogen compression, e.g. for refuelling stations), and HyMove (manufacture of hydrogen buses).

**Automobile industry.** Most OEMs have ongoing FCVs R&D programs, with overall spending well above government investment in this area (Solomon and Banerjee 2006). Prototypes and demonstration vehicles have been developed by major OEMs since the 1990s, with some hopes towards delivering commercial products in the coming years, although existing FCVs remain far from affordable (Solomon and Banerjee 2006).

Daimler “was the first major car manufacturer to present prototypes of fuel cell vehicles, after the fuel cell experiments conducted by General Motors (GM) in the 1960s” (Budde et al 2012:1077), a competence and interest that was developed by diversification intentions into different alternative drivetrains options, as well as dedicated moves such as the purchase of aerospace subsidiary Dornier. Daimler presented a number of prototypes that attracted a lot of interest in the 1990s (NECAR I, and II), and injected substantial energy into becoming a ‘technology leader’, seeking to deliver a substantial number of commercial vehicles by the mid-2000s (Budde et al 2012). However, facing a number of obstacles, Daimler has dropped its initial ambitions of producing 100,000 FCVs by 2010 (Solomon and Banerjee 2006).

At this stage, there are only few new entrants in the field of FCVs, which is dominated by OEMs (Bakker 2010), with some notable exceptions, such as Th!nk. HyTruck ([www.hytruck.nl](http://www.hytruck.nl)) is an innovative Dutch company developing proof-of-concept HEFC trucks for commercial delivery systems since 2005.

**Energy industry.** Because of coupling potentials arising from HFCVs with fuel processing and distribution capabilities, energy companies are following and taking part in their development with interest. Among those, particularly BP and Shell (Dutch) stand out (Solomon and Banerjee 2006), with substantial resource commitments into hydrogen R&D and demonstration programs. AirLiquide is also a well-established company with interest and capabilities in hydrogen production. Fringe actors include companies such as Air Products and Linde.

**Fleet operators.** In these early stages, fleet operators (i.e. bus operators, taxi operators, regional commercial delivery operators, etc.) are well positioned to provide an environment for demonstration projects, since their refuelling requirements and transportation logistics allow them to better control for infrastructure barriers.

**Cooperative initiatives.** A number of groups are pushing for the development of HFVs, including:

- The Nederlandse Waterstof en Brandstofcel Associatie (NWBA, [www.nwba.nl](http://www.nwba.nl)) brings together a number of Dutch stakeholders for the promotion of fuel cells. They are a member of the European Hydrogen Association (EHA, [www.h2euro.org](http://www.h2euro.org)).
- H2 Mobility was established in September 2009 and brings together EnBW, Linde, OMV, Shell, Total, Vattenfall, and the NOW GmbH.
- HyER is a European association seeking the coordination of local hydrogen infrastructure rollout

### 3.3.3 Governance and policy

The push for FCVs is mainly perceptible through large-scale government sponsored programs, initiated in the 1970s (oil shocks), although funding was reduced in the mid-1990s despite major technological progress (Budde et al 2012).
Currently, the European Commission is engaged in supporting HFCVs, as demonstrated by contributions to R&D funding, and coherence with its long-term agenda. Solomon and Banerjee (2006) suggest that EU plans are more ‘aggressive’ than their counterparts. This is most notable in Germany (with positive links to the Netherlands and the North Sea basin in general). European research efforts are channelled through the Fuel Cells and Hydrogen Joint Technology Initiative, and H2FC European Infrastructure, which is to serve as a platform to coordinate public R&D activities.20 Closer to markets, a number of partnerships are encouraging coordinated efforts, such as the Fuel Cells and Hydrogen 2 Joint Undertaking (FCH 2 JU) dedicating 1.33 B€ (half EC, half industry funding) “accelerate the market introduction” of Hydrogen and Fuel Cell technologies,21 or the IEA’s Hydrogen Implementing Agreement (IEA-HIA).

Given the considerable uncertainties remaining, however, these ambitions (especially in the 2000s) should be contextualized:

“The EU […] has a plan to introduce [FCVs] so that its total on-road fleet could reach 15% by 2030, and more than double that level by 2040. These levels are not proposed targets, however.” (Solomon and Banerjee 2006:791)

Dutch-specific support for HFCVs include:

- In 2010, a 5 million € subsidy has been made available for companies to experiment with Hydrogen in the Netherlands.22

3.3.4 Momentum

The development of FCVs is still at an experimentation (demonstration) stage, with precursor market experiments just emerging. FCVs are still much more expensive than any other alternative vehicles, and are considered an option for the medium and long term. Current demonstrations are mainly technical proofs of concept rather than broader exercises in market exposure. A number of commercial models are expected by 2015, in a dynamic led by Hyundai. While there are today “doubts that (hydrogen) fuel-cell technology will be ready for commercial use any time soon” (Orsato et al 2012), namely considering technological and cost challenges, “there is a good perspective that these challenges can be overcome, as exemplified by the ongoing efforts of large automotive companies (e.g. Daimler, Toyota) and the emergence of [collaborative] industry initiatives” (Van Bree and Bunzeck 2010:10), and an emerging consensus that the time horizon for a proper commercial deployment of the technology will not materialise before 2030.

20 http://h2fc.eu/objectives
FCV development is still a relatively experimental venture and can only be judged by its potential. While some observers suggest that FCVs are “[t]he main alternative technology considered for the longer term” (Köhler et al 2013:176), others express some doubts over repeated hype cycles, suggesting that the high technological hopes around hydrogen technology as a transportation fuel in the Netherlands, particularly in the mid-2000s, have led to decreasing thereafter (Alkemade and Suurs 2012, Bakker and van Lente 2009).

3.4 Niche 4: Biofuels

3.4.1 Innovation and market trajectory
Biofuels are currently the main alternative to oil-based fuels in Europe, with blending rates of around 5% in transport fuel. There are however significant concerns about resource competition with food production and other land use issues, pointing towards upper limits to their market development of conventional biofuels.

Historical overview. The development of biofuels in the Netherlands has been inherently tied to changes in policy support, which have followed ups-and-downs. Biofuels emerged in the early 1990s, in relation to calls to decarbonise transportation, reduce oil dependence, and the need to find new outlets for agricultural production. A number of early entrepreneurial experiments with bioethanol and biodiesel in city buses (Groningen, Rotterdam), and service boats in Friesland, achieved technical success but limited economic viability (Suurs and Hekkert 2009). Policy support initially failed to stabilise in the 1990s due to scientific controversy about biofuel environmental performance, and technicalities of a potential fuel tax exemption. The obligation for oil companies to blend an increasing percentage of biofuels in transport fuel created a market. This was followed by a new period of contestation about the sustainability benefits.

Technical distinctions. Biofuels can be used in blends of up to 10-15% in conventional engines, or in greater concentration in dedicated engines (flexi-fuel engines), for which the Dutch market is relatively poorly developed. A distinction has been introduced to distinguish 1G (first-generation or conventional) and 2G (second-generation or advanced) biofuels, which involve different technologies and actors (Suurs and Hekkert 2009, see also Table 6) Advanced (2G) biofuels are more versatile, as they can be produced from a larger variety of raw material (e.g. waste and non-food crops), and offer greater potential for carbon emission reductions, but are only emerging on markets.

Motivations. The main motivations for biofuel development are oil dependence (particularly in the 1970s and 1990s), overproduction in the agricultural sector in the 1980s and 1990s (Ulmanen et al 2009), and more recently concerns about climate change (2000s). The importance of the petrochemical industry and international commodity transport in Rotterdam are further explanations for Dutch biofuel developments.

Technical components. The most common biofuels are bioethanol and biodiesel, which can both be produced according to conventional or advanced processes (see Table 6 for an overview). Conventional processes are well developed. Advanced processes present greater difficulties, mainly in terms of integration of known technological components, but these are rapidly being overcome.
Biofuels can be blended in small proportions with base fuels (petrol and diesel respectively) for use in conventional engines. European manufacturer are increasingly guaranteeing the use of E10, while American and Brazilian manufacturers increasingly support E15 an even E25, respectively (Kampman et al 2013). The common low blend of biodiesel is B7.

Flexi-fuel vehicles (FFVs) can run on 100% bioethanol or any blend (the current main high blend used in Europe is E85), but also conventional oil which means that range anxiety is not an issue for consumers. It is possible to retrofit diesel engines to run on biodiesel, although it is much cheaper to do so at the design stage.

**Infrastructure.** Biofuels production requires appropriate raw material supply (including collection in the case of waste), stationary chemical production facilities, and distribution networks. Large-scale undertakings can benefit from Rotterdam’s important international freight and petrochemical infrastructure. Abengoa Bioenergy’s bioethanol plant in Rotterdam, for instance, opened in 2010, is a massive production facility that can produce over 384000 m3 bioethanol yearly, as well as animal feed, and high quality carbon dioxide.

---

23 The refueling stations on this map offer biofuel in addition to regular fuels.
Low blending of biofuels in base oil relies on existing capacity and retail distribution infrastructure. For high biofuel blends, however, there is a need for dedicated fuel pumps infrastructure, which is poorly developed. The Netherlands is committed to developing biofuel refuelling infrastructure (Kampman et al 2013), with currently 30 fuelling stations offering bioethanol, and 26 fuelling stations offering biodiesel in and around the Netherlands (see Figure 3).

Markets. Dutch Biofuel consumption is above European average, but far from leading (European Commission, 2013y). This consumption is almost evenly spread across bioethanol and biodiesel. The main form of biofuel consumption in Europe is through low blends, as flexi-fuel vehicles (FFVs) remain a fairly small niche market.

Although there have been some development flexible cars running on 100% biofuel, this niche market is currently fairly small when compared to the blending of biofuels with conventional oil. While flexifuel cars are available from a range of manufacturers,24 only 2768 (out of 6.4 million) registered cars were running on bioethanol in the Netherlands in 2013 (RAI 2014). The Dutch market is small when compared to countries like Germany, France and Sweden.

Production. While global biofuel production is dominated by the US and Brazil, European countries, including Sweden, France, Germany and the Netherlands, are stepping up production (see Table 7), supplying an increasing share of their own requirements. In the Netherlands, biodiesel production was initially stepped up to cater to the German market (Ulmanen et al 2009).

Table 7: Biofuel production in the Netherlands, ktoe (data: BP Statistical review of world energy 2014)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>World</td>
<td>14682</td>
<td>16446</td>
<td>19701</td>
<td>25678</td>
<td>34832</td>
<td>46453</td>
<td>51949</td>
<td>59555</td>
<td>60684</td>
<td>61752</td>
<td>65348</td>
</tr>
<tr>
<td>Netherlands</td>
<td>0</td>
<td>6</td>
<td>3</td>
<td>22</td>
<td>80</td>
<td>77</td>
<td>241</td>
<td>385</td>
<td>627</td>
<td>1255</td>
<td>1182</td>
</tr>
</tbody>
</table>

1G biofuels are commercially available. The European blending obligation created a market for 1G biofuels and the development of local supply and distribution networks. However, concerns about sustainability of 1G biofuels is rapidly shifting the trend, with a greater role for advanced biofuels. In 2011, advanced biofuels constituted 40% of all biofuels supplied in the Netherlands (Peters et al 2013). Table 8 and Table 9 provide further details about the current Dutch biofuel supply capacity.

Table 8: 1G biofuel production in the Netherlands (data: Peters et al 2013)

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Date</th>
<th>Type</th>
<th>Capacity (t/y)</th>
<th>Process and feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cangill (acquired Nedaalco)</td>
<td>Bergen op Zoom</td>
<td>2012</td>
<td>Commercial</td>
<td>32000</td>
<td>Bioethanol from cereal and potatoes</td>
</tr>
<tr>
<td>Abengoa Energy</td>
<td>Rotterdam</td>
<td>2010</td>
<td>Commercial</td>
<td>385000</td>
<td>Bioethanol from cereal and potatoes</td>
</tr>
<tr>
<td>Maatschapp Bosna</td>
<td>Zuidwede</td>
<td></td>
<td>On stream</td>
<td>4600</td>
<td>Bioethanol from potatoes and sugarbeet</td>
</tr>
<tr>
<td>Biodiesel Kampen</td>
<td>Kampen</td>
<td></td>
<td>On stream</td>
<td>120000</td>
<td>Bioethanol from used cooking oil</td>
</tr>
<tr>
<td>Biodiesel Amsterdam</td>
<td>Amsterdam</td>
<td></td>
<td>On stream</td>
<td>100000</td>
<td>Bioethanol from used cooking oil</td>
</tr>
<tr>
<td>Sunoil Biodiesel</td>
<td>Emmen</td>
<td></td>
<td>On stream</td>
<td>70000</td>
<td>Biodeisel from used cooking oil &amp; animal fats</td>
</tr>
<tr>
<td>Ecocar (VION)</td>
<td>Son</td>
<td></td>
<td>On stream</td>
<td>5000</td>
<td>Bioethanol from animal fats</td>
</tr>
<tr>
<td>Goes on Green</td>
<td>Sluisikil</td>
<td></td>
<td>On stream</td>
<td>250000</td>
<td>Bioethanol from plant oil, used oil &amp; animal fats</td>
</tr>
<tr>
<td>Biovalue</td>
<td>Delfzijl</td>
<td></td>
<td>On stream</td>
<td>66000</td>
<td>Bioethanol</td>
</tr>
</tbody>
</table>

24 See, for instance, [http://www.fuelswitch.nl](http://www.fuelswitch.nl)
**Research and innovation.** Biofuels are a relatively mature alternative transportation fuel. Current R&D efforts within 1G biofuels are focussing on applications such as the use of waste and crops like algae that present high potential yields and less direct competition with food. Advanced biofuels and biogas are the most innovative segments of the biofuels industry. In 1998, the Dutch government agency for energy and environment (Novem) initiated the GAVE programme for the assessment and support of gaseous and liquid CO2-neutral energy carriers, paving the way for broader support of 2G biofuels in the Netherlands. It “serve[d] as a catalyst, bundling and connecting [knowledge production and resource mobilisation] activities” around 2G biofuels at the turn of the century (Suurs and Hekkert 2009:1012), and was followed by the support of biofuel supply networks demonstrations. Ligno-cellulosic biofuel processes are still at demonstration and pilot stages, oil-based biofuel conversion processes are becoming commercially viable.

Recently, a new initiative was developed to experiment with the use of biofuels for aviation, involving KLM, Neste Oil, SkyNRG, Schiphol and Rotterdam. Another area of research development is the conversion of biogas from waste into natural gas for use in CNG vehicles (IEA 2010).

**Consumers, legitimacy and credibility.** Low biofuel blends have no impact on driving practices. Flexi-fuel vehicles have been engineered to perform equally well on conventional fuels, which means that range anxiety is not an issue. Biofuels have, however, been the target of serious controversies, challenging their legitimacy and the ethical responsibility of their advocates, particularly in relation to controversies about competition with food production, deforestation, increased carbon emissions, and rising food prices, exacerbating the division between advocates of 1G and 2G biofuels.

### 3.4.2 Actors and networks

Biofuels in the Netherlands involves a wide range of actors: farmers, regional authorities, public transport companies, SMEs, research organisations, government agencies and incumbent companies (Lovio and Kivimaa 2012), with a strong role for local entrepreneurs and authorities. Biofuel blending has led to a strong involvement of established oil companies.

The biofuels field has been marked by the division between 1G and 2G advocates. 1G biofuel production in the Netherlands involves small actors and new entrants:

“mainly small entrepreneurs, collaborating with farmers’ associations, providers of public transport, and provincial fleet owners” (Suurs and Hekkert 2009:1017)

Ulmanen et al (2009:1415) suggest that in the 1990s, support to biofuels “was always the outcome of lobbying by local politicians and biofuel supporters with links to the national political parties”, suggesting strong but highly diverse actor coalitions and networks.

The main actors involved in early 2G biofuels developments, on the contrary, were “large vested firms with stakes in the oil, alcohol and technology development business” (Meijer

---

**Table 9: 2G biofuels pilot plants in the Netherlands (Data: www.iea.org)**

<table>
<thead>
<tr>
<th>Company</th>
<th>Location</th>
<th>Date</th>
<th>Type</th>
<th>Capacity (t/y)</th>
<th>Process and feedstock</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNO</td>
<td>Zeist</td>
<td>2002</td>
<td>Pilot</td>
<td>100</td>
<td>Biochemical conversion of lignocellulosics into pretreated biomass</td>
</tr>
<tr>
<td>ECN</td>
<td>Petten</td>
<td>2008</td>
<td>Pilot</td>
<td>346</td>
<td>Thermochemical conversion of lignocellulosics into SNG</td>
</tr>
<tr>
<td>BioMCN</td>
<td>Groningen</td>
<td>2009</td>
<td>Commercial</td>
<td>200000</td>
<td>Thermochemical conversion of glycerine into methanol</td>
</tr>
<tr>
<td>Neste Oil</td>
<td>Rotterdam</td>
<td>2011</td>
<td>Commercial</td>
<td>800000</td>
<td>Chemical conversion of oils/fats into HVO biodiesel</td>
</tr>
</tbody>
</table>
and Hekkert 2007:292), benefiting from policy and scientific support due to the clearer environmental impact of their product. Specific segments, such as the generation of biofuels from waste, attracts new entrants, such as Rotie and Biodiesel Amsterdam, for instance, who specialise in collecting waste cooking oil and producing advanced biodiesel. However, powerful players such as Shell are able to diversify across a wide portfolio of technologies. Royal Dutch Shell sees biofuels as the main alternative for fossil fuels in transport in the short- to medium-term. Traditionally involved in blending and distribution, as well as biofuels R&D, Shell has recently made steps into 1G biofuels production, notably through Raizen, a Shell-Cosan joint venture, mainly generating ethanol from sugarcane in Brazil. Shell is also developing advanced biofuels in the UK, the USA, India, and the Netherlands, but has recently cut down investment due to uncertainties to scale up in the near term.

Local authorities such as Groningen, and Rotterdam have been and continue to play a strong role in terms of generating early markets and supporting infrastructure for biofuel deployment. More generally, in the Dutch context, support has tended to come from regional and EU levels:

“the earlier entrepreneurial experiments were most strongly related to regional initiatives. Later, the development was largely the result of European pressure and related regional efforts, whereas the national government generally hampered rather than supported the development” (Lovio and Kivimaa 2012:786)

Car manufacturers have been involved in the development of flexi-fuel vehicles, as well as in ways of improving the compatibility of new vehicles with bioethanol and biodiesel blends. The involvement of the car industry has been noted as successfully assisting the development of quality standards for these new fuels (Di Lucia 2013).

3.4.3 Governance and policy
Policy influence in the area of biofuels has been primarily for three motives: 1) innovation support, 2) market creation, and 3) regulation and certification.

Innovation support. Early experimentation with biofuels have been supported by the Dutch government and regional actors in the early 1990s, via research/trial funding and tax exemptions to support biofuel vehicle experiments (e.g. bioethanol buses in Groningen, and various biodiesel boat fleets), but also biofuel production from agricultural feedstock. This support was interrupted with the emergence of an anti-biofuel coalition from the mid-1990s. RD&D funding shifted to 2G biofuels around that period.

Market creation. The municipality of Rotterdam was involved in generating a local market for FFVs with its own fleet, but implementation was rather slow (Ulmanen et al 2009). The turning point in market creation came through the impulse of the EU. Dutch biofuels policy has mainly been driven by European directives (van Grinsven and Kampman 2013). The Biofuels Directive (2003) called for a step-wise increase of the share of biofuels (2% by 2005 and 5.75% by 2010). It was replaced in 2009 by the Renewable Energy Directive (RED), setting a target of 10% renewable energy in the transport sector by 2020, amended in 2013 to include sustainability requirements (biodiversity and land use). European prescriptions were translated into the Dutch biofuels obligation (introduced 2007), which required fuel suppliers to include a minimum share of biofuels in their sales, from 5.75% in 2010 (revised down to 4%) to 10% in 2020. The Dutch Emissions Authority (NEa) monitors the performance of individual companies and revises yearly objectives.

Legitimation: regulation and standards. Following controversy about the sustainability of biofuels, particularly heated between 2007 and 2009 (Breukers et al 2014), a number of measures were taken to address this issue and raise the legitimacy profile of biofuels. The so-called ‘Cramer criteria’ (NTA 8080) are ‘verifiable sustainability requirements’ that were
formulated in 2008 for the introduction of certified biomass on the Dutch market. In addition, Dutch companies signed a declaration of intent to voluntarily report on the nature, origin, and sustainability of biofuels, which is an important step towards transparency and traceability. A recent study found that biofuels on the Dutch market had on average a low ILUC impact, although there is high variability across distributors (van Grinsven and Kampman 2013).

In 2012, the EC proposed a number of sustainability measures in a recent legislative proposal (COM(2012)595), including a cap of 5% of food-based biofuels by 2020, the promotion of biofuels from food production waste and forestry residues, and the inclusion of ILUC criteria. There are worries that the materialisation of this proposal could depress a not so profitable 1G biofuels industry and provide positive incentives for 2G biofuels producers (Peters et al 2013). Reacting to the differentiation of 1G and 2G biofuels, and recent concerns about the possibility for scaling up sustainable biofuels, the European Parliament agreed on differentiated targets by 2020 (6% 1G biofuels, 4% 2G biofuels and other renewable transport options).

### 3.4.4 Momentum

Biofuel path creation in the Netherlands was initiated in the 1990s, and has been marked by a lack of continuity (Lovio and Kivimaa 2012), which has been interpreted as a hype/disappointment cycle (Alkemade and Suurs 2012). Since the early 2000s, however, biofuels have been driven by EU policy, as the Biofuels Directive created a solid (but caped) niche market for biofuels blending. The FFV niche is comparatively small and stagnant.

On the supply side, the field is marked by the distinction between 1G and 2G biofuels, erected as a frame to navigate the sustainability controversy. While considerable progress has been made towards the commercialisation of 1G biofuels, there are questions as to the commercial viability of 2G biofuels in the near future. The recent deployment of a number of pilot and commercial plants in the Netherlands seems to indicate that the field is stabilising, despite some ongoing concerns about traceability and the scope for sustainably scaling up production.

### 3.5 Niche 5: Carsharing and car clubs

#### 3.5.1 Innovation and market trajectory

Carsharing and car clubs offer an alternative to traditional automobile vehicle ownership. They propose a shift from mobility consumption based on material ownership to mobility as a service: private mobility on demand. Individuals can hire a vehicle from a fleet operator or from a community of individuals. While vehicle hire services have long been an important part of the mobility landscape, particularly for tourism and business purposes, we here focus on the more innovative short-term access membership-based schemes that have emerged in recent years, offering greater convenience, proximity and instantaneity. This form of mobility is a growing alternative to conventional car ownership. Private mobility on demand has significantly been enabled by innovations in ICT, community logistics of online platforms, new services and organisational models.

**Historical overview.** Early car sharing and car club communities have existed since mid-twentieth century, with growing networks in Germany and Switzerland in the 1980s (Kent

---

25 We here refer to carsharing and car clubs interchangeably. Carpooling or ride sharing (the practice of sharing a journey with other passengers), though often referred to as car sharing, falls beyond our focus.
and Dowling 2013). The Witkar in Amsterdam was an early experiment with a city-wide EV carsharing system running from 1974 to 1986, inclusive with multiple parking/charging stations, advanced control switches and automation. Greenwheels, launched in the Netherlands in 1995, is the largest Dutch carsharing provider. Widespread awareness and popularity of sharing grew in recent years with the development of bike-sharing schemes, notably in Paris (Vélib’) since 2007. The main form of bikesharing in the Netherlands, OV-fiets, is run by the national railway (NS) as a sort of extension of its network since 2003 and currently offers 8000 bicycles.

**Technical distinctions.** In the Netherlands, a number of carsharing services coexists. Professional fleet managers offer either ‘classic’ round-trip service (e.g. Greenwheels, ConnectCar), or one-way service (e.g. Car2Go) for which fleets tend to be concentrated in dense area. ‘Classic’ carsharing usually benefit from fixed parking stations from which to pick up and deposit the vehicle, while one-way car sharing vehicles are never parked in the same place. Peer-2-peer services (e.g. MyWheels of SnappCar) are offered by private individuals, and tap into the pool of unused cars, which are made available via online marketplaces. This latter form of carsharing is experiencing the steepest growth in recent years (Figure 4), and has been facilitated by insurance companies and user associations.

**Motivations.** Carsharing offers a number of potential environmental benefits as an alternative to private car ownership, including 1) reduced car stock, 2) reduced car usage through the emergence of more cost-conscious users, 3) the promotion of a multi-modal mobility culture, and 4) lower-emission vehicle fleets. Moreover, carsharing allows drivers to overcome the growing perceived inconvenience of conventional automobility: high investment costs, maintenance and repair, parking fees and scarcity, etc. While it is these latter practicalities that tend to motivate carsharing users, the societal and symbolic motivations are important reinforcing justifications.

**Markets.** Netherlands is, with Switzerland, Germany and Belgium, among the leading carsharing countries in Europe. According to CROW-KpVV, carsharing is on the rise in the Netherlands, with 11,210 available cars in March 2014 (a 113% yearly rise), and around 110,000 carsharers. The development of new forms of carsharing, i.e. P2P and one-way, have greatly accelerated market growth since 2011. Carsharing is supported by new business and pricing models (e.g. Car2Go charges per minute/hour).

![Figure 4: The diffusion of carsharing in the Netherlands, vehicle availability by service type, Source: CROW-KpVV](https://www.youtube.com/watch?v=EItrvudZy4w)

---

26 See [https://www.youtube.com/watch?v=EItrvudZy4w](https://www.youtube.com/watch?v=EItrvudZy4w)
Technical innovation. In terms of technological components and infrastructure, “the car that is shared today […] is not much different from hegemonic automobility” (Kent and Dowling 2013:88), with the exception of the ICT that has allowed sharing to become so seamless. Recent advances in ICT have supported the development of carsharing to an increasingly credible alternative to private car ownership. Crucially, the development of ICT has enabled major leaps in user convenience through e.g. 24/7 access with electronic card (un-)locking, online or mobile interface, real-time geo-localisation of available vehicles, one-stop registration/verification/booking/billing, etc. These innovations together make carsharing a much stronger proposition in terms of user flexibility, convenience and trust. From the fleet operator perspective, ICT developments have also enabled leaner and more effective logistics, namely based on real-time geographical information data, on-board user control and tracking (fuel, mileage, position, etc.), and the automation of routinised tasks such as fleet management and maintenance.

Vehicle fleet. Carsharing is more developed in urban locations, with both greater density of potential users, and greater convenience of parking spaces. Amsterdam has the largest carsharing fleet (2,391), but has just been taken over by Utrecht in terms of fleet density (with 300 cars/100,000 inhabitants). The more rural municipalities currently have considerably smaller carsharing vehicle fleets. However, carsharing is diffusing beyond urban municipalities, particularly with the development of peer-2-peer sharing.

Figure 5: Carsharing fleet size (number of vehicles) in Dutch municipalities, 2014, Source: CROW-KpVV

Another benefit from (fleet-based) car sharing is the emergence of new criteria for vehicle purchase, such as fuel economy and durability, or even corporate image. Carsharing operators tend to offer smaller and low emission vehicles, and even to support the deployment of alternative vehicles (Bohnsack et al 2014). Car2Go, for instance, has become a major EV fleet, which makes economic sense in an urban short-trip pay-per-use mobility model. Car2Go is influencing EV deployment:

“...two years’ time, Car2Go has acquired 11,500 participants, who are driving 300 vehicles. As a result, roughly 15,000 people have been introduced to electric driving, 230,000 regular kilometres have been replaced with electric ones, and more than 300 people have decided to purchase an electric vehicle.” (RVO 2014:6)

Consumers, legitimacy and credibility. CROW-KpVV notes positive user reaction and general public support for carsharing in the Netherlands. Carsharers tend to be greater users of public transport and other ‘soft’ mobility options. Carsharing is not often used for commuting, but rather for occasional trips on relatively long journeys, or in combination with other modes in an urban setting. Anxieties and negative expectations about vehicle availability and service convenience are important hurdles to reach potential users. The development of satisfactory customer service are proving key to a more positive image. The more innovative forms of carsharing are becoming highly popular and associated with positive symbolic meanings.

3.5.2 Actors and networks

Fleet operators. Fleet operators are the central actor developing innovative carsharing business models. The industry was led by new entrants in the mobility sector, more recently followed by established actors. The role of the automotive industry has recently become important. Conventional car hire companies are also adapting to this new market, e.g., Hertz 24/7. The increasing number of fleet operators is either competing in dense urban settings, or pioneering in new territories with highly localised fleets, e.g., Flexcar with only 4 cars in Zutphen.

Automobile industry. Recognising the emergence of a niche market for alternative mobility consumption, automakers like Daimler-Chrysler, BMW and Volkswagen have supported or invested in schemes. However, only Daimler-Chrysler (with Car2Go in Amsterdam) and Volkswagen (with Greenwheels) are currently present on the Dutch market. BMW announced its intention to deploy DriveNow in the Netherlands in 2012, but never went beyond the planning phase. It is however present in a number of German cities, San Francisco and Vienna. Volkswagen, after dropping plans to introduce the Hannover-based Quicar in the Netherlands, acquired a 60% share of Greenwheels in 2013.

Local and regional authorities. Local authorities have been involved in the development of carsharing, through reserved parking spaces, operating licenses, information sharing on road safety and traffic disruption, and the local promotion of carsharing schemes. They may act as catalysts or inhibitors for the deployment of specific initiatives. The City of Amsterdam, for instance, has been seen as proactive municipal actor that has achieved to created positive conditions for the deployment of a number of carsharing schemes. The City of Utrecht has recently developed a carsharing promotion campaign together with fleet operators and a communications agency. While many schemes in Germany build on carsharing’s high compatibility with multi-modal transport (Loose 2010), only MobilityMixx seeks to tap into...
this potential source of competitive advantage in the Netherlands, offering carsharing as one of their multi-modal portfolio of options, including public transport, taxi, and cycle sharing.

3.5.3 Governance and policy

Socio-cultural meaning. Carsharing may be associated with new forms of freedom and autonomy, in a context of decreasing perceived automobile convenience, and (material) commitments more generally. Carsharing’s collaborative nature and its compatibility with a sharing economy contribute to its popularity, particularly with the younger urban population. Carsharing taps into an emerging trend towards less car dependence and lesser interest in car ownership amongst younger generations, whose stance tends to favour pragmatic utilitarianism over emotional attachment:

“Car sharing is based on a belief that Generation Y is more interested in mobility as such than in car ownership, which opens up partial ownership as viable value proposition.” (Bohsack et al 2014:294)

Policy interventions and objectives. In terms of formal institutions, carsharing exhibits a great deal of continuity with the automobility regime, and hence requires little change of policies and regulations. Notable exceptions include the availability of dedicated parking spaces, and special exemptions or negotiated parking fees. In the Netherlands, local authorities have the right to determine the usage of public space (Loose 2010). They hence play an important role in enabling carsharing practices, by granting dedicated parking space or parking permits.

In terms of further encouraging the uptake of carsharing, national and local authorities can play a role to increase awareness (e.g. marketing and advertising strategies), and making carsharing business models more profitable (e.g. via targeted subsidies or incentives). Most incentives, however, are indirect and targeted at specific technologies, such as the EV niche nurturing. Carsharing is increasingly seen by official bodies as an integral part of future mobility trends, with a role to play in transition objectives. SER (the Social Economic Council of the Netherlands), for instance, in its Energy Agreement, signed by the Federation of Dutch municipalities, specifies a target of 100,000 carsharing cars by 2020.

There is scope for greater involvement of transport planning authorities and public transport operators to actively tap into the role of carsharing in an integrated multimodal transportation system in terms of “filling in the gaps left by the limited carrying capacity, timetables and inflexibility associated with other alternative modes” (Kent and Dowling 2013:87). Switzerland and Germany provide interesting examples in this respect.

3.5.4 Momentum

Although car sharing only accounts for a small fraction of overall mobility and remains concentrated in the most densely populated areas, there are positive signs of increasing momentum in recent years. More importantly, carsharing has increasingly become embedded in existing automobile networks (e.g. manufacturers, car hire services, municipalities), associated with positive symbolic meanings and aspirations (e.g. environmental, congestion), able to absorb and generate innovation (e.g. ICT, EVs, insurance, business model). Together, these elements suggest that carsharing is more than a passing fad (Kent and Dowling 2013), and that it may be envisioned as an integral part of future mobility systems with a different role to play in a variety of pathways (Marletto 2014). Carsharing can be seen as an important link in visions of multi-modal mobility chains and the development of a market for alternative vehicles, providing at once a source of continuity with the past and a bridge to the future.
3.6 Niche 6: Compact cities

3.6.1 Innovation and trajectory

‘Compact city’ most commonly refers to high-density, mixed-use urban form. It is associated with the promotion of non-motorised mobility, efficient public transport, and generally presented as an alternative to car-centric urban sprawl (Burton 2000). The notion has been influencing urban planning since the 1960s, spurred by rapid suburban expansions during the 1950s to 1970s (Alpkokin 2012), gaining momentum as planning concept during the late 1970s and early 1980s (Scheurer 2007). In particular during the 1990s, in line with the discourse on sustainable planning, it became a promising response to environmental, economic and social challenges in and around cities (Hofstad 2012).

Zijlstra and Avelino (2012) define sustainable urban planning as a radical socio-spatial mobility niche. The compact city follows the rationale that a city’s sustainability—especially its transport patterns and impacts—is determined by how much land it requires to house its people and economic activities (Kenworthy 2006). However, many have questioned its success as sustainable mobility proposition because the relationship between urban density and transport is ambiguous (Zijlstra and Avelino 2012). Nonetheless, compact development has been highly influential—particularly in Dutch spatial planning—and is often echoed in other sustainable city strategies (e.g. eco-cities).

In the Netherlands, compact development was the prevailing spatial planning strategy over several decades. Through four planning terms, the national government imposed a strict approach against dispersed urban form. The rationales changed over time (e.g. preserving agricultural land; decreasing inner-city decline), with a strong environmental agenda arising after 1980. This brought to the fore the assumed merits of compact growth with respect to promoting walking, biking, and using public transport while limiting car usage and hence tackling energy use and CO₂ emissions (Dieleman et al. 1999). In 2000, a major overhaul of the planning system, which aimed at decentralisation and a market approach for spatial planning, but also reacted to the doubted impacts of dense development on mobility patterns, led to a shifting focus away from the compact city to a wider city network model (Hanssen and Hofstad 2013; MIE 2011).

Geographically, efforts for compact development were predominantly directed to the Randstad—a distinctive pattern of urban centres in the western Netherlands including Amsterdam, Rotterdam, The Hague and Utrecht as well as a substantial number of smaller cities, and encircles the rural Green Heart.

Technical characteristics. The compact city is a vision for urban form that uses spatial proximity as organising principle (Hajer and Zonneveld 2000). Its implementation highly depends on socio-economic and geographical contexts. Some universal characteristics can nonetheless be identified (Scheurer, 2007; OECD, 2012). The city structure is ideally hierarchal with a concentration of development in nodes. Each node should offer a balance of housing, employment, and subsidiary functions (multi-functionality), and guarantee user-friendly public transport and access to retail and services within walking distance. Development should be oriented around existing transport routes and their extension to under-served nodes. Nodes around rail stations shall be seen as catalysts for development and provide intermodal links. To encourage non-motorised mobility, traffic shall be calmed by speed and volume, and parking provision reduced.

Spatial developments. Nabielek (2012) summarises that during the 1990s and early 2000s, the total urban area in the Netherlands increased much less than in preceding decades. Newly built-up areas developed mostly adjacent to existing urban areas, density increased around
infrastructure nodes, including inter-city stations, and around motorway exits. These successful elements of compactness were paralleled by greenfield locations gaining prominence. Between 2002 and 2008, about 75% of new jobs and more than 60% of new dwellings were created outside existing urban areas. This trend towards more dispersal seems to be continuing (Keleher 2012).

Regarding mobility and compact planning, developments are difficult to assess (Dieleman et al. 1999). Schwanen and colleagues (2004) analyse a number of different compact planning strategies and their effects on mobility: Especially in large and medium-sized cities, efforts of inner-city development were effective in supporting high shares of cycling and walking, and reducing car use. The strategy of developing dense neighbourhoods in pre-determined growth nodes is, however, associated with higher car dependency and also with no reduction in commuting times. Leidsche Rijn on the fringe of Utrecht (Figure 6) is a famous example of such a growth node, also referred to as VINEX locations. Compact city strategies do not seem to have prevented massive use of private cars outside city centres (Van der Burg and Dieleman 2004).

![Figure 6: Leidsche Rijn at the outskirt of Utrecht— one of the best known examples of so-called VINEX neighbourhoods, developed directly adjacent to existing cities as part of the compact city policy. Source: MIE 2013](image)

### 3.6.2 Actors and networks

In the Netherlands, compact city development was primarily a national Government endeavour, resting on planning restrictions to be enforced by provinces. The Ministry of

---

29 VINEX locations emerged from the 1991 national spatial planning policy that focused on new, large-scale residential developments in close proximity to cities. Because public transport facilities were often not realised quickly enough, the VINEX policy has generally been viewed as a failure with respect to mobility (MIE 2013).
Housing, Spatial Planning and the Environment played a leading role both as developer and preservationist (Hanssen and Hofstad 2013). There was a successful alignment with interests especially from the housing and agriculture domains (Hajer and Zonneveld 2000). “From farmers to business people” (Keleher 2012), and environmentalists to planners, the compact city received broad support and was espoused also by the public (Dieleman et al. 1999).

Implementation-wise, besides the national government, four provinces, some 165 municipalities, private organisations and lobbies were involved in the Randstad (Dieleman et al. 1999). The structure was hierarchical (Figure 7).

![Hierarchical structure of actors for compact development implementation, Source: adapted from Roggema 2009](image)

Compliance was ensured by regulation under the national spatial planning law along with subsidies and covenants between different public actors, leading to the development of new towns and local growth centres in the 1970s, and extending to brownfield and greenfield sites from the mid-1990s (Sandkj and Hofstad 2013). Since then, agreements have been made with private developers, who committed themselves to housing developments in exchange for subsidies for land and infrastructure (e.g. sanitation, public transport), under local area planning restrictions (Sandkj and Hofstad 2013).

The compact city policy was supplemented by a successful urban renewal programme with large government subsidies to upgrade inner-city housing stock. Also strict regulations for retail facility locations were in place, banning for instance the development of large out-of-town shopping malls (Schwanen et al. 2004). In terms of directing development to where it was foreseen, compact city strategies were successful (Dieleman et al. 1999).

**Motivations.** Generally speaking, the prevailing arguments in favour of compact development are: It can reduce energy, make public infrastructure investments more viable, reduce land usage, and preserve agricultural and natural areas. It has been positively associated with social diversity and cultural and economic development (Burton 2000). Clearly, proponents also maintained the positive correlation between compact urban form and a decrease in transportation needs, particularly car dependence. Viewed from a city level and a fixed point in time, compactness seems indeed to produce less automobile travel. However, long-term spatial development patterns are increasingly moving towards regional interdependencies, which makes the issue more complex (Scheurer 2007).

**Research and learning.** The effects of compact city development have received much attention but are still not fully understood and study results remain often inconclusive (Geurs and van Wee 2006). Compact city implementations were trial-and-error processes and policy enactments seem to often have preceded research insights.

Regarding mobility, research has shown that socio-economic and cultural aspects have been underestimated. Income and car ownership are often more influential on travel behaviour than urban form is (Dieleman et al. 1999). Further, the compact city contradicts today’s
“network society” (Castells 1996 in Hajer and Zonneveld 2000). This society is characterised by spatially expanding activities. Its growth seems to undercut proximity and land-use control as means to steer socio-spatial development (Hajer and Zonneveld 2000). Travel—it is argued—will increasingly be perceived in time rather than distance. The move from the compact city towards the network city approach, which not only accepts but reinforces existing regional travel patterns, can partly be seen as a reaction to this trend (Van der Burg and Dieleman 2004).

3.6.3 Governance and policy
Since the period of post-war construction, when the state and provincial levels exerted their influence through subsidies, regulations, traffic planning, and agricultural modernisation (Keleher 2012), spatial planning was largely institutionalised and centralised in the Netherlands. Planning policy and political discourses often merged. In recent years, neoliberal logics, which embrace an underlying belief in individual freedom and choice, have been reflected in market-oriented spatial planning approaches but also in support of individual motorised transport (Ziljstra and Avelino 2012).

A whole range of policy measures to control urban sprawl were designed and put into action in the past. Regarding mobility, the *Fourth Report on Physical Planning* (1991) was perhaps the most significant policy document. Its policy dictated that the distance between place of residence, work, and services must decline by making locational choices subservient to considerations of mobility. Additionally, the use of public transport, cycling and walking should increase at the expense of car use. The *ABC location* policy was key here. *A* locations were central sites, often close to main railway stations and readily accessible by public transport. *B* locations—typically situated in nodes outside the larger centres—were reasonably well connected to public transport and accessible by car. *C* locations had good motorway access (Schwanen et al. 2004). The intention was to direct employment and public services towards *A* and *B* locations. Partly because of the attractiveness of *C*-locations and the fact that *B*-locations were often underserved, this policy failed in terms of mobility and led perhaps to even more car-dependent commuting patterns (Alpkokin 2012; Schwanen et al. 2004). The fourth planning term ended in the early 2000s and national transport policy abandoned the aim of a modal shift away from the car (Van der Burg and Dieleman 2004).

3.6.4 Momentum
Transitions to sustainable mobility in cities require the interplay of change across transportation as well as land-use regimes (Næss and Vogel 2012). Given its explicit spatial rather than technological focus, the compact city differs from many other niche-innovations. Its singular focus on density has proven insufficient to deliver on promises, but spatial (urban) planning can nonetheless make an essential contribution to a transition towards sustainable mobility in providing conditions under which future mobility patterns and behaviour *can* change (Zijstra and Avelino 2012).

While the compact city did not deliver on all its promises in terms of mobility, and led to unexpected and often counterproductive results (Zijstra and Avelino 2012), it has been credited for halting the inertia of regime urban development trends associated especially with environmental impacts:

“[Without] compact urban development policies, urban sprawl in the Netherlands is likely to have been greater, car use would have been higher at the cost of alternative modes, emissions and noise levels in residential and natural environments, and the fragmentation of the wildlife habitats would have been higher” (Geurs and van Wee 2006).
In terms of its development, the compact city can be considered a niche of the past (1960s-1990s) that has achieved a substantial degree of momentum in the Netherlands, influencing local planning regulations and practices through the national government’s continuous reinforcement, along with extensive support and the involvement of major regime actors (e.g. local authorities, developers). Following disappointment as to the original objectives, support has dwindled and compact development ambitions have been revised. This has created space for the institutionalisation of the network city model, which is compatible with recent developments towards more market-led spatial planning.


4 Conclusion

4.1 Momentum analysis

In this section, we provide an assessment of momentum for each niche-innovation, based on the consideration of innovation and market trajectory, supporting actors and networks, and policy and governance. The results are presented in Table 10, which also tries to assess momentum by using a rating.

Table 10: Momentum analysis of 6 niche-innovations in the mobility domain in the Netherlands

<table>
<thead>
<tr>
<th>Niche</th>
<th>Momentum</th>
<th>Main drivers of momentum</th>
<th>Pathway</th>
</tr>
</thead>
</table>
| 1. Hybrid electric vehicles (HEVs) | High (beyond niche) | - high momentum: mass commercialisation, important market share, stable design features. No longer niche?  
- Stepping stone within a broader governmental vision of ‘electric mobility’  
- Gradual introduction of electric features within conventional cars paving the way for EVs  
- Next evolutionary step: plug-in hybrids  
- BUT unlikely that it will survive a mobility transition in the long-run because of technical compromise  
Techno-economic momentum: high (installed)  
Socio-cognitive momentum: high (accepted)  
Governance and policy momentum: stable | A         |
| 2. Carsharing                  | High     | - positive signs of increasing momentum in recent years  
- urban markets developing fast. New services, new locations, etc.  
- Increasingly embeddedness in existing automobility networks (e.g. manufacturers, car hire services, municipalities)  
- Positive cultural and symbolic meanings (e.g. environmental, congestion)  
- Linked to high innovation rate (e.g. ICT, EVs, insurance, business model)  
- Policy visions as integral part of future mobility systems with a different role to play in a variety of pathways  
Techno-economic momentum: high  
Socio-cognitive momentum: high (actors and acceptance)  
Governance and policy momentum: high (support) | B with elements of A |
| 3. Battery electric vehicles (BEVs) | Moderate | - multiple hype/disappointment cycles  
- Currently renewed momentum with indications that a significant threshold has been passed  
- market deployment of commercially viable vehicles  
- strong policy support for progress towards charging infrastructure rollout and national deployment targets  
- enthusiastic involvement of fleet operators  
- successful deployment of hybrids vehicles as a ‘stepping stone’  
- increasing public exposure.  
- BUT achieving high density and interoperability of charging opportunities crucial for the stabilisation of development trajectory  
Techno-economic momentum: moderate (innovation but no dominant design)  
Socio-cognitive momentum: high (expectations and visions)  
Governance and policy momentum: moderate (support for rollout) | A with elements of B |
### 4. Biofuels

| Moderate | - Path creation initiated in the 1990s with hype/disappointments |
| - Developments driven by EU policy since the early 2000s: market creation for biofuels blending |
| - Flexifuel niche is small and stagnant (in Europe) |
| - Technological diversity: 1G and 2G biofuels, in reaction to sustainability controversy |
| o Progress on 1G commercialisation |
| o Remaining doubts about commercial viability of 2G |
| - Recent deployment of pilot & commercial plants indicates stabilisation |
| - BUT concerns about traceability & scope for sustainably scaling up |
| Techno-economic momentum: high (innovative sector) |
| Socio-cognitive momentum: low (controversies) |
| Governance and policy momentum: moderate (obligations) |

#### 5. Compact cities

| Moderate (past) | - Past innovation. Substantial momentum and instalment (1960s-1990s), then abandoned in NL, in favour of network model |
| - Transportation and land-use regimes interaction |
| - Spatial planning innovation rather than technological focus |
| - Strongest driver was political will (national govt support) for change and policy implementation process (local planning regulations and practices) |
| - Agreements with developers (powerful private regime actor) |
| - Unexpected and often counterproductive results on sustainable mobility: no lasting improvement, but halting more negative development |
| Techno-economic momentum: low |
| Socio-cognitive momentum: moderate (consensus – at the time) |
| Governance and policy momentum: high (strong political will – at the time) |

#### 6. Hydrogen fuel cell vehicles

| Very low | - Technologically at an experimentation (demonstration) stage |
| - Precursor market experiments just emerging |
| - High costs |
| - Considered as option for the medium and long term (2030 and beyond) |
| - BUT doubts because of repeated hype cycles to date |
| Techno-economic momentum: low (early days) |
| Socio-cognitive momentum: low (not much exposure) |
| Governance and policy momentum: low |

### 4.2 Conclusion about transition pathways

In this section, we provide an assessment of the niches-innovations in terms of their fit to the ideal-types Pathways A and B, ‘technical component substitution’ and ‘broader regime transformation’, respectively. For most cases, we find a dominant leaning towards one of the ideal Pathways, but also some elements of the other.

Battery electric vehicles have many elements of a Pathway A development insofar as they offer substantial improvement of propulsion technology within the frame of existing automobility (component substitution), and that most existing car manufacturers are now involved. However, they also have elements of a Pathway B development because they have been spearheaded by and generate space for new entrants, they require massive investments in charging infrastructure for which public authorities are most likely to be involved, they currently challenge drivers by requiring them to overcome or address their range anxieties, and are developing hand in hand with new forms of (service-oriented) mobility.

Hybrid electric vehicles have many elements of a Pathway A development insofar as they are an add-on technology that complements existing ICE engines with an electric drivetrain, and
are developed by large incumbent car manufacturers without challenging prevailing notions about automobility or its underlying infrastructure. They however provide an interesting ‘stepping stone’ opportunity towards BEVs.

Hydrogen fuel cell vehicles have many elements of a Pathway A development insofar as they offer substantial improvement of propulsion technology within the frame of existing automobility (component substitution), and that many existing car manufacturers are currently developing prototypes. However, they also have elements of a Pathway B development because they require massive investments in charging infrastructure for which public authorities are most likely to be involved, they would challenge drivers by requiring them to overcome or address their range anxieties, and are linked to visions of a hydrogen economy which entails fundamental changes within the industrial (hydrogen production) fabric. Their time horizon appears further away than other niches considered here.

Biofuels have many elements of a Pathway A development insofar as their current NL application in blending with conventional fuels is not challenging the automobility regime (underlying processes, roles, and institutions), but only creating space for new actors and processes at the margin of the petrol fuel and distribution regime. However, they also present elements of a Pathway B development, in relation to land use, agri-food, and resource extraction regimes as they propose fundamental new ways of harvesting energy from land (and the oceans), with a potential new role for actors crossing traditional domain boundaries.

Carsharing has many elements of a Pathway B development insofar as it is centred on new ways of considering (auto)mobility, operating a shift from material ownership to on-demand service, involves new entrants (fleet managers), encourages and builds on innovation across domains (e.g. ICT-intensive, compatibilities with BEVs, etc.), and is in greater alignment with visions of multi-modal transport. However, it also presents elements of a Pathway A development, insofar as it is based on automobility.

The compact city has many elements of a Pathway A development insofar as it is mainly based on the central agency and influence of (national and local) policy actors in reshaping urban development patterns in more desirable directions with objectives spanning multiple domains (housing, mobility, land use, etc.), but with limited involvement of dynamics on other dimensions (technological, cultural, etc.). Spatial planning at the city level nonetheless offers interesting opportunities for the alignment of socio-technical change that may provide acceleration and directionality to Pathway B type changes.
References


EY, 2013. Expanding the electric vehicle experience, Global Ignition Sessions summary report. Ernst & Young.


Loose, W., 2010. The state of European car-sharing, Final Report D2.4, momo Car-Sharing project, Bundesverband CarSharing e.V.


RVO 2013. We are Holland. Ready to market e-mobility, NL Agency, Utrecht.


