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The emergence of an electric mobility trajectory

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ABSTRACT

In this paper, we analyse the emergence of a trajectory of electric moblity. We describe developments in electric vehicles before and after 2005. The central thesis of the paper is that electric mobility has crossed a critical threshold and is benefitting from various developments whose influence can be expected to grow in importance: high oil prices, carbon constraints, and rise of organised car sharing and intermodality. We find that the development of vehicle engine technology depends on changes in (fueling) infrastructure, changes in mobility, changes in the global car market, evolution of energy prices, climate policy, and changes in the electricity sector. Special attention is given to interaction of technological alternatives: how these work out for the future of battery electric vehicles, hybrid electric vehicles and hydrogen fuel cell vehicles.

1. Introduction

In the last five years there has emerged new momentum for (battery) electric vehicles (BEVs), after a period of dissapointment in BEV around the turn of the 21st century. In this paper, we describe developments in electric mobility before and after 2005 and we analyse the emergence of a trajectory of electric moblity. The central thesis of the paper is that electric mobility has crossed a critical threshold and is benefitting from various developments: some technological, both within and outside the automotive sector, and some developments in the social context of car mobility. Special attention is given to interaction effects between the two and how these work out for the future of battery electric vehicles, hybrid electric vehicles and hydrogen fuel cell vehicles.

We adopt a socio-technical transition perspective as an instrument for our analysis, which does not prioritize social and technical elements, but sees these as inexorably linked (Rip and Kemp, 1998; Hoogma et al., 2002; Geels, 2002, 2005; Geels and Schot, 2007). The socio-technical approach is both structuralistic and actor-based, highlighting the close alignment of social and technical elements, including product technology, industry, markets, consumer behavior, policy, infrastructure, spatial arrangements and cultural meaning' (Geels, 2005). Such a view is instrumental for understanding change that is not driven by single factors such as price or technological change, but typically involves co-evolution between multiple developments. The perspective is also actor-based, for it addresses actor perceptions, strategies, actions and interactions between car drivers, car manufacturing firms, policy makers and public opinion. Therefore, it differs from functionalistic approaches that tend to focus on system functions being fulfilled (e.g., in industry sector assessments and comparisons of various technologies) or pure economic approaches (where cost, performance, prices, incentives are the main variables).

The socio-technical transition perspective is instrumental to explain dynamic *stability* and incremental change on the one hand, and radical innovations and system *change* on the other. To explain *change*, it uses concepts such as 'niches', which are protected spaces where potentially radical innovations emerge, and 'socio-technical landscape', which are external developments that can create pressure on existing systems (or better 'regimes'). To explain *stability*, the notion of sociotechnical regime plays an important role, which helps to describe how car mobility is locked into internal combustion engines because the societal context is adapted to their use in terms of expected speed and power, training and knowledge and maintenance networks, regulations (e.g., safety, maximum speed), cultural acceptance, etc. The transition perspective deviates from simple drivers and linear cause-and-effect relationships because it puts emphasis on mutually reinforcing developments and (sometimes unexpected) alignments, co-evolution, circular causality, knock-on effects, and hype-disappointment cycles.

There are various ways in which a possible transition towards electric car mobility could occur, and Geels and Schot (2007) have

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suggested four generic types of 'transition pathways'. In this paper, the term pathway is, however, necessarily broader that the pathways of Geels and Schot, since the automotive sector may not go through transition at all. Therefore we use the term pathway synonymous to scenario, for instance regarding pathways of automobility, referring to possible future developmental path of the car mobility sector (which may involve various technologies). We distinguish the related term trajectory from pathway, and we use trajectory in relation to a specific technology, for instance a trajectory of electric mobility, similar to how various studies on technological trajectories apply the term. In this terminology the future pathway of a sector may thus consist of a range of technological trajectories.

The paper is structured as follows: Section 2 explains the stability of the sector and the lack of momentum of the electric mobility (EM) niche before 2005 by addressing the alignment of social and technical elements, including regulations, pilot projects on the new technology, demand structures and responses in the industry. Section 3 analyses EM developments after 2005, what we termed 'present continuous' to describe how the allignment of social and technical elements is becoming more malleable through certain trends but also through the deliberate practice of a few specific actors. Section 4 examines prospects for the electrification of automobility and, finally, Section 5 summarizes the factors behind EM activity in recent years.

2. The recent past: EM niche developments in the 1990s

After the early appearance and decline in the late 19th and early 20th century, interest in battery electric vehicles (BEVs) re-emerged in the 1960s and 1970s in the USA, mainly due to the negative effects of air pollution and rising oil prices. The 1965 Clean Air Act triggered several research institutes and firms to develop electric cars, but results were poor in terms of both technological performance and price compared to their gasoline counterparts (Mom, 1997). At the end of the 1970s, less than 4000 BEVs had been sold worldwide. After a period of little activity, public interest on BEVs revived once again in the second half of the 1980s and the early 1990s, bringing renewed hopes to environmentalists that BEVs would finally become a mass market reality. This was mainly due to the new regulatory push done by American State of California and, to a lesser extent, to the environmental policies and programs promoted in Europe.

2.1. Regulatory push and bottom-up developments of BEV enthusiasts

Following a tradition of being in the vanguard of emission legislation, in the early 1990s the American State of California led a technology forcing approach for the introduction of zero emissions vehicles (ZEV). The California Air Resources Board (CARB) had the ambition to set strict emission standards to curb health problems in the Los Angeles area provoked by motor vehicles' toxic emissions. Coincidentally, in January of 1990, General Motors presented an BEV concept car (later marketed as the *EV1*) in the Los Angeles Auto Show, which greatly impressed the public and sent signals to CARB that BEVs were ready for mass commercialisation. Though GM did not intend the car to be mass-produced, it encouraged CARB to include BEVs in the Mandate[3], which was adopted in September of that year (see Hoogma et al. 2002). With the standards, CARB intended to trigger further development and sales of electric vehicles. Since California represented about 4% of the world market for cars and about 12% the US car market at that time, the ZEV Mandate was quite important for automakers (Kemp, 2005). By 1994, four additional states (New York, Massachusetts, Vermont and Maine) had adopted the California ZEV mandate and eight more joined the National Low Emissions Vehicle (NLEV) Program, approving stricter requirements than the federal ones from the Environmental Protection Agency (EPA).

The organisation of the European Union with its system of environmental Directives made it difficult to adopt a regulatory framework similar to the American ZEV mandate. Although national or local authorities could impose a ZEV regulation, there was an apparent consensus among policymakers that the use of incentives, rather than disincentives, was a more desirable and potentially more effective way of promoting cleaner vehicles (Nieuwenhuis and Wells 1997). In Europe, interest in BEV technology had its main origins in engineering schools — Germany, Denmark and Switzerland, in particular. Ecological-conscious students and technicians in small enterprises were able to move from developing solar vehicles to the artisanal manufacturing of lightweight BEVs. After being showcased to the public, coinciding with the developments in California, these vehicles motivated politicians to promote their mass production and commercialization (Hoogma 2000). This led to the support of R&D programmes in several Western European countries, involving the sponsorship of demonstration projects, subsidies, and tax reductions for such vehicles.

2.2. Pilot and demonstration projects

In the early 1990s, a few small companies outside the (high volume) car industry were dominating BEV-developments. These niche players adopted a different design for the car body, which depended less on economies of scale and allowed them to be profitable by selling only a few hundred vehicles — even though their cars were relatively more expensive than conventional ones. Forced by the Californian ZEV Mandate, high volume car manufacturers showed increasing commitments to the BEV technology and, after presenting prototypes in auto shows, some started to sell a small number of BEVs. Different from the dedicated BEV producers, automakers opted for a low-risk, low-cost strategy of converting existing models into BEVs (the Renault Clio and Peugeot 106 are good examples).

Hoogma et al (2002) studied the European demonstration experiments with electric vehicles in Germany (Rugen Island, 1992–1996), Switzerland (in the town of Mendriso, after 1995), and Norway (via the development of an BEV called *Th!nk*, after 1991), among others. Possibly the most remarkable project was the one led by EDF, the French electric utility, which ordered 2000 BEVs for the experiment in the city of La Rochelle in the West coast of France. The experiment initially seemed a small miracle, since users loved BEVs. Public attention was high and much was learned about user acceptance and the conditions needed to support BEVs. As it turned out, however, only a few consumers were willing to buy the new car outside the experiment. People's willingness to pay for an BEV was not really tested by the experiment.

More positive results were achieved in the large-scale pilot and demonstration project for lightweight electric vehicles (LEVs)

[3] The ZEV Mandate in 1990 required that 2% of all new cars sold in California should be "zero emission" by 1998. In the year 2000 all new cars sold had to be either "low emission", "ultra low emission" or "zero emission". Moreover, by 2003 75 % had to be low emission vehicles (LEV), 15% ultra low emission vehicles (ULEV) and 10 % zero emission vehicles (ZEV). For a more detailed analysis on how this regulation came about, see Kemp (2005).