

MATISSE

WORKING  
PAPERS

7  
2/2007

IDENTIFYING OPPORTUNITIES AND  
PATHWAYS FOR TRANSITION TO  
SUSTAINABLE TRANSPORT  
IN SWEDEN UND THE UK

Björn Nykvist  
Lorraine Whitmarsh



## Series Editors:

Jill Jäger

*SERI Sustainable Europe Research Institute, Garnisongasse 7/27, 1090 Wien, Austria, jill.jaeger@seri.at*

Paul M. Weaver

*Wolfson Research Institute, University of Durham, UK, pweaver@noos.fr*

## Authors:

Björn Nykvist

*Stockholm Environment Institute  
Stockholm, Sweden, bjorn.nykvist@sei.se*

Lorraine Whitmarsh

*Tyndall Centre for Climate Change Research, School of Environmental Sciences,  
University of East Anglia, Norwich, UK. l.whitmarsh@uea.ac.uk*

**MATISSE** (Methods and Tools for Integrated Sustainability Assessment) aims to achieve a step-wise advance in the science and application of Integrated Sustainability Assessment (ISA) of EU policies. In order to reach this objective the core activity of the MATISSE project is to improve the tools available for conducting Integrated Sustainability Assessments.

Project duration: April 1st, 2005 - March 31st, 2008

MATISSE is supported by the 6<sup>th</sup> Framework Programme of the European Union.  
Contract number: 004059 (GOCE) - MATISSE

**MATISSE Working Papers** are the outcome of ongoing research activities in the integrated research project MATISSE, funded by EU 6FP. They present preliminary results, which are open for debate and improvement for publication in scientific journals. All comments and suggestions are welcome.

The MATISSE Working Papers can be downloaded at <http://www.matisse-project.net/>.

## **Preface**

### **About the MATISSE project**

The MATISSE (Methods and Tools for Integrated Sustainability Assessment) project is funded by the European Commission, DG Research, within the 6<sup>th</sup> Framework Programme. The project is interested in the role that Integrated Sustainability Assessment (ISA) could play in the process of developing and implementing policies capable of addressing persistent problems of unsustainable development and supporting transitions to a more sustainable future in Europe. The core activity of MATISSE is to develop, test and demonstrate new and improved methods and tools for conducting ISA.

This work is carried out through developing and applying a conceptual framework for ISA, looking at the linkages to other sustainability assessment processes, linking existing tools to make them more useable for ISA, developing new tools to address transitions to sustainable development and applying the new and improved tools within an ISA process through a series of case studies.

The extent to which the case studies are carrying out a complete ISA for their area of focus varies between attempts to cover all phases of an ISA process to partial implementation of the process. Equally, different case studies are oriented to developing and testing tools and approaches to some, but not all, of the methodological challenges of ISA. The case studies are complementary, however, and the set of cases offers the opportunity to address a wide range of methodological challenges and to explore linkages between cases. An evaluation of practical experiences with ISA implementation in the case studies will provide guidance on the further improvement of methods and tools. Results will also contribute to more informed policy advice.

### **What is ISA?**

Within the MATISSE project, Integrated Sustainability Assessment (ISA) has been defined as a cyclical, participatory process of scoping, envisioning, experimenting, and learning through which a shared interpretation of sustainability for a specific context is developed and applied in an integrated manner, in order to explore solutions to persistent problems of unsustainable development. ISA is conceptualised as a complement to other forms of sustainability assessment, such as Sustainability Impact Assessment, Integrated Assessment and Regulatory Impact Assessment. Whereas these other forms of assessment fulfil the pragmatic need for *ex ante* screening of incremental sectoral policies that are developed within the prevailing policy regime, ISA is conceptualised as a support to longer-term and more strategic policy processes, where the objective is to explore persistent problems of unsustainable development that have a systemic pathology and possible solutions to these. ISA is therefore oriented toward supporting the development of cross-sectoral policies that specifically address sustainable development and at exploring enabling policy regimes and institutional arrangements.

### **MATISSE Working Papers**

Matisse Working Papers are interim reports of project activities that are published in order to illustrate ongoing work and some provisional conclusions, as well as providing the opportunity for discussion of the approaches taken by the project and interim results. This discussion should be both within the project and between project members and the broader scientific and policy communities. Readers are encouraged to contact the authors to discuss the content of MATISSE Working Papers.

Jill Jäger and Paul Weaver  
Editors of the MATISSE Working Paper Series

**Abstract**

A wide range of intractable problems such as emissions of greenhouse gases and local air pollutants, noise, accidents, depletion of resources, and inaccessibility of amenities and services are associated with the current transport regime. Given the limited impact of technical and policy solutions to date, more radical, systemic innovation - a transition - is required to move towards a more sustainable mobility system. Broadly speaking, this may be achieved via three main routes: improving efficiency and reducing the impact of vehicles (technological change); using more sustainable modes of travel (increased use of public transport and slow modes); and reducing the need to travel (through urban planning, lifestyle change and increased use of information and communication technologies). Drawing on concepts from the transitions literature (e.g., Rotmans et al., 2001; Geels, 2005), we conceptualise each of these three routes as a form of 'niche' activity, deviating to differing degrees from the current mobility 'regime' of oil-dependence, steel chassis and internal combustion engine technologies, and personal/private transport. Using this analytical framework, we firstly review the potential for each of these three niche areas to offer sustainable mobility solutions, and show that each offers different strengths and weaknesses. We then present empirical evidence of ongoing (policy, market, cultural) development in these three areas within the UK and Sweden; and explore processes of co-evolution, divergence and tension within and between these niche areas. Findings from this research indicate a recent market penetration of novel transport technologies, more advanced than modal shift or demand management activities; however, different transport technologies are more successful in each country. We also identify examples of a close relationship between development of radical vehicle/fuel technologies markets and provision of mobility services (e.g., car leasing); and information technology as a major driver in all three niche areas. We conclude that future innovation in transport depends on diversity and co-evolution of niches, as well as hybridisation to bridge the gap between current and novel technologies and concepts. Policy implications for fostering a transition to a more sustainable mobility system are discussed. Proposals include the need to develop sustainable mobility 'visions' with niche and regime stakeholders and coordinate activities to achieve these visions, as well as policies (e.g., congestion charging) which encourage development in several niches.

## Table of Content

Preface.....	3
Abstract .....	4
1 Introduction.....	6
2 Theoretical background.....	6
3 Methodology .....	8
4 Opportunities for sustainable transport .....	9
4.1 Defining innovations for sustainable transport .....	9
4.2 Sustainable transport at the regime level.....	11
4.3 Niche 1 - Radical technological change.....	12
4.4 Niche 2 - Shift from products to services.....	14
4.5 Niche 3 - Post-industrial lifestyles .....	16
5 Evidence for pre-development and take-off phases of sustainable transport transitions in UK and Sweden .....	18
5.1 Policy context.....	18
5.2 Technology and market development .....	23
5.3 Cultural/behavioural context .....	26
5.4 Summarising empirical evidence .....	33
6 Ongoing and future Niche accumulation within and between Niche 1, 2, and 3 .....	33
6.1 Niche accumulation within the alternative fuel sector and importance of Niche 2 development.....	33
6.2 Importance of Niche 1 and 2 co-evolving.....	34
6.3 Information Technology as a driver in all three niches.....	34
6.4 Electric drive train development .....	34
6.5 Lifestyle change niche affecting other niches .....	35
6.6 Future niche accumulation and radical innovations .....	35
7 Conclusions.....	37
7.1 Theoretical implications.....	37
7.2 Determinants of sustainable transport and implications for policy making .....	37
7.3 Achieving multiple sustainability goals .....	38
7.4 Further work.....	39
8 References.....	40

# Identifying opportunities and pathways for transitions to sustainable transport in Sweden and the UK

## 1 Introduction

Our current road-based land transport systems suffer from a number of intractable problems. These include congestion, emissions of greenhouse gases and local air pollutants, noise, accidents, depletion of resources, and inaccessibility of amenities and services (e.g., European Commission, 2001a; European Environment Agency, 2006). For example, transport is the sector with the highest increase of greenhouse gas emissions in recent decades, rising by 24% between 1990 and 2003 (European Environment Agency, 2005).

Given these problems, and their associated economic, social and environmental impacts, we can conclude that the current transport system is in many respects unsustainable. The concept of 'sustainability' is inherently subjective and contested; discussion and decision-making about sustainable futures therefore demands a more participatory and inclusive approach than traditional scientific models of knowledge production or policy assessment (Gibbons et al., 1994; Gibson *et al.*, 2005). On this basis, we have drawn on sustainable transport criteria expressed by policy-makers and other stakeholders (e.g., European Commission, 2001a; Whitmarsh and Wietschel, 2006) to identify opportunities and propose several *pathways* of developments towards a more sustainable transport future in Europe. We discuss how these pathways have been defined and examine to what extent they might be developing- and might continue to develop - in two contrasting European countries (Sweden and the UK). Finally, we highlight the importance of co-evolution among the discussed pathways.

Section 2 describes the theoretical concepts (e.g., transition, regime, niche, niche-accumulation) we use to frame our research into sustainable transport. Section 3 outlines the methodology we have used to collect evidence of emerging 'transitions' to sustainable transport in two European jurisdictions: Sweden and the UK. In Section 4, we propose and describe three main pathways - vehicle technology, product-to-service shift, and post-industrial lifestyles - through which sustainable transport might be achieved. Subsequently, in Section 5, we review evidence for emergence and development of these pathways within Europe, particularly focussing on Sweden and the UK. In Section 6 we discuss the possibilities for these pathways to co-evolve and finally, Section 7 discusses the implications of this evidence for future transport, and outlines plans for further research in this area.

## 2 Theoretical background

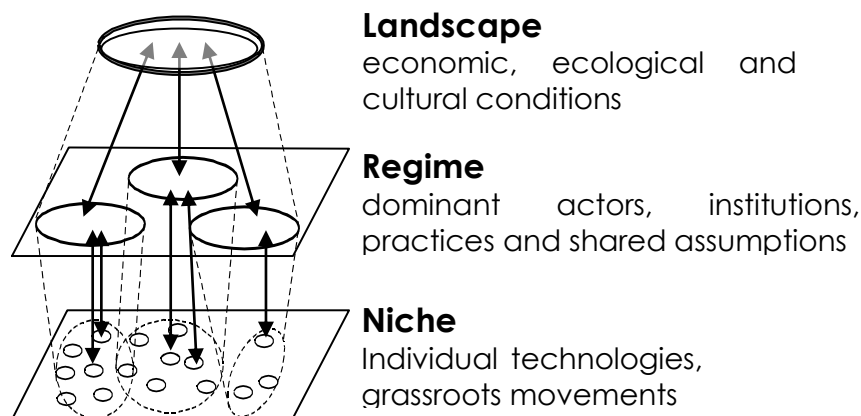
Exploring potential sustainable pathways for road-based transport is essentially, and simply put, a study of transportation utilisation and technologies used. Utilisation includes consideration of modes of transport, as well as actual demand. Technological options include novel vehicle technologies but also choices of primary energy sources and their conversion to energy carriers. Several promising technological options exist, but to date no alternative can be described as the unquestionable winner for the future, as has been concluded in a range of comparative technology appraisals (Ahman, 2001; Johansson and Ahman, 2002; MacLean and Lave, 2003; Hekkert, Hendriks, et al., 2005). It is unlikely that there is an optimal solution when all aspects of sustainable development are weighed together - unchallengeable criteria for such a best option are difficult to establish and future technological innovation is not possible to foresee. Furthermore, tackling *all* aspects of sustainable transport will require both major technological and behavioural changes - and behavioural/cultural change will be at least as challenging as technological change. To date, policy measures to influence individual travel decisions (e.g., congestion charging, vehicle taxation) have had little effect relative to the underlying growth in demand. In some cases, interventions to reduce demand or foster modal shift have had the reverse effect (e.g., Goodwin et al., 2004). Similarly, the benefit of technical measures to reduce

vehicle emissions and noise has often been outstripped by the increase in vehicle numbers, engine size, travel frequency and trip length (European Commission, 2001b).

It appears that incremental technological or policy improvement is unlikely to be sufficient to address this type of persistent problem. Instead, radical, systemic innovation - a 'transition' (e.g., Rotmans, Kemp, and van Asselt, 2001; Smith, Stirling, and Berkhout, 2005) - is necessary to move away from the current road-based transport regime and towards a more sustainable transport system. The literature on transitions highlights the interdependency of institutions and infrastructures constituting societal systems and sub-systems, which has created various types of lock-in that stifle innovation (Geels, 2005b). The dominant transport paradigm constitutes a regime locked in to a stable state of oil- and car- dependence (personal mobility, using internal combustion and steel chassis technologies) with infrastructure, manufacturing, and consumer behaviours enforcing the regime. In relation to infrastructure, the built environment has co-evolved alongside automobility, so that amenities and workplaces are often only accessible by car. Vehicle manufacturing has developed along 'technological trajectories' (Dosi, 1984), which constrains the development of vehicle and fuel technologies to the development of core competences, particularly in internal combustion engine and Budd-type steel chassis (Nieuwenhuis and Wells, 1997). Consumer decisions fulfil emotional-symbolic functions (e.g., status, comfort, safety) as well as practical requirements (space, cost, etc.) (Steg, Vlek, and Slotegraaf, 2001). Socio-cultural norms - for example, the expectation that quality of life entails vehicle ownership - and habitual behaviour serve to lock in these preferences and patterns of behaviour (Bandura, 1971; Verplanken et al., 1998; Urry, 1999), presenting a major challenge for tackling unsustainable actions. Due to these psychological, technological and institutional dependencies, there is typically widespread resistance to radical change (Elzen, 2005).

Transitions theorists have developed the multi-level perspective (MLP) as an analytical frame for the empirical study of transitions (Figure 1). This perspective highlights three functional levels - 'niche', 'regime' and 'landscape' - with increasing structuration and coordination of activities, ranging from individual technologies and grassroots movements to larger-scale social structures and institutions (Geels and Schot, 2005; cf. Giddens, 1984). The *regime* comprises dominant actors, institutions, practices and shared assumptions (Rotmans, 2005). While it provides stability and cohesion of societal systems, it also tends towards incremental change and optimising the current system, using the capabilities and resources of dominant players. System innovation, or radical change, is restricted since habits, existing competencies, past investment, regulation, prevailing norms, worldviews and so on, act to lock in patterns of behaviour and result in path dependencies for technological and social development (Geels and Schot, 2005).

Figure 1. The Multi-Level Perspective (from Geels, 2002)



At the micro-level, *niches* have been identified in historical empirical studies of transitions as the typical loci for radical innovation, operating at the periphery of, or outside, the dominant meso-level regime (although recent work suggests there are exceptions to this, in which regime capabilities are effectively transformed in response to landscape pressures: de Haan and Rotmans, 2006; Geels and Schot, 2005). The macro-level comprises a *landscape* of changing economic, ecological and cultural conditions, in which the regime may be more or less well-suited to fulfil its functions. In the case of the current transport regime, for example, we can say it is misaligned with environmental, social and economic landscape conditions, as evidenced by the problems outlined in Section 1.

The niche and regime may exist in either a symbiotic or competitive relationship; furthermore, niche development of innovations may precede or follow landscape pressure on the regime. In response to landscape pressures, regime actors may also draw on niche expertise/innovations if they are unable to adequately respond with their own resources (Smith et al., 2005). As we discuss in the following sections, for example, several niche innovations (e.g., hydrogen fuel cell and hybrid vehicles) are funded and driven by regime actors (e.g., automotive industry) who perceive these as viable solutions to current landscape threats of resource depletion, climate change and industry regulation. Other niche practices and technologies are less compatible with those of the incumbent transport regime, and are therefore resisted or opposed by some or all regime actors. Bio-ethanol vehicle development, for example, is opposed by many fossil fuel companies; measures to reduce transport demand are resisted by many regime actors.

Central, then, to understanding many types of socio-technological transition is niche development (Geels, 2005b). This includes ‘niche-accumulation’, ‘technological add-on’, and ‘hybridisation’. *Niche-accumulation* refers to the gradual addition of a series of niche innovations and developments that facilitate the shift from an incumbent to a new regime. *Technological add-on* and *hybridisation* are the processes of new technologies physically linking up with existing established technologies, enabling a smooth transition from one technological option to the next. An example is steamships, which first developed as hybrids between steam and sail technologies (Geels, 2005b). In this article we use niche-accumulation in the sense of broad socio-technological transition, not only technological transition, to explore pathways for sustainable development of road-based transport.

This MLP is complemented by the multi-phase concept. Building on the s-shaped (sigmoid) diffusion curve (e.g., Rogers, 1995), four phases of a transition can be identified: ‘pre-development’, ‘take-off’, ‘acceleration’, and ‘stabilisation’ (Rotmans et al., 2001). In the *pre-development* stage, there is uncoordinated experimentation at the niche level but no visible change in the status quo. By the *take-off* stage, a coordinated network of niche actors forms and a dominant concept of the innovation they are developing emerges; the technology/idea is used in niche applications and rapidly improves. The *acceleration* phase occurs when there is a convergence of pressures on the regime, which allows the innovation to diffuse rapidly. As the niche enters the mainstream, it challenges the incumbent regime and the structure of the system visibly changes. Finally, in the *stabilisation* phase, the speed of change decreases and a new dynamic equilibrium is reached once the old regime is replaced.

In this article we draw on the concepts outlined above to explore the potential for a transition to sustainable transport in Europe today. In particular, we identify three promising areas of niche development - vehicle technologies, products-to-services shift, and lifestyle change - which may contribute to the sustainable development of land transport. These are discussed in Section 4.

### **3 Methodology**

This paper draws on secondary data and documentary analyses to explore various transport sector indicators and policies within Europe, particularly focussing on two member states: the UK and Sweden. These two countries represent diverse spatial, cultural and political contexts in which to explore the development and uptake of potential ‘sustainable’ transport niches. The UK has a much higher and denser population - and transport network - than Sweden: UK population is around 60 million, while Sweden has a population of around 9 million; yet citizens in both countries travel about

the same distance on average each day (30km) (Strelow, 2006). Politically and culturally, Sweden has embraced sustainability more forcefully than the UK. While UK transport policies have prioritised tackling congestion, Sweden has a long history of niche experiments with alternatives fuels (Sandén and Jonasson, 2005), and a range of recent policies supporting introduction of renewable energy in the transport sector.

National and European-wide data relating to transport indicators (e.g., demand, modal split) were obtained from Eurostat, and supplemented where necessary from electronic national statistics archives (primarily, Department for Transport, 2005b; Swedish Institute for Transport and Communications Analysis, 2006a). Vehicle sales data was obtained from European Automobile Manufacturers Association (<http://www.acea.be>) and national sources. Complementary short personal communications with experts were in a few cases conducted to obtain data on aspects of niche development that are poorly documented in the literature or statistics. Finally, we conducted an analysis of key national and European policy documents and reviewed the literature on transport technologies, behaviour and policy.

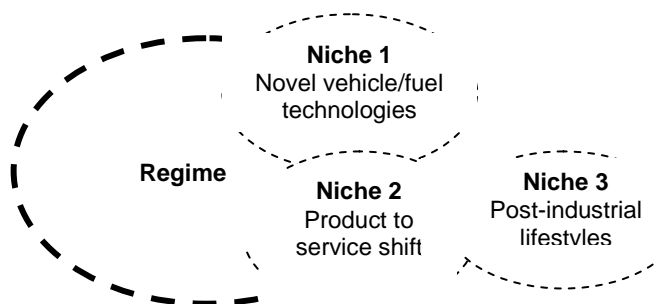
## 4 Opportunities for sustainable transport

### 4.1 Defining innovations for sustainable transport

In this section we draw on the concepts outlined in Section 2 to explore the potential for a transition to sustainable transport in Europe today. Firstly, we discuss the pressures and changes evident within the incumbent land-transport regime, including regime responses to landscape pressures (e.g., climate change). Secondly, we identify three promising areas of niche development, which may contribute to the sustainable development of land transport. These niches differ in their compatibility with the regime, with each positioned closer or further from the regime in terms of its technologies, practices, values and actors (see Figure 2).

- i) *Novel vehicle technologies* – Increased proportion of renewable primary energy in the transport sector; development of novel technologies to use this energy; and technologies providing overall greater energy-efficiency [symbiotic relationships with most automotive regime actors, but more often antagonistic to fossil fuel energy companies]
- ii) *Product-to-service shift* – Cultural, institutional and behavioural changes support new modes of transport utilisation to enable more efficient use of resources and energy [may be either symbiotic or competitive with regime]
- iii) *Post-industrial lifestyles* – This constitutes a more ‘local and green’ way of living with lower overall transport demand and resource consumption as a result of changes in values of quality of life and widespread institutional changes [predominantly antagonistic relationships with regime]

Figure 2. Indicative model of compatibility of regime and three identified niches



Primarily Niche 1, but also Niche 2 share many actors, activities and values with the regime; while Niche 3 constitutes a largely distinct set of actors, activities and values only shared with Niche 2. As will be discussed, Niches 1 and 2 also have some potential linkages through actors sharing values on

new technologies such as fuel-efficient models or alternative fuels. The outlines of all three niches and the regime are broken because of the dynamic and heterogeneous composition of niche/regime membership.

Each niche contributes in different ways to the criteria for sustainable transport proposed by various organisations and individuals (e.g., European Commission, 2001a; European Commission, 2006a; Whitmarsh and Wietschel, 2006; Commission Expert Group on Transport and Environment, 2000; SUMMA, 2005). Although different criteria are emphasised by different groups, broadly speaking sustainable transport is understood to contribute to social and economic welfare, without damaging the environment or depleting environmental resources. For example, the World Business Council for Sustainable Development defines ‘sustainable mobility’ as ‘the ability to meet the needs of society to move freely, gain access, communicate, trade, and establish relationships without sacrificing other essential human or ecological values today or in the future’ (World Business Council on Sustainable Development, 2004). The European Commission Expert Group on Transport and Environment (2000) defined a sustainable transport system as one that:

- “allows the basic access needs and development of individuals, companies and societies to be met safely and in a manner consistent with human and ecosystem health, and promotes equity within and between generations;
- is affordable, operates efficiently, offers choice of transport mode, and supports a vibrant economy, and regional development;
- limits emissions and waste within the planet's ability to absorb them, uses renewable resources at or below their rates of generation, and, uses non-renewable resources at or below the rates of development of renewable substitutes and minimises the use of land and the generation of noise”.

Based on this definition, the SUMMA project<sup>1</sup> has grouped the various dimensions of ‘sustainable transport’ under the three pillars of sustainability: social, economic and environmental (see *Table 1*).

*Table 1. Dimensions of sustainable transport (SUMMA, 2005)*

<b>Economic outcomes</b>	<b>Environmental outcomes</b>	<b>Social outcomes</b>
Accessibility	Resource use	Accessibility and affordability
Transport operation cost	Direct ecological intrusion	Safety and security
Productivity/ efficiency	Emissions to air	Fitness and health
Costs to economy	Emissions to soil and water	Liveability and amenity
Benefits to economy	Noise	Equity
	Waste	Social cohesion
		Working conditions in transport sector

There are three broad approaches to tackling unsustainable transport and achieving the criteria outlined above:

- a) *Improving efficiency and reducing the impact of vehicles* (primarily through improvements to existing vehicle technologies, development of new vehicle or fuel technologies).
- b) *Using more sustainable modes of travel* (increased use of public transport and slow modes).
- c) *Reducing the need to travel* (through lifestyle change, shifts in land use patterns and increased use of ICT).

<sup>1</sup> SUMMA (Sustainable Mobility, policy measures and Assessment) was funded by the EC (DGTREN) 2002-2005. The project aimed to defined and operationalise sustainable transport, and to assess the contribution of EC policies for tackling transport problems and promoting sustainable transport in Europe. See: [www.summa-eu.org](http://www.summa-eu.org)

Each of the three niches discussed in this paper employs a or b or c, above. However, although we discuss these niches separately in subsequent sections, we do not assume that any one niche alone might be able to achieve the diverse criteria for sustainable transport outlined above; rather, as we suggest later in the paper, the most promising outcome is a composite arrangement of aspects from all three niches.

## 4.2 Sustainable transport at the regime level

During the past two decades, there has been a significant cultural shift within the automotive and energy industries, as in wider society, towards recognition of landscape pressures, including climate change, air pollution and resource depletion. This change has perhaps been most evident amongst US automotive firms. Hoffman (2001) describes the 1970s and 80s as a time when ‘any talk of advanced propulsion technologies, clean energy, or concern with environmental issues was considered heresy in the blinkered automotive world of Detroit’ (p.102). Since then, all major car firms have begun investing in more environmentally-benign vehicle and fuel technologies, including catalytic converters, three-way catalysts, and more recently hybrids, biofuels, hydrogen and fuel cells (Köhler, Whitmarsh, Michie, and Oughton, 2007).

The policy regime began to respond to rising air pollution threats to health in urban areas in 1960 in California and in 1970 across the US with the passing of the federal Clean Air Act (Gerard and Lave, 2005). More recently, climate change, congestion, energy and resource use in manufacturing, and ‘liveability’ for citizens have become the focus of policy attention (Elzen, 2005; Nieuwenhuis and Wells, 1997). Although EU transport policy has historically focussed on liberalisation and harmonisation of transport to form a single trans-European transport network (European Commission, 2001a), more recently it has incorporated sustainability considerations into transport policies. Mobility is one of the six priority areas of the EU’s Sustainable Development Strategy (European Commission, 2001b). Furthermore, the European Commission’s (2001a) *White Paper on the Future Common Transport Policy* highlights a range of initiatives necessary for tackling problems of sustainability in the transport sector, including fostering modal shift towards environmentally friendly modes (rail, inland waterways, short sea shipping); promoting alternative vehicle and fuel technologies; improving efficiency; and internalising environmental costs in transport prices. Together with the industry responses to economic and environmental landscape pressures, these policy shifts suggest an ‘opening up’ of the prevailing regime to consider radical changes within the current sustainable transport systems. In this paper, radical technologies are defined as ‘disruptive’ technologies, which ‘at some level cause a large perturbation in the system, whether in the market structure, product or consumer behaviour’ (Adamson, 2004, p. 1). In this sense, they disrupt technological trajectories or other types of lock-in mentioned earlier (e.g., behavioural routines) associated with the prevailing transport regime.

However, a closer look at the transport regime highlights that this is not a homogeneous group of actors; in some cases, interests have become misaligned in response to landscape pressures. An example is the response of the natural gas and oil industries to biofuel development, with actors lobbying the UK government to impose standards in order to constrain and delay commercialisation (Taylor, 2006). Transport policy responses similarly indicate competing priorities and ambiguity, with more attention currently given to economic (e.g., costs of congestion and infrastructure) and environmental impacts (emissions) of transport than social impacts, such as exclusion and community severance (see also Section 5.1.2). In Sweden on the other hand, the biofuels lobby has successfully influenced the regime in the past ten years, visible through the active policy making of the former Swedish government (A new centre right coalition is in place as of September 2006), and the gas and oil industries are adopting and increasingly supplying alternative fuels. While the regime is adapting in some aspects, new issues are emerging such as conflicting interest over incentives for domestic production of biofuels vs. cheaper imports, debate over the potential loss of ecosystem services due to intensified land use, and lock-in to new inefficient technologies. These examples of tensions are what de Haan and Rotmans (2006) refer to as ‘stress’ - internal misalignment within the regime - which is typically a precursor to transition;

notably in the case of the transition from horse-drawn carriages to automobiles the old regime collapsed completely before a new regime emerged (Geels, 2005b).

Within wider society, too, there is considerable resistance to changing behaviour to more sustainable forms. Driving is not only perceived to be the most convenient and is often the cheapest form of transport, it is also tied to social values and identity (e.g., Steg et al., 2001). In the UK, for example, there is a widespread association between car ownership and ‘having a good lifestyle’ (Whitmarsh, 2005; cf. Black, Collins, and Snell, 2001). UK research organisation MORI concludes that most people in the UK are ‘determined to retain car use in the face of virtually any barrier - excessive cost, tighter legislation, vehicles banned from urban centres etc.’ (Norton and Leaman, 2004, p.9). This is despite public recognition of the need to tackle rising congestion and other transport problems (Department for Transport, 2005a). In the case of Sweden, Nilsson and Küller (2000) find similar patterns in the literature describing values attached to cars in Sweden (p 213), and show that car affection and ownership have a negative influence on pro-environmental awareness and behaviour. It has also been shown that public acceptance of road pricing among car owners in Sweden decreases if it is perceived as unfair or limiting freedom (Jakobsson, Fujii, and Garling, 2000). Interpreting freedom resulting from this car ownership as an attribute of having a good lifestyle, MORI’s conclusion is supported also in the Swedish culture of car ownership.

### **4.3 Niche 1 - Radical technological change**

All major car manufacturers are investing in alternative vehicle and fuel technologies. Radical technologies, especially hydrogen and fuel cells for use in vehicles, were initially developed by ‘niche’ players or outsiders (e.g., universities, firms in other sectors or enthusiastic amateurs, entrepreneurs or start-ups), but have now been ‘institutionalised’ into mainstream auto firms (van den Hoed and Vergragt, 2004). This institutionalisation of radically new technology development can be described as a regime response to landscape changes. Increasing oil prices and awareness of scarcity of oil supplies, growing societal recognition of environmental impacts such as climate change and local air pollution from transport are examples of landscape changes forcing the regime to open up. The solutions, or rather adaptations, aligned most closely with the regime are technological fixes. There is also a political preference for technological solutions to environmental/sustainability problems - the so-called ‘techno-fix’ or ‘end-of-pipe’ approach. These tend to offer economic as well as environmental benefits (win-win) (see European Technologies Action Plan: European Commission, 2002), and avoid the more challenging issue of changing consumer behaviour.

Novel vehicle technologies with regard to sustainable transport can be classified along two main lines of innovation. A first line of innovation is enabling use of different sources of primary energy including conversion to different energy carriers. A second line concerns developments in the drive train technologies that are used to convert stored energy to physical movement. A third line of innovation, which concerns further improvement in the already-dominant technology, is devoted to improving the existing internal combustion engine and reducing vehicle weight so as to improve overall energy efficiency of conventional cars. This last line of development is occurring to a large extent in a symbiotic relationship within the regime. Larger efficiency gains as a consequence of this trend are discussed in later sections.

Possible options for renewable primary energy are renewable electricity (i.e., electricity produced from solar, hydro, tidal, wave, and wind energy), and fuels and electricity produced from biomass. Technologies for the necessary capture and conversion of the primary (solar) energy exist, but most are not economically viable under prevailing market prices. Research is underway to improve the technological and economic performances of these production routes. Meanwhile, a multitude of alternative and complementary technological options are being developed in parallel. There is a rather large variability between car manufacturing companies not only in terms of R&D focus in new technological solution, but also in terms of strategy and level of ambition. Virtually all car

manufacturing companies invest in different novel technologies (Köhler et al., 2007) heading for future developments, but some are leading in the commercialisation of new solutions.

Each set of technologies under development will not be reviewed in detail here, but some basic features will be discussed. Energy carriers directly linked with the types of primary energy are electricity stored in batteries (or directly supplied from the grid) and different liquid or gaseous biofuels. A wide range of options for the later category of biofuels exist among which Ethanol, Methane, and Bio diesel are the most developed and widespread today, see Table 2. Reviews of these different options include Johansson and Ahman (2002), MacLean and Lave, (2003), Sandén and Jonasson, (2005), and Semelsberger, (2006), Azar, Lindgren et al. (2003). Hydrogen as an energy carrier can be produced with a range of technological options (Wietschel, 2006). Also methanol is an energy carrier that can be produced from a range of sources with similar technologies as hydrogen. Finally, technologies challenging the dominant technology of Internal Combustion Engine (ICE) in terms of drive train solutions are Fuel Cells (FC), batteries, and electric motors, and novel ways of combining these options as in Hybrid Electric Vehicles (HEV).

Table 2. First and examples of second generation biofuels.

<i>First generation biofuels – Fermented and reformed biomass</i>	<i>Second generation biofuels - Gasified and synthesised biomass</i>
<ul style="list-style-type: none"> <li>- Methane from renewable resources, often referred to as biogas</li> <li>- Ethanol</li> <li>- Fatty Acid Methyl Esters (FAME), often referred to as bio diesel.</li> </ul>	<ul style="list-style-type: none"> <li>- Fischer Tropsch Diesel (FTD)</li> <li>- Methanol, Dimethyl Ether (DME)</li> </ul>

However, sustainable transport pathways do not exclude fossil alternatives in the short to medium term. Renewable primary energy could be introduced gradually, with more efficiently-used fossil primary energy in the short- to medium-term (Hekkert et al., 2005; Wietschel, Hasenauer, et al., 2006). It is also likely that a widespread use of carbon sequestration from continued fossil fuel use will be needed in order to meet the global energy demand under CO<sub>2</sub> emission constraints. Widening the definition of sustainability, from energy for transport only, and studying the global energy system with stringent carbon dioxide emissions, it has been argued that it is better to continue the dependence on fossil oil-based fuel use in transportation, and focus renewable energy use in the power and heat sectors (Azar, Lindgren, et al., 2003)..

There is an extensive amount of literature discussing the comparative advantages of different combinations of fuels and power train technologies (Johansson and Ahman, 2002; Azar et al., 2003; MacLean and Lave, 2003; Hammerschlag and Mazza, 2005; Romm, 2006) often also broadening the discussion to include primary energy supply for energy carriers (hydrogen and electricity), since the sustainability of each combination is evidently determined by the well-to-wheel, or source to service analysis (Semelsberger, Borup, et al., 2006; Wietschel et al., 2006).

However, while HEV technologies are being discussed as one of the most promising pathways with a rapidly developing market in the wake of the success of Toyota’s Prius, few have discussed the importance of hybridisation and technological add-on in the context of wider niche-accumulation, enabling transition pathways. Johansson and Ahman (2002) and Romm (2006) discuss hybrids as a technological solution with different fuels, comparing their potential to other alternatives. Yet others do not agree that hybrid solutions as such offer a cost effective solution (Lave and MacLean, 2002). Sandén and Jonasson, (2005) are inspired by the transition frameworks of Geels (2002; Geels, 2005a) and Rotmans et al. (2001) in their discussion of bio-fuel development in Sweden with the help of the concepts of landscape, regime, niches and niche-accumulation, but fail to broaden the discussion to hybrid technologies and technological add-on. Several authors also argue for the potential for other combinations of technologies. The most prominent are: ‘plug-in hybrids’ (the intermediate of a BEV

and a HEV) (Romm, 2006), and hybrid FC-electric cars (Jeong and Oh, 2002; Pede, Iacobazzi, et al., 2004). Hekkert and others (2005) review options for Natural Gas (NG) use and discuss two different transition pathways to a sustainable transport future based on NG. However, this analysis does not include Ethanol and Biogas, and fails to broaden the discussion to the hybrid drive train potential.

Merging the different strands of literature on novel vehicle technologies for road-based transport, we conclude that all of these solutions might have a role and could be included in a transitions framework. Different technological solutions have their pros and cons, with no solution the obvious winner (cf. Köhler et al., 2007). Hydrogen and FCs offer potentially very clean, efficient and quiet technologies at the point of use, but their rate of development and cost reduction potential is highly uncertain (McDowall and Eames, 2006). Furthermore, a sustainable hydrogen path fundamentally requires rapid development of renewable energy for electricity production. First generations of bio-fuels are already becoming cost-effective for consumers and available within European markets, but current options do not offer an efficient carbon dioxide emission reduction path compared to use of biomass in power heat generation, and the bio resource base is limited imposing severe constraints on future bio-fuel supply. The different versions of HEV offer efficiency gains and new compelling opportunities to bridge current technologies to future high efficiency pathways and BEV solutions, but technical limitations and high vehicle costs have so far constrained a broad market introduction.

In addition to the weaknesses of each of the niches, outlined in Table 3, novel vehicle/fuel technologies are unable to contribute to social aspects of sustainable transportation, such as accessibility, obesity and congestion (Whitmarsh and Wietschel, 2006). Furthermore, OECD research (see CST, 2001) indicates that technology alone would only be able to offer 41% of the necessary emissions reductions to mitigate climate change; the remainder would need to come from changes in transport demand and use. On the other hand, development of these technologies presents economic opportunities for the automotive and related sectors, and is compatible with regime values of ‘automobility’. Final choices of climate change mitigation strategies must be assessed across sectors.

*Table 3. Strengths and weaknesses of Niche 1 developments*

<b>Categories of Niche development</b>	<b>Strength</b>	<b>Weakness</b>
HEV	High potential to become new standard Uses existing infrastructure	Fossil-fuel dependent
BEV and plug-in hybrids	Flexibility of primary energy sources, enabling shift to renewables	Battery technology immature, with high cost and practical constraints Need for (some) new infrastructure
Biofuels	Low CO <sub>2</sub> emissions Economic opportunities for other sectors, e.g., agriculture	Land (area) constraints – competition with food Risk of unsustainable use of land Need for (some) new infrastructure
Hydrogen and Fuel cells	Enables use of broad range of renewable primary energy in transport No emissions at point of use Reduced vehicle noise	Immature technologies – high uncertainties over range of aspects, including the sustainability of the primary energy Need for new infrastructure

#### **4.4 Niche 2 - Shift from products to services**

This niche encompasses a shift from product to service provision by automotive firms, as well as transport service provision by public transport (bus, train, etc.) companies. Town planning policies and initiatives to support shared and collective forms of transport and to discourage private car use (e.g., bus lanes, car-share parking zones) are also associated with this niche. Landscape changes affecting this shift are mainly related to continued urbanisation. Urban lifestyles are less dependent on individual transport, and more closely aligned with public transport, shared transport and ICT than with car

ownership. Growing problems with congestion and commuting times as well as local air pollution contribute to the broader development of Niche 2.

Some firms (notably, GM and Toyota) are not only developing new competences in vehicle technologies in response to environmental change, but are also changing their business model away from vehicle production and towards provision of services such as vehicle rental, servicing and finance. Seidel and colleagues (2005) identify the possibility that the large-scale car makers will continue to move in this direction towards a 'brand worlds' scenario involving a shift to mobility service provision and an expansion into other consumer products.

A shift from car ownership to car transport service acquisition also extends beyond the automotive industry. Car-sharing schemes have so far played a minor role in societies in both the UK and Sweden and the topic is relatively little discussed in the literature (see Enoch and Taylor, 2006 for a recent review). Throughout Europe there are some 120,000 members of car-sharing schemes (Enoch and Taylor, 2006) and the potential of car sharing in Europe has been discussed by Prettenthaler and Steininger (1999) and then estimated to be roughly 9% of present car owners through a survey in Austria, a figure affirmed by a Swedish car-sharing expert Peter Markusson (Markusson, 2006) in the case of Sweden. This figure is however not an upper limit, but estimations given the present regime, that is including 'lifestyle characteristics' and current behaviour patterns. Mont (2004) discusses car sharing in the wider context of a product-to-service shifts and also recognises two different Car Sharing Organisations (CSO); Communal and Commercial (Mont, 2004, p. 141). The development of information technology solutions are important drivers in this niche as explored by Shaheen (Shaheen, 1999, p. 4). Easy-to-use web-based booking, electronic keys, GPS- and GSM-based tracking of driving distances, and automated invoicing are some examples of developments that reduce the cost of such systems and make them easier to use (Swedish road administration, 2002).

A range of very fuel efficient ICE cars such as the Toyota Aygo, Citroen C1, and Peugeot 107 demonstrates that transport needs can be met with less fuel consuming cars. With transportation marketed as a service the price is likely to be relatively more important than the performance and prestige of owning a higher end car, which in turn puts pressure on lower fuel consumption. Comparing three types of car utilisation; i) privately owned, ii) shared cars, and iii) rented cars, Prettenthaler and Steininger (Prettenthaler and Steininger, 1999, p. 449) show that there are differences in engine size between the three types. Privately owned cars on average show the largest engines and rented the smallest with shared in between.

Finally, the growth of this niche encompasses changes in modal split, and continued development of alternative transport services. Growth of purchased car services in this niche could contribute to the development of public transport, since access to alternative means of transport when car services are not bought is necessary (Prettenthaler and Steininger, 1999), but we also include endogenous growth of public transport services and solutions.

Although great variability in public transport infrastructure investment and use exists within the current broad transport paradigm, there is considerable room for growth of the public transport sector. Light rail and trams virtually disappeared throughout the 20<sup>th</sup> century in Sweden and the UK as cars became the dominating mode of transport (Geels, 2005b), but face renewed interest once again due to landscape developments, discussed above. In the longer run, further developed public transport is a forerunner to advanced, individualised public transport solutions such as Personal Rapid Transport (PRT) (Rodier, 1998). Already, several metro systems globally operate autonomously. ICT development in general also contributes to efficient public fleet management and consumer information, making public transport more cost effective and reliable.

The contribution of this niche to a more sustainable transport system is through more efficient resource use and reduced congestion due to lower levels of absolute number cars in society, and relatively high energy efficiency. A growing service sector could be a key driver to both increased use of public

transport and more energy efficiency innovations in terms of the ICE engine, light weight materials, and eventually wider use of hybrid electric technologies. Alternative car services and car sharing also offer social inclusion, since this form of car use is cheaper than private ownership, and in wider terms communal CSO fosters sustainability-oriented (community) world views.

Table 4. Strengths and weaknesses of Niche 2 developments

Categories of Niche development	Strength	Weakness
Car manufacturer switch from product to service	Efficiency Technology driver Regime actors leading	May still rely on fossil fuels
Car sharing and rental	Resource efficiency Social inclusion (reduced costs, community interaction) Compatible with existing 'automobility' values	Some problems with accessibility and availability – Mainly limited to urban areas with broad growth potential and alternative modes
Public transport	Resource efficiency Social inclusion (reduced costs, community interaction)	Can suffer from poor public perceptions (status, safety, comfort) Problematic for mobility impaired or transporting luggage

#### 4.5 Niche 3 - Post-industrial lifestyles

This niche is the most radical of the three - that is, it represents the most divergent cultures and practices from the current regime, and therefore predominantly comprises of alternative institutions and actors. In essence, this niche represents reduced travel demand. This encompasses walking and cycling ('slow modes'), and use of ICT for home-working and -shopping, as well as methods of town planning and development that encourage reduced travel demand (e.g., cycle lanes, live-work areas). Common to the activities that comprise this niche is a less consumer-oriented (individualistic) and more sustainability-focussed (community) worldview. The car loses its unique symbolic status and is regarded simply as another 'white good' (e.g., refrigerators, washing machines) (Nieuwenhuis and Wells, 1997); autonomous personal mobility is less important than convenient, safe, affordable, and clean transport. In effect, this closely mirrors the *Local and Green* scenario developed for the East of England (Turnpenny, O'Riordan, and Haxeltine, 2005) or the *Local Stewardship* Foresight scenario developed for the UK Office of Science and Technology to inform policy-making in several government departments. These scenarios emphasise pro-sustainability cultural values and lifestyles focussed around local communities. This niche also has close links with the product-to-service niche (Niche 2), which - in contrast to the current regime - attaches little value to vehicle ownership.

This niche is likely to have the greatest potential for achieving a transport future that is sustainable in its broadest sense (encompassing social, as well as environmental and economic benefits). Firstly, with the most rapidly-growing proportion of greenhouse gas emissions coming from transport, reduced transport demand is a core element of climate change mitigation. There is also evidence that increased traffic reduces opportunities for social interaction, and can result in community severance (Appleyard, 1981). Therefore, reducing traffic flows through residential areas - for example, creating 'home zones' - can encourage community cohesion and improve road safety and environmental quality (Department for Transport, 2005a). Research into 'soft transport measures' (i.e., not involving major investment in infrastructure), such as travel planning, individualised marketing, car-sharing, and increased use of home-working and -shopping, suggests these can reduce transport demand by up to 21% in peak times (Cairns et al., 2004). However, other research suggests there may be rebound effects from increased use of ICT for home -shopping and -working, with transport demand being displaced into (and even increased in) other activities, such as leisure (Skinner et al., 2004). This highlights the important intrinsic psychological and social values associated with transport held by many people (Ory and Mokhtarian, 2005).

In many respects, Niche 3 development is being fostered through landscape changes, as well as policy intervention on a number of levels. Landscape changes include changes in societal values beyond materialistic to post-materialistic values, and greater concern for quality of life and environmental quality than income. This is reflected, for example, in the development of European and member state sustainable development policies (e.g., Department for Environment Food and Rural Affairs, 2005), which give attention to community cohesion, quality of life, and environmental quality, alongside economic indicators such as GDP. Furthermore, several studies suggest an emerging change in behaviours and attitudes to car ownership and use, in particular among young citizens, a growing proportion of whom in several European countries are choosing not to obtain a driving license (e.g., Cedersund and Henriksson, 2006; Department for Transport, 2005b). Kondratiev Wave theory indicates that the shift from cars to ICT as the dominant socio-technical system has already commenced: while the automobile was the defining cultural icon of the 20<sup>th</sup> Century, the computer and related technologies are now in the ascendant (Freeman and Louçã, 2001; Seidel et al., 2005). The automotive industry is very mature, characterised by fierce competition, fully-exploited economies of scale, and low profitability (Köhler et al., 2007); the ICT sector, however, is continuing to expand, exploring new products, functionalities, and markets. In fact, much of the technological development in the automotive industry in recent years has been a result of integration of information technologies within vehicles. Consistent with this theoretical framework, home-working and -shopping, and web-based communities, may ultimately replace the need for much travel.

The policy context is also largely favourable for development of this niche. Climate change and energy policies include measures for demand management (e.g., DEFRA, 2006). Furthermore, with congestion and social inclusion a concern for many European member states, national transport and related policies are increasingly supportive of these niche activities.

Examples of policy instruments include congestion charging and road tolls, vehicle and fuel taxation, energy labelling of vehicles, and information campaigns/marketing. However, while there is evidence of the success of many of these economic and informational measures (e.g., Transport for London, 2006), there is also a need to address the socio-cultural determinants of demand. Contrary to the predictions of post-materialist theory (Inglehart, 1990), to date there has been little success in decoupling transport demand from income within Europe (Glaister, 2002). Goodwin et al (2004) highlight asymmetry in the income-travel demand relationship - while demand for transport increases proportionally with income, reduced income does not necessarily result in reduced demand for transport. This is likely to be because individuals become used to, and (socially-) dependent on, a certain standard of living and largely unconstrained personal mobility, and are therefore ‘locked in’ to this lifestyle. The social and cultural dimensions of car ownership and use (e.g., Steg et al., 2001) pose a challenge for effective policy-making. Without bottom-up change in social *values* and transport policies that produce *structural* change (including infrastructural interventions like ‘home zones’, public transport and cycle paths) there may be a backlash against policies that restrict personal mobility, as demonstrated for example, in the UK 2000 fuel duty protests.

Table 5. Strengths and weaknesses of Niche 3 developments

Categories of Niche development	Strength	Weakness
Slow modes (walking, cycling)	Health benefits Widely accessible (no/low cost, community interaction) Zero emissions/ low resource use	Limited range
ICT for home-shopping and -working	May improve work-life balance May reduce emissions and congestion	May lead to increased transport demand in other areas (e.g., leisure) Reduced community interaction Potential exploitation (e.g., low pay)

## **5 Evidence for pre-development and take-off phases of sustainable transport transitions in UK and Sweden**

In this section we summarise the evidence of ongoing pre-development of a transition to more sustainable transport within Sweden and the UK. For reference, and as evidence of active support for sustainable options in the transport sector throughout the three discussed niches, this section begins with a review of relevant policies in the two countries. Following that, we present evidence of market/technological and cultural/behavioural change that may indicate active development of Niches 1, 2, and 3. The evidence is presented separately for Sweden and UK, with aggregated discussion and conclusion in the final sub-section. The complex and interlinked future development in between these niches is not directly visible in a single indicator. Instead, we present a wide range of indicators highlighting some key aspects of each niche and in the following section try to sketch ongoing and potential future niche-accumulation.

### **5.1 Policy context**

Policies and assessment practice for sustainable development are still very much challenging the existing paradigm in Europe in general and Sweden in particular (Jordan et al., 2006). The prevailing paradigm of economic growth limits policies related to sustainability to those most closely aligned with Niche 1. Sustainable development is an increasingly prioritised issue at the level of rhetoric, as expressed at EU level in the Sustainable Development Strategy and Lisbon Agenda, and at national level in corresponding strategies addressing sustainability issues. In practice, however policies are largely sectoral and developed and assessed with a broad gap between best practice guidelines and reality (Jordan et al., 2006). Transport is no exception, and policies supporting sustainable transport are to be sought in sectoral approaches to addressing congestion, air quality, safety, new technologies, climate change etc. The following two sections give a descriptive jurisdictional background and highlight policies framing sustainable transport development.

#### *5.1.1 Sweden*

Recent Swedish policy making on transport increasingly embraces sustainable development as an aspiration (Regeringskansliet, 2006). Safety, social inclusion, accessibility, public transport development, and to some extent reduced environmental impacts of transport (green tax reforms from income to CO<sub>2</sub>), have been key aspects of transport policies by the Social Democrats influenced and supported by the green and left parties over the last 12 years (Swedish Road Administration, 2006b). However, Sweden is heavily dependent on the vehicle manufacturing industry with two car producers (Volvo and Saab) and two truck producers (Volvo and Scania) within a relatively small country, and the policy paradigm is in broad terms well-aligned with the current transport regime. This was illustrated only recently when the government acted swiftly when GM-owned car manufacturer Saab faced major potential job losses. Previous infrastructure budgets were altered, increasing investments beneficial to Saab/GM in the west coast region, and the threat of close down of production capacity was withdrawn by GM.

The most prominent policy issue on road-based traffic in Sweden is probably safety. Aspects of safety are deeply embedded in the transport regime in Sweden, with the two car manufacturers Saab and Volvo being pioneers in safety innovation. Transport policies and adoption of safety measures are aligned with this regime and Sweden was an early adopter of legislation on seat belts and other safety measures. In 1995 a 'Vision Zero' was adopted with the goal of reducing fatal accidents to zero. The Swedish road administration works with several measures such as alternating 2+1 lane highway with a median barrier (a road type developed in Sweden), programs for alcohol ignition interlocks in duty vehicles (such as light and heavy trucks), and an aggressive expansion of automated road safety cameras capturing violations of speed limits (Swedish Road Administration, 2006a). Another recent legislation in this area is a law for children and adolescents up to the age of 15 to wear a cycle helmet when riding a bicycle.

**Box 1. SWE transport and transport-relevant policy instruments***Generic transport policies:*

Punctuality and Information, and Accessibility for disabled, have continuously been worked on in the current transport policy regime and are important aspects of the latest strategic bill from the government (Regeringskansliet, 2006)

Road safety: A 'Vision-Zero' of eliminating lethal accidents is in place since 1997 and has since become a guiding principle and prioritised area of work for the Swedish Road Administration (Swedish Road Administration, 2006a).

*Congestion*

- Test period of congestion charges in Stockholm during first half of 2006. Probable adoption of a revised system in 2007 (Svensk Författningssamling, 2004b)

*Climate Change policy regime*

- As of May 2006 taxation of private cars and other light duty vehicles is linked to carbon dioxide (CO<sub>2</sub>) emissions (Svensk Författningssamling, 2006).
- A range of local initiatives within municipalities creating incentives for individuals such as free parking and subsidised purchases, as well as support for filling stations to add a fuel pump for a renewable fuel. These initiatives originate from a generic investment program 'Klimp' supporting investments in abatement of CO<sub>2</sub> emissions through the Swedish Environmental Protection Agency (Svensk Författningssamling, 2003).
- Two recent pieces of legislation impose a requirement for agencies and authorities to buy or lease a minimum of 50% environmental friendly cars as of 2005, and 75% from 2006 (Svensk Författningssamling, 2004a, 2005a).
- Employees utilising a car supplied by his or her employer have to pay a tax corresponding to some of this added value. For cars using renewable fuels or with a hybrid technology, a tax reduction guarantees that this taxation is at the same level for such a car as for a comparable car with a petrol or diesel engine. The otherwise more expensive environmentally friendly car is hence subsidised in this context (Skatteverkets meddelanden, 2005; Svensk Författningssamling, 1999).

*Alternative fuel infrastructure regulation.*

- Requirement for gas filling stations to supply bio-fuels if above a certain size (Svensk Författningssamling, 2005b).

*Product to service shift*

- Recent committee reviewed measures for increased product to service shift in general with numerous suggestions for how to support such a transition (Statens Offentliga Utredningar, 2005b)

Infrastructure investments in general have declined since a peak in 1960 and during the latest 10 years railroad infrastructure has been given increased relative priority over roads. With Sweden being much more scarcely populated and with fewer and smaller metropolitan areas compared to the UK, the debate is naturally centred on accessibility and road quality more so than capacity. However, in recent years congestion has been increasingly debated, linked to environmental concerns, and a trial of congestion charges was conducted during the first half year of 2006 in Stockholm. The Stockholm region suffers from bottlenecks in both rail and road infrastructure and regional policy making on infrastructure investments have been politically contested for several decades.

Fossil fuels for road-based vehicles are historically taxed with different ratios of Energy tax and Carbon dioxide tax depending on fuel type and use. These taxations are not enforced on renewable energy carriers with zero net CO<sub>2</sub> emissions (Svensk Författningssamling, 1994). Also, starting in October 2006, there is a component in this tax directly linked to nominal CO<sub>2</sub> emissions per kilometre for the vehicle.

Finally, it is interesting to note that a recent committee inquiry for the first time reviewed options for sustainable consumption and production in general (Statens Offentliga Utredningar, 2005b). This report

included several suggested measures for achieving a generic shift from resource-intensive products to a service-based economy among which a few have been implemented in recent years.

### 5.1.2 UK

“The British travel much the same as other Europeans, yet our road and rail network is the least developed of any major country - the result of decades of below average investment. As a consequence we have overcrowding on much of the rail network, and the most congested roads in Europe. Travel is forecast to continue to grow, and congestion will worsen further by 2010” (Strategy Unit, 2001).

Research into the development of transport policies in the UK indicates evidence of a shift in focus during the last 15 years. Transport planning has traditionally followed a ‘predict and provide’ approach - building and expanding large-scale infrastructure in response to rising traffic levels. In particular, since the Beeching reforms of the 1960s spending on road infrastructure has radically increased, while the rail network - including stations, tracks, rolling stock and staff - has been reduced, contributing to the major increases in road-based freight and personal transport. At the same time, the cost of motoring has remained relatively constant in real terms, while the cost of public transport has risen (Lucas, 2006). This is despite increases in fuel prices and fuel taxation: by 2000, UK petrol had become the most expensive in Europe (Glaister, 2002). During the 1980s and 1990s, the Conservative government privatised the railways and bus companies outside of London, limiting governmental control over public transport.

With growing international attention to sustainable development goals, increasingly militant anti-road protests and public spending cut-backs at national level (Glaister, 2002), not to mention evidence that creating transport network capacity may in fact be counter-productive, stimulating additional demand (Cairns et al., 2004), transport policy in the UK is beginning to focus less on road building and more on integrated demand management strategies (Bulkeley and Rayner, 2003). This is reflected in the government’s 1998 white paper *A New Deal for Transport: Better for Everyone* (Department of the Environment Transport and the Regions, 1998), which highlighted the need for more strategic and integrated transport planning including greater local authority control over public transport providers, and the Road Traffic Reduction Acts of 1997 and 1998.

The creation of the Greater London Authority through the GLA Act of 1999, which provided the Authority with powers to use revenue from user-charging, paved the way for the introduction of the London Congestion Charge. This scheme, which currently charges drivers £8 per day to enter central London (with reductions for residents and exemptions for buses, taxis and certain other vehicles including alternative-fuel vehicles), is widely regarded as successful: since its launch in 2003, there has been around a 30% reduction in congestion, as well as fewer accidents and emissions, with no negative impact on businesses in the capital. The revenue generated by the Charge (£122m) has been largely spent on improving bus services (Transport for London, 2006).

The subsequent Transport Act of 2000 enables congestion charging and similar road pricing or workplace levy schemes to be introduced by other local authorities, in order to generate revenue for other transport-related projects. More recent policy discussion has focussed on standardising road-pricing schemes by introduction of a national road-pricing framework and road-pricing pilot projects (Letter to PM, July 2006; DEFRA, 2006). The Transport Act has also seen the creation of the Strategic Rail Authority, with responsibility for increasing the capacity of the rail network. The UK’s rail system is notoriously outdated, and part of the government’s *10-Year Plan* (Department for Transport, 2000) involves extending and modernising the rail network. Other improvements to public transport are also outlined in the Plan, including encouraging local authorities to procure bus services through Quality Contracts, and increased local authority spending on bus schemes, including bus lanes and the ‘rural bus grants’ and ‘urban bus challenge’.

‘Softer’ measures to encourage modal shift and reduce transport demand have also become very popular in central government, not least because they do not involve major investment in infrastructure.

Following research which suggested that soft measures - including individualised marketing, travel-plans, car-sharing and more tele-working/shopping - could cut urban traffic by 21% in peak periods (Cairns et al., 2004), the government has launched three Sustainable Travel Towns to pilot such measures and is encouraging schools to develop travel plans. Other schemes include energy labelling on new vehicles, introduced in 2004 (in advance of EU proposals to introduce such a scheme).

Alternative transport fuels and vehicle technologies - primarily bio-fuels, but also hydrogen and fuel cells and hybrid ICE-electric - are also supported through a number of measures. London has been the focus of both hydrogen fuel cell and hybrid bus demonstration projects. The government has also established the LowCVP stakeholder group to stimulate alternative vehicle technology development. In response to the EU 2003 Biofuels Directive, which specifies a 2 % target for 2005, the UK has recently introduced measures to encourage bio-fuel uptake (see Box 2).

Furthermore, the Labour government has reformed regional planning guidance and processes of appraisal, to promote more strategic, participatory and integrated transport planning at the local level (Bulkeley and Rayner, 2003). Shared priorities for local transport planning were agreed in 2002 by central government and the Local Government Association. These included: improving accessibility and public transport and reducing the problems of congestion, air pollution and safety.

Here, however, researchers have highlighted a 'potential tension between the existence of nationally-declared objectives for transport policy and the discretion allowed for local determination' - through stakeholder involvement - of the strategic objectives that should inform Local Transport Plans (LTPs) (Bulkeley and Rayner, 2003; Wood et al., submitted). Furthermore, other researchers point out that there is little evidence of decoupling GDP from transport demand, and a lack of genuine commitment to reducing demand for fear of alienating the 'motoring majority' (Glaister, 2002; Bulkeley and Rayner, 2003). In the wake of the 2000 fuel duty protests, which resulted in the government removing the fuel duty escalator, there is a political reluctance to regulate demand through fuel taxation. Indeed, despite the change in political rhetoric and introduction of demand management initiatives, vehicle kilometres and associated greenhouse gas emissions in the UK are continuing to rise (Department for Environment Food and Rural Affairs, 2003).

Thus, the government has tended to prioritise measures to tackle congestion (e.g., 'intelligent highways', carpooling, and road pricing particularly on new inter-urban roads: Letter to PM, July 2006; DfT, 2004) rather than politically less popular measures to mitigate climate change and improve accessibility. Expanding road network capacity through programmes of road widening and building continues to be a core area of government transport policy (DfT, 2004) - albeit in combination with measures such as road tolls and carpooling (High Occupancy Vehicle) lanes - suggesting they have not yet fully rejected the traditional 'predict and provide' model of transport planning. Furthermore, the focus in the UK on tackling congestion seems to be to the detriment of climate change mitigation measures, since fuel duty may be reduced or removed in favour of differentiated 'pay-as-you-go' road pricing to discourage driving at peak-times.

**Box 2. UK transport and transport-relevant policy instruments****Box 2. UK transport and transport-relevant policy instruments***Graduated Vehicle Excise Duty and Company Car Tax*

Since 2001 and 2002, respectively, these have been linked to vehicles' carbon emissions. The Budget in 2006, decreased to £0 the tax on the lowest emission vehicles to develop this market (company car tax fuel benefit charge was also reformed in 2003 to favour lower emission vehicles)

*Renewable Transport Fuels Obligation*

To be introduced in 2008 - five per cent of transport fuel sold in the UK will have to come from renewable sources by 2010. Budget 2006 announced that the level of obligation will be 2.5% in 2008-09 and 3.75% in 2009-10. This measure encourages clean production of biofuels through state aid awards, and encouraging sustainable sourcing of biofuels through a carbon and sustainability assurance scheme

*Alternative Fuels Framework*

Includes 20 pence per litre duty incentive for bioethanol and biodiesel until 2008-09

*Hydrogen and Fuel Cells Demonstration Programme*

This will provide £15m support from four years from 2006 to demonstrate hydrogen and fuel cells, including the use of hydrogen as a transport fuel

*Alternative refuelling infrastructure grant programme.*

This could, for example, include funding for hydrogen, electric, bio-ethanol and natural gas/biogas refuelling points: Details of the grant programme are at [www.est.org.uk/fleet/funding/infrastructurep](http://www.est.org.uk/fleet/funding/infrastructurep).

*Powering Future Vehicles Strategy (2002)*

Sets out the main policies and targets in this area and a grant programme supports research and development into low carbon vehicle technologies. ([www.est.org.uk/fleet/funding/lowcarbonresearch/](http://www.est.org.uk/fleet/funding/lowcarbonresearch/))

*National Air Quality Strategy*

Objectives for carbon monoxide, lead, nitrogen dioxide, particles, sulphur dioxide, benzene and 1, 2-butadiene (Joint DfT/Defra target)

*Climate Change Programme (2006)*

Includes:

- *Sustainable distribution scheme in Scotland*, which provides advice on reducing lorry mileage, fuel consumption and accidents;
- 'Smarter choices' soft measures to encourage modal shift and reduce demand;
- *Sustainable Travel Towns* and six cycle demonstration towns;
- *Rural bus grants* and *urban bus challenge*;
- *Grants for rail freight* - currently around £20m each year;
- *Vehicle fuel efficiency labelling* introduced in 2005 to inform car buyers about the benefits of lower emissions vehicles;
- Funding for the *Low Carbon Vehicle Partnership (LowCVP)*, a stakeholder organisation set up in 2003 to help the shift towards low carbon vehicles and fuels;
- Launch of *Transport Direct transport information service* - to help encourage a move to more environmentally friendly means of transport;
- *Carbon off-setting* of Presidency of EU and G8, and all of central government since April 2006;
- Use of *renewables and CHP by Highways Agency to power road network lights and communication*.

Local authority transport measures include congestion charging, bus lanes, parking measures, etc...

## 5.2 Technology and market development

Technologies such as catalysts and particulate filters lowering emissions from cars have evolved rapidly since emission standards for passenger cars and light vehicles were initiated in the EU in 1993. In this section we primarily review market development for alternative fuels or propulsion system technologies to counter fossil fuel use and thereby climate change. The picture of innovative technologies is somewhat mixed throughout Europe. Germany, which is the leader in biofuels use in Europe, has adopted bio diesel as the primary alternative fuel (Christian Bomb, Article in press), while Sweden is a leader in Ethanol and biogas use, and others are yet to initiate programs on bio fuels. Overall, the market is evolving rapidly.

### 5.2.1 Sweden

In Sweden, petrol-fuelled ICE cars have historically dominated road-based personal transport completely. Diesel account for only 5% of light vehicles in 2005 but is increasing due to changed taxation levels relative to petrol. The market for alternative fuels was until 2000 well below 0.1% in total. However, this situation is now changing rapidly.

Sweden has had a long period of what could be characterised as pre-development for a bio-fuels transition. Sandén and Jonasson (2005) make an excellent review of this development describing the important collaborations among public transport actors, car manufacturing companies, refilling station owners and municipalities. They describe 30 years of pre-development where ideas on alternatives shifted from methanol, to methane, to ethanol, and how from this mixture of niche developments a range of pilot projects emerged. Finally, successful initial build-up of ethanol and NG buses and related initial infrastructure development in conjunction with the climate change debate entering the policy-making context led to decisions within Volvo to start producing CNG vehicles (for NG or Biogas) on a commercial basis in the late 1990s. Ford flexi fuel vehicles were at the same time imported starting in 1999 for commercial sale, and in 2004 the decision was taken among both Saab and Volvo to start producing E85 flexi fuel vehicles (Sandén and Jonasson, 2005).

Today a range of models is available and is growing rapidly (see Table 6). Use of several renewable fuels is now gaining momentum and the share of the total vehicle stock at the end of 2006 is almost 2%.<sup>2</sup>

Table 6. Models with novel technologies in Swedish market

ICE-electric hybrids (4 models - Honda Civic, Lexus GS450H and RX400H, Toyota Prius)  
 Bi-fuel/flexi fuel using Ethanol and/or Petrol (17 models – 11 versions of Ford Focus, 4 versions of Saab 9-5, Volvo S40 and V50)  
 Bi-fuel/flexi fuel using Natural gas and/or Petrol (11 models – Fiat Punto, Mercedec-Benz E200NTG, Opel ComboTour CNG, Volkswagen Golf Variat and Tuoran EcoFuel, Volvo S60, S80, V70 both manual and automatic transmission versions)  
 Diesel models certified for RME (7 models from Seat - 2 versions of Cordoba, 3 versions of Ibiza, one Altea, and one Toledo)  
 Fuel efficient, lower than 120g/km (6 models – Citroën C1 1,0, Peugeot 107 1,0, Toyota Aygo 1,0, Smart Fortwo 0,7, Kia Picanto 1,0 Citroën C3 1,6 HDi)  
 Source: The Swedish Consumer Agency

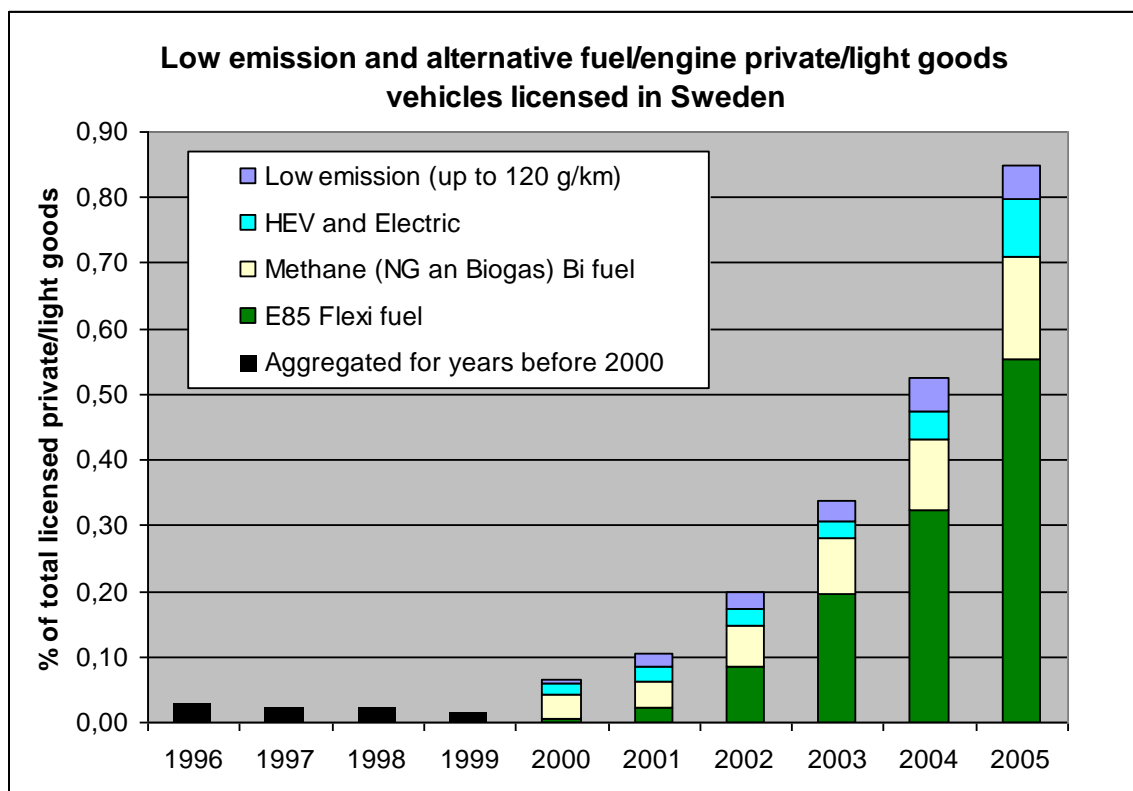
<sup>2</sup> These figures, and the following figures on environmental friendly cars are taken from the following sources unless otherwise stated: Bil Sweden (<http://www.bilsweden.se>), Swedish Association of Green Motorists (<http://www.gronabilister.se>), Miljöfordon.se ([www.miljofordon.se](http://www.miljofordon.se)), The Stockholm trials ([www.stockholmsforsoket.se](http://www.stockholmsforsoket.se)).

The largest quantity of bio-fuels is however used for blending in ordinary petrol and diesel. In 2005 over 90% of petrol sold in Sweden included the maximum 5% allowed level blending of Ethanol, a very rapid growth since the practice started in 2002 (Svenska Petroleuminstitutet, 2006). For diesel the corresponding trend has just started and in 2005 10.5% of the diesel sold included the 5% allowed blending of bio-diesel, or FAME. Hybrid models on the market have a small share in absolute terms, but 2004 and 2005 constituted a breakthrough with doubling of car numbers in the total fleet (see

*Figure 3).*

On the basis of the market development and the policy context presented, it can be concluded that incentives for alternative fuels use have coincided with decisions among car producers and retailers to put vehicles on commercial sale. Furthermore, initial infrastructure is available due to build up in niches, and hybridisation of existing petrol and new alternative-fuel technologies in “flexi”-fuel and “bi”-fuel solutions ensures that consumers will not have to limit use to areas with filling stations supplying the alternative fuel. A steady growth of cars using alternative fuels was established between 2000 and 2004, accounting for a few percent of the total sales. The last year annual sales share of alternative fuel cars increased further, from 4% in 2005 to 13% in 2006. Significantly, this sharp increase correlates with the test period of congestion charges in Stockholm, in which environmentally-friendly cars were exempted from taxation. The sales share of alternative fuel cars for the Stockholm region during 2006 is approximately 20% as reported by the body “Stockholmsförsoeket” evaluating the trials. Since the Stockholm region in turn accounted for nearly half of all alternative-fuel cars sold in 2005, the impact of the trials is far from negligible, also in the national statistics.

*Figure 3. Share of alternative fuels and technologies in the Swedish light vehicle parc*



In terms of novel technologies within transport services an estimated 15-20% of fleet cars for rent are hybrids or alternative fuel cars and the two largest taxi companies in Stockholm have between 10 and

15% hybrids or alternative fuel cars<sup>3</sup>. Fleet cars hence act not only as incubators for pre-development, but also early adopters in the ongoing take-off phase. A recent Swedish example of product-to-service shift is shown by Toyota, who initially introduced their new Aygo model solely as a leasing service, marketing the car towards young consumers with urban lifestyles. The Aygo is a very small car, powered with a 1.0 litre three-stroke engine with only 4.6 l fuel consumption per 100km according to the manufacturer. This corresponds to 109 g CO<sub>2</sub>/km emissions, which is considerably lower than the average European car which emits 162 g CO<sub>2</sub>/km, and almost half the current mean level of 197 g CO<sub>2</sub>/km in Sweden<sup>4</sup>, in turn the highest figure in Europe (Toyota, 2006; European Commission, 2006b). Innovations like Aygo have an important potential contribution to sustainable transport in terms of reduced CO<sub>2</sub> emission compared to the industry average. The recent introduction of Aygo has been a commercial success according to Toyota Sweden (Dahlström, 2006) with double the estimated sales and an established 25% market share of the sub-compact segment. The success of the subscription business model, specifically aimed at younger consumers with the ambition to have a predictable monthly low cost according to Dahlström, account for 60% of the sales. It is now probable that Toyota will expand the concept to other modes and market segments.

### 5.2.2 UK

Table 7. Models with novel technologies in UK market

<p>ICE-electric hybrids (4 models - Honda Civic, Lexus GS450H and RX400H, Toyota Prius)          Bi-fuel/flexi fuel using bio-ethanol and/or gasoline (2 models: Ford Focus flexi-fuel vehicle (FFV), Saab BioPower)          Electric vehicles (2 models: GoinGreen G-Wizz, Peugeot 106 electric)          Liquefied petroleum gas (LPG) (5 models: Vauxhall Astra, Vauxhall Vectra, Vauxhall Zafira, Volvo S/V40, Volvo V40)          Compressed Natural Gas (CNG) (2 models: Volvo S60, Volvo S80)          Bi-fuel/flexi fuel using Natural gas and/or Gasoline (none)          Diesel (most models available in diesel)          Fuel efficient, lower than 120g/km: (30 models: Toyota Prius, Honda Civic hybrid, Citroen C1 petrol, Citroen C1 diesel, Citroen C2, Citroen C3 manual/automatic, Toyota Aygo petrol, Toyota Aygo diesel, Peugeot 107, Smart Fortwo, Daihatsu Charade, Vauxhall Corsa petrol, Vauxhall Corsa diesel manual/automatic, Smart Roadster, Daihatsu Sirion, Fiat Panda, Ford Fiesta 1.6l/1.4l, Smart Forfour, Peugeot 206, Renault Clio, Hyundai Getz, Audi A2, Fiat Grande Punto, Ford Fusion 1.6l/1.4l, Toyota Yaris, Renault Modus)          Source: <a href="http://www.whatyoucando.co.uk/travel_switch">www.whatyoucando.co.uk/travel_switch</a>; <a href="http://www.vccarfueldata.org.uk">www.vccarfueldata.org.uk</a></p>
--

As European car manufacturers have improved vehicle technologies, in line with voluntary EU agreements, vehicles sold in the UK have much lower proportions of local air pollutants than historically. Recent figures show a dip in UK sales of 4 wheel-drive vehicles/SUVs for the first time in several years (Department for Transport, 2005b). Diesel vehicles are much more popular in the UK - accounting for around a quarter of all licensed vehicles (8.6m out of 32.2m) - than in other European countries (Eurostat, 2006; Department for Transport, 2005b). Petrol remains the most popular fuel, with

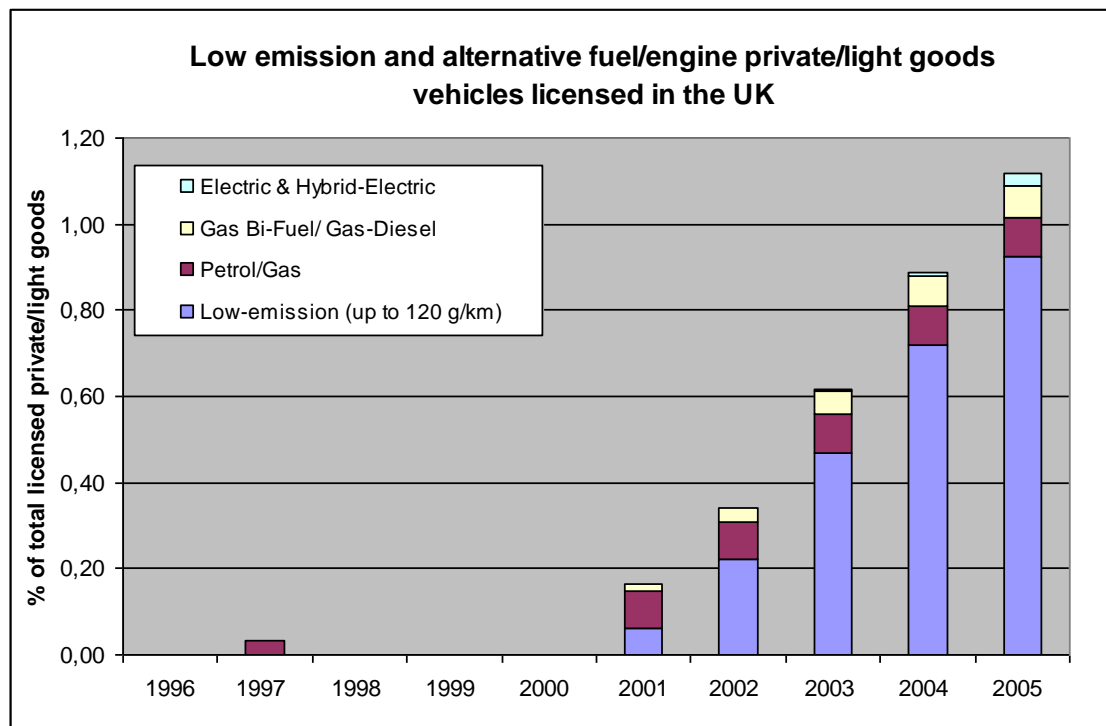
<sup>3</sup> Newsletter from Miljöbilar i Stockholm • 3/2006

<sup>4</sup> The average of 197 g CO<sub>2</sub>/km for Sweden refers to average of vehicle fleet using petrol or diesel, and thus not exempted from the effect of a growing share of alternative fuel vehicles.

23m petrol vehicles currently licensed in the UK. Availability of low-emission vehicles is greater in the UK than in Sweden.

Uptake in the UK of alternative propulsion systems, including electric and hybrid electric, accounts for 14,900 (0.5%) of all licensed vehicles. Alternative transport fuels, including liquefied petroleum gas (LPG), compressed natural gas (CNG), and biofuels, are somewhat more popular: LPG vehicles account for 28,100 (0.9%) of licensed vehicles; CNG vehicles account for 22,900 (0.07%) (Bomb et al., 2006). Uptake of biofuel-vehicles has not yet reached levels of Germany (the highest in the EU). In 2004, biofuels accounted for only 0.06% share of total transport fuels markets in the UK (Bomb et al., 2006). Most of this was domestic low-level bio-diesel production from waste vegetable oil. However, this proportion is likely to increase with the introduction of policy incentives to stimulate biofuel markets, and the recent emergence of a bio-ethanol refuelling infrastructure in two regions of the UK. The UK market is characterised by technology push, with actors driving this potential transition including the UK government, biofuels producers (e.g., farmers) and suppliers, and vehicle manufactures (notably Ford UK); while the public is not playing a significant role (Taylor, 2006; Bomb et al., 2006). “There are signals that the biofuels industry is becoming more organised” in the UK; this emerging industry is “engaged in transforming the institutional infrastructure as well as the physical infrastructure” (Bomb et al., 2006, p.7-8). Oil companies are more supportive of bio-diesel (extending the diesel market) than bio-ethanol (reducing the petrol market); however, currently, all bio-ethanol is imported predominantly from Brazil rather than domestically produced.

Figure 4. Share of alternative fuels and technologies in the UK light vehicle parc



### 5.3 Cultural/behavioural context

Overall, transport demand is rising across Europe: with the highest rises in Ireland and Portugal. While car use is typically increasing in EU-15 countries, new member states generally have lower shares of car use. Decoupling of transport demand and income has been achieved in few countries.

#### 5.3.1 Sweden

In Sweden, transport demand is increasing across all modes, but primarily private car (*Figure 5*). Average kilometres travelled per person per day is 36, slightly higher than the EU-25 average (Strelow, 2006). However, car use as a proportion of total transport demand in Sweden (83%) is slightly lower than average for EU-25. Bus and train use in Sweden accounts for 9% and 8% of travel, respectively. Car ownership is growing in Sweden, with almost one car per 2 residents (Strelow, 2006). In summary, studying car ownership and usage at the aggregate level, the trend is toward higher car dependence. However, applications for new driver licenses are declining amongst the youngest age groups (*Figure 6*). This may highlight an emerging trend for urban lifestyles, observed in Scandinavian countries, which depend on slow and public transport modes (Nenseth, 2005).

### *Teleworking and Internet shopping*

Support for a shift in consumer behaviour towards growth in Niches 2 and 3 can also be found in indicators of utilisation of ICT. ICT for home-shopping has increased rapidly both among individuals and firms: 36% of the population and 66% of companies reported use of internet for purchasing goods or services in 2005. The resulting direct impact on road transportation is difficult to estimate; few figures directly linking ICT development and transport demand can be found. Home working is statistically reported to be at a stable level between 4-7% according to national statistics<sup>5</sup> but the use of video and telecommunications equipment is increasing and roughly 10% of all companies have access to video conferencing equipment (Swedish Institute for Transport and Communications Analysis, 2000; SCB, 2005).

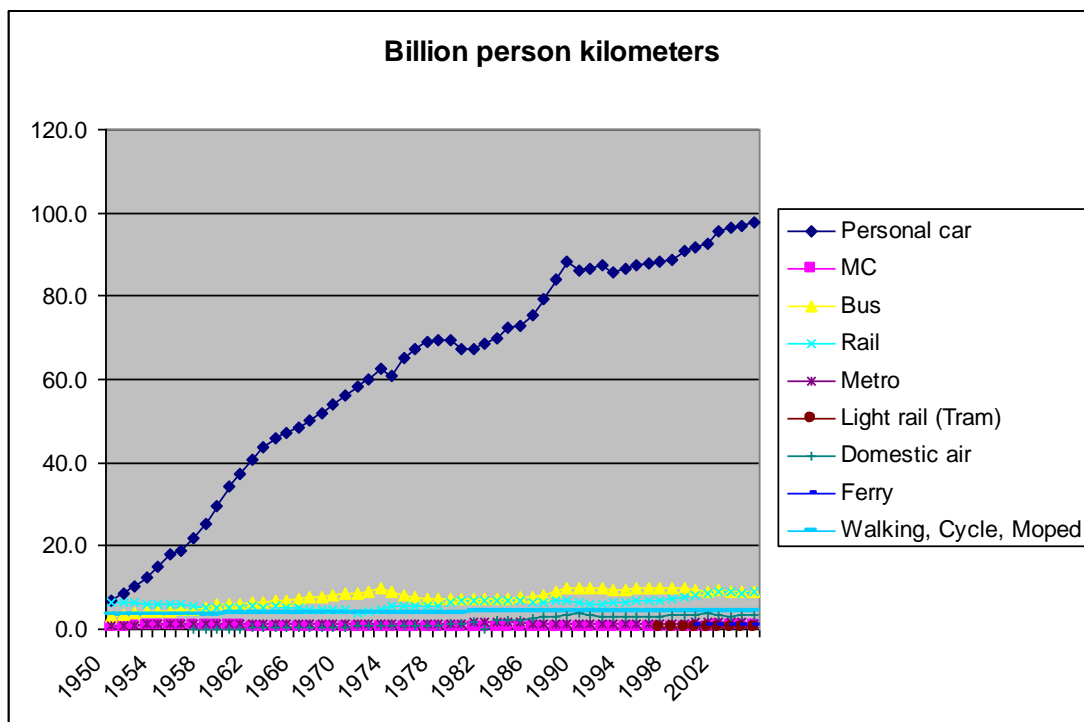
### *Car sharing and car clubs*

A rapid expansion of car sharing can be observed in Sweden (Figure 7). Recent developments in Sweden have established a range of transport service alternatives: Ordinary full-service car rental, communal car sharing organisations (CSO) with a high level of individual commitment for the shared car, and commercial alternatives in between. In Figure 7 estimated total members in car sharing schemes with access to communal and commercial car pools are presented for a selection of years for which data could be obtained through personal communication and media (Markusson, 2006; Malmst rm, 2006; Edenhall, 2005).

### *Car Leasing and Rental cars*

Finally, the trend for rental cars shows an increase in purchased and total number of cars within the sector, but a trend is difficult to estimate. More stable figures in terms of number of purchased services and total turnover in the sector indicate that the trend could be explained by a higher turnover of cars (BURF, 2006). Car leasing is relatively widespread in Sweden and is increasing slowly, from 4.3 % of the total car parc in 1996, to 5.9% in 2005 (Swedish Institute for Transport and Communications Analysis, 2006b).

Figure 5 a. Travel demand in Sweden, by mode



<sup>5</sup>

Figure 5b. Travel demand in Sweden, by mode

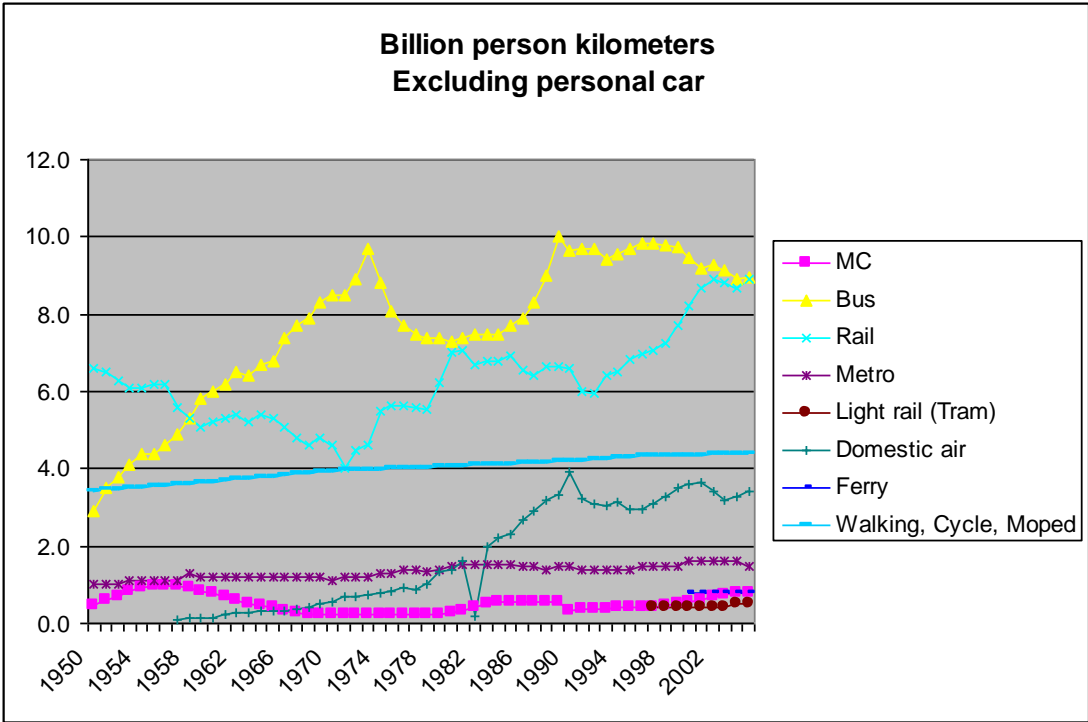


Figure 6. Driving licenses in Sweden by age group

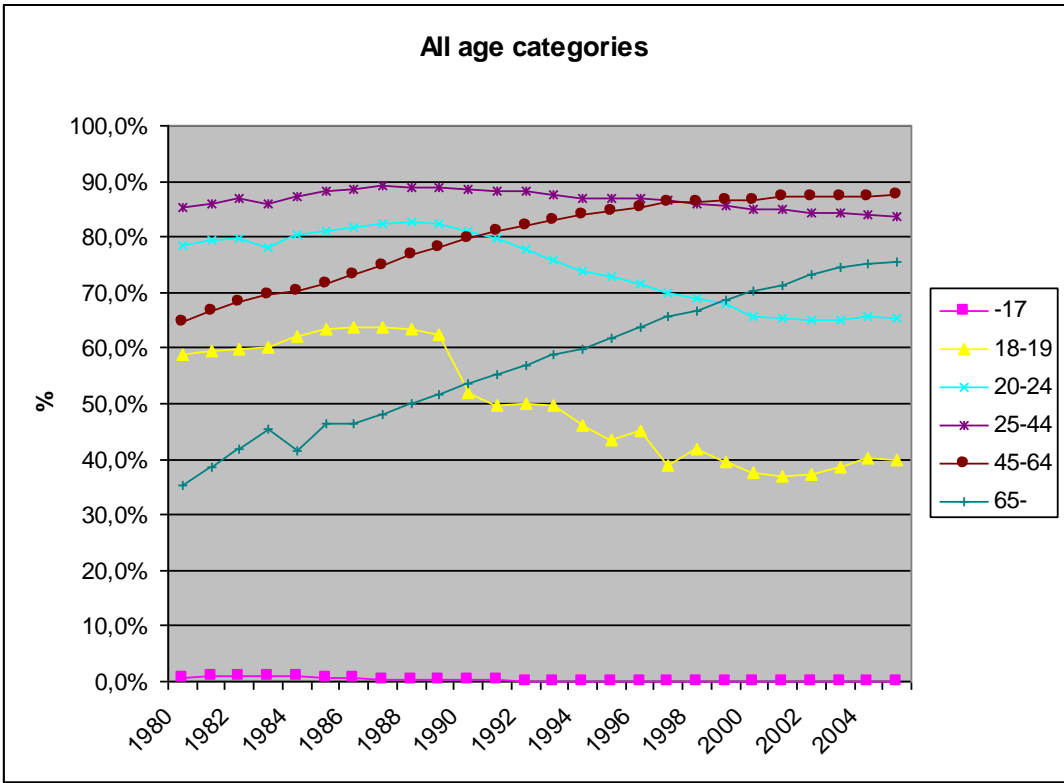
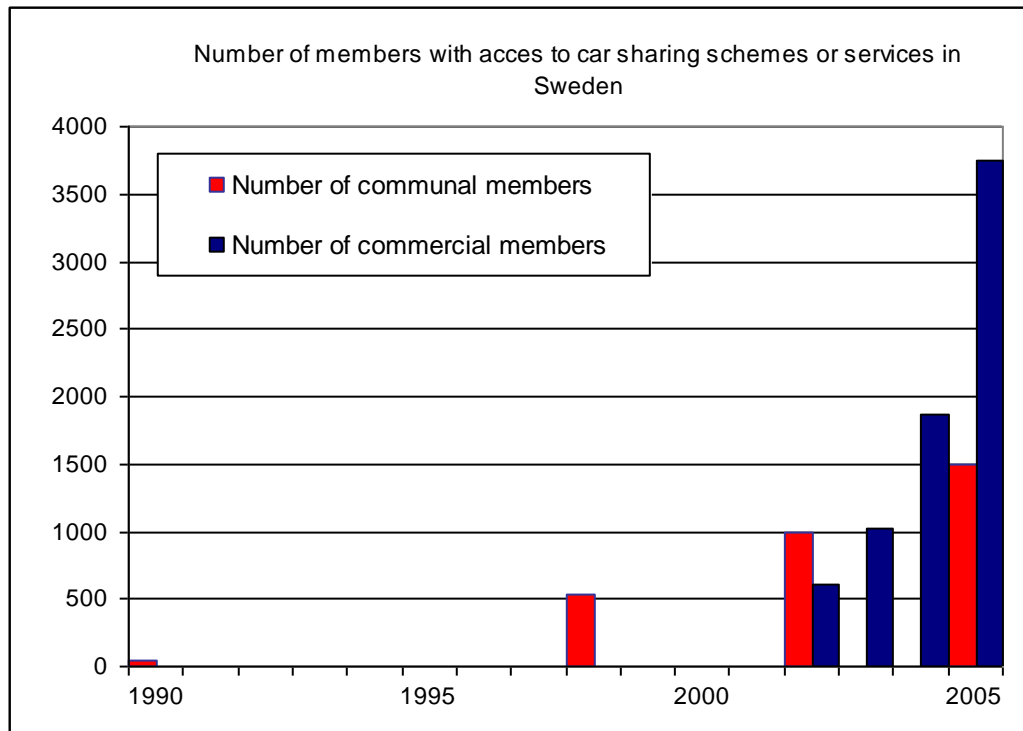


Figure 7. Communal and commercial Car share growth in Sweden



### 5.3.2 UK

Like Sweden, the UK has seen an increase in travel demand in recent years, particularly within private car use (Figure 8). The UK also has similar average levels of kilometres per person per day (36) as Sweden (Strelow, 2006). However, the UK has a higher proportion of car use relative to total transport demand than Sweden, or the EU average, at 88% of passenger kilometres. Consistent with this, public transport use in the UK is lower than in Sweden, with 6% of passenger kilometres accounted for by bus and 6% by train. Levels of walking and cycling ('slow modes') have decreased in the UK by almost 20% since 1990, to amongst the lowest proportions in Europe. This is despite targets to increase them as part of the 10-Year transport plan announced in 2000 (Department for Transport, 2000).

Car ownership is growing more rapidly in the UK than in Sweden, but is around the same level, with almost one car per 2 residents (Strelow, 2006). In 1980, 41% of UK households did not have access to a car; this fell to 26% by 2003. The proportion of households having access to one car has remained stable over the last 25 years, at around 45%. However, the number of households owning two or more vehicles has increased significantly from 13% in 1980 to over 25% by 2003 (Department for Transport, 2005b).

Nevertheless, as in Sweden, the proportion of younger people applying for drivers' licenses is dropping (Figure 9). Between 1990 and 2004, the percentage of 17-20 year-olds who held a licence fell from 43% to 26%. The UK Department for Transport (2005b) suggest this may be because the driving test has become more difficult (now involving a written theory examination, as well as a practical test; indeed, pass rates have dropped from 47% to 42% between 1994 and 2004) and/or increased costs of driving lessons and vehicle insurance. It is interesting to speculate about whether there is an emergent cultural shift away from the 'car-culture', as suggested by Nenseth (2005).

### Car sharing and car clubs

The UK has seen a gradual increase in the establishment of car share schemes and car clubs in the past 5-10 years, although levels have not yet reached those of Germany and Switzerland. A recent Department for Transport study (2004) found some 480 reported UK-based 'closed' (i.e. (organisation-based, local, or regional) car sharing schemes (including groups of closed schemes within open car

sharing schemes); over 40 'open' car sharing schemes; and 29 reported UK based car club schemes (of which 26 were active). Car clubs involve flexible access to hire of a vehicle; while car shares involve a driver and passenger(s) travelling from and to similar locations, and are often implemented as part of an organisational 'travel plan' to reduce car use.

#### *Car leasing*

Car leasing is widely available in the UK for both business and personal transport, offering consumers a means of running a new car for 2-4 years and then exchanging it for a new one (e.g., [www.carleasing.co.uk](http://www.carleasing.co.uk), [www.leaseacar.co.uk](http://www.leaseacar.co.uk)). Furthermore, a 'green' taxi company has recently opened in London: fleet cars are ICE-electric hybrids and all emissions are offset, while it claims that fares are no higher than other taxi firms ([www.greentomatocars.com](http://www.greentomatocars.com)).

#### *Teleworking*

The UK government estimates that 8% of the workforce (3.1 million people) work from home or use their home as a base for work; this proportion has doubled since 1997 (Office for National Statistics, 2005). Of this total, 2.4 million can be considered 'tele-workers' (using a telephone and computer for their work), almost two-thirds of whom are self-employed and most of whom are professionals and managers. This is higher than the average EU-10 (see Figure 10), but lower than Sweden. The Institute of Employment Studies estimates that 22.6% of the workforce could potentially telework, the highest in Europe (cited in Hotopp, 2002).

#### *Internet shopping*

The proportion of UK households with internet access at home has risen significantly in recent years: from around 10% in 1999 to 42% in 2002. Furthermore, the proportion of adults using the internet to buy goods and services is also increasing. UK government survey in March 2002 (Office for National Statistics, 2002) found that, of the 46% of adults who had accessed the internet during the past month, 38% ordered tickets, goods or services or searched for information related to education (a higher proportion browsed for information on services or goods). The most popular purchases were flights and holiday accommodation, books or magazines, tickets for events, and music or CDs. The survey also found that the main reasons for never having used the internet for shopping was concern for security or a preference for shopping in person. In February 2004, the figure had risen to 47% and in February 2005 it rose again to 56% (Office for National Statistics, 2006).

Figure 8a. Travel demand in the UK, by mode

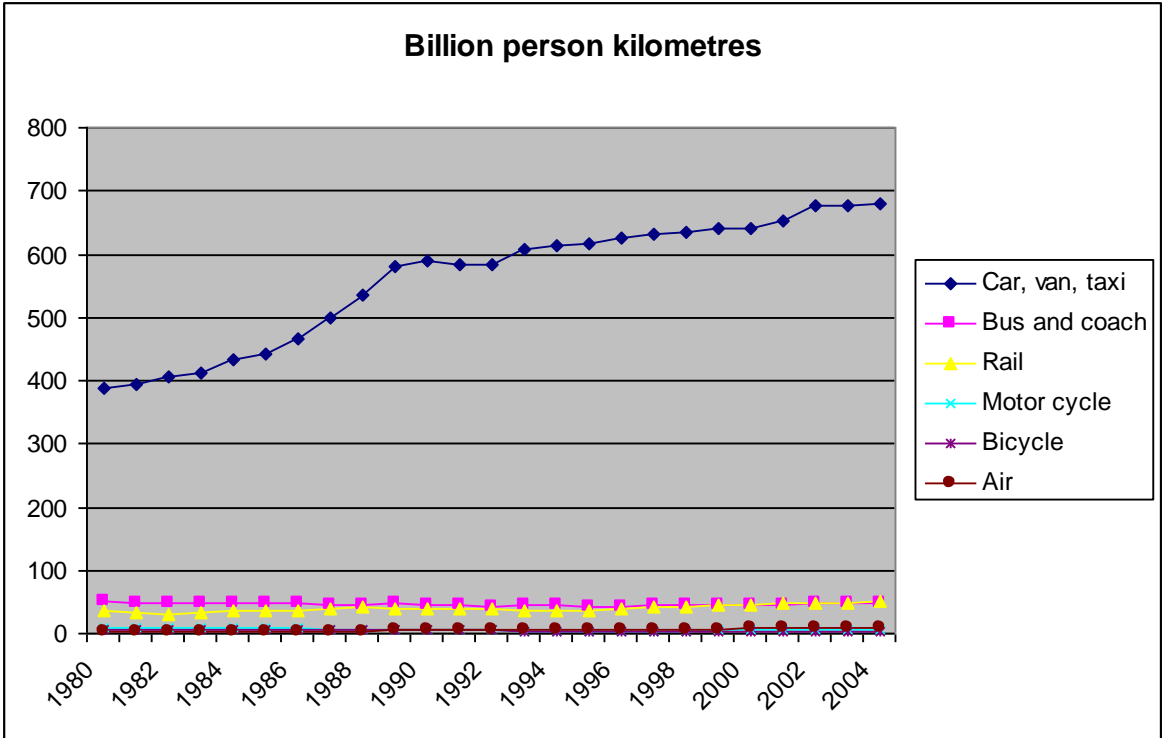


Figure 8b. Travel demand in the UK, by mode

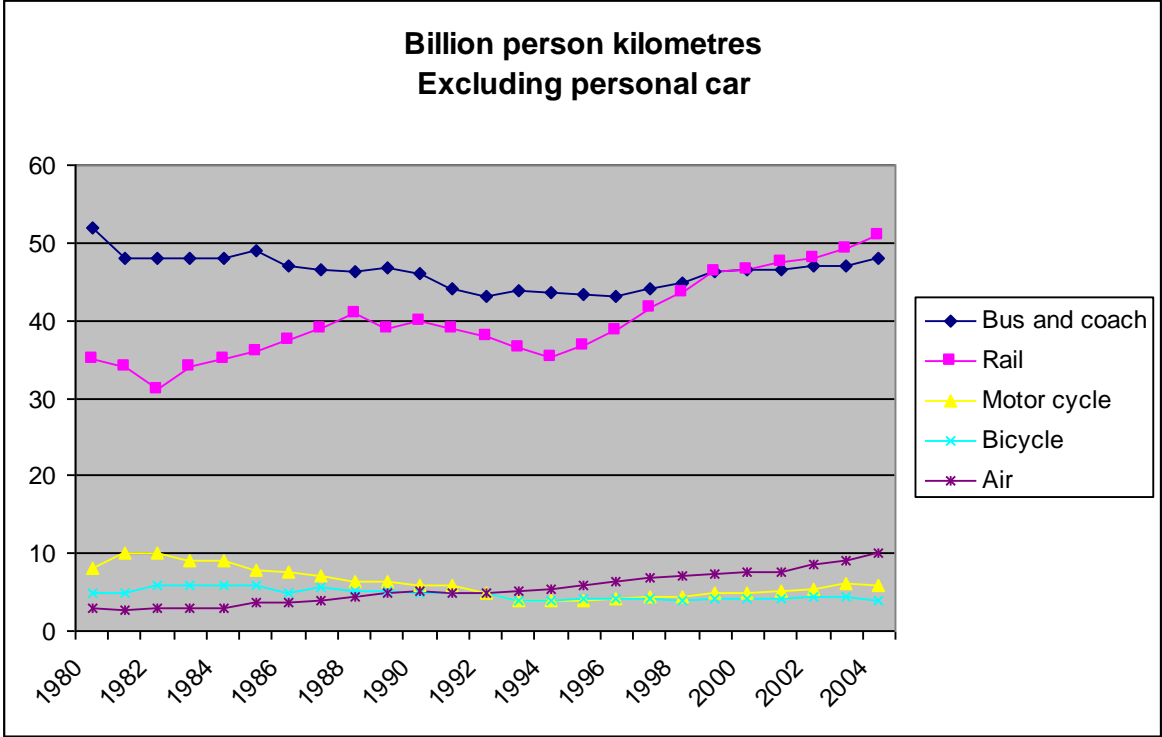


Figure 9. Driving licenses in the UK, by age group

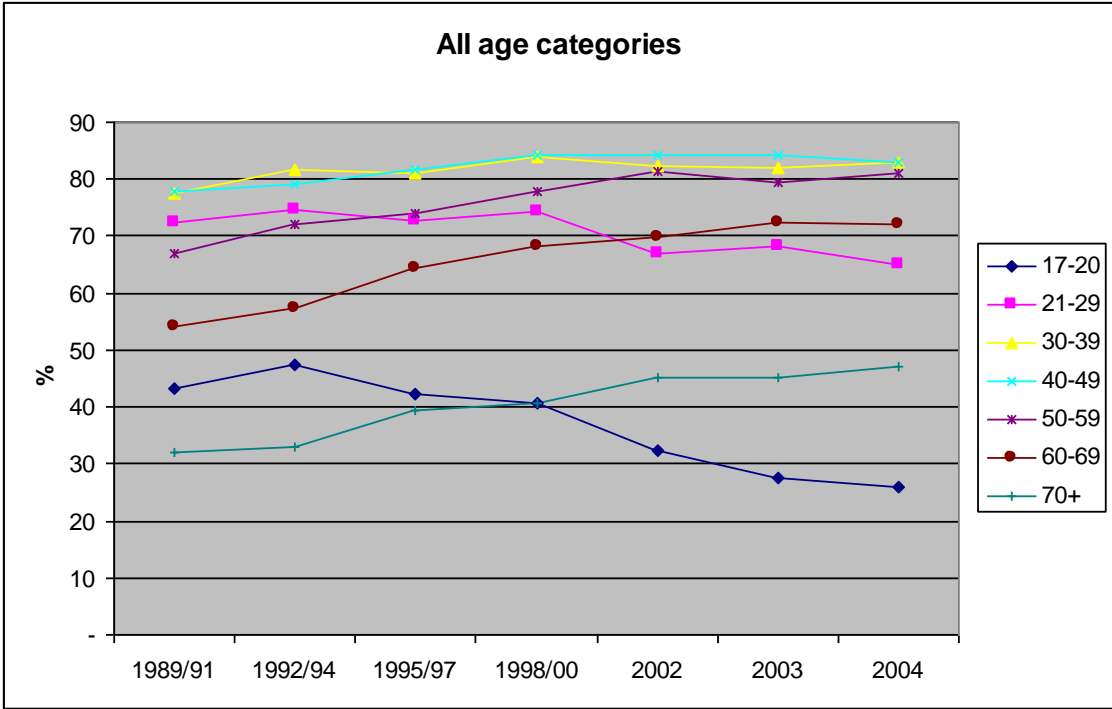
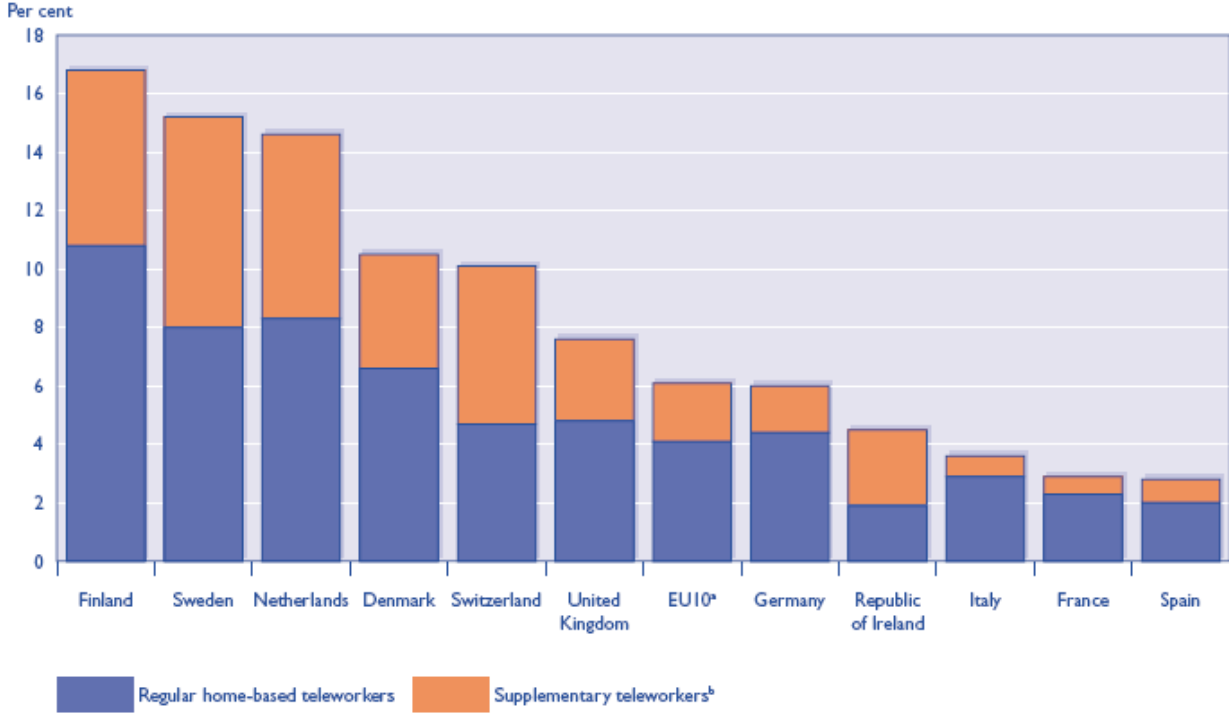


Figure 10. Teleworking in Europe



Source: Electronic Commerce and Telework Trends

a The EU10 figure is an average of the ten EU countries represented in the chart. It does not include Switzerland.

b Home-based teleworkers who spend less than one full day teleworking from home a week.

#### **5.4 Summarising empirical evidence**

In Sweden, a takeoff in Niche 1 development can be observed. Several new technologies are gaining momentum and figures suggest a rapid growth for current year and near term future. Although the Niche shows strength this trend is still in its infancy and impacts have yet not materialised in terms of lower average CO<sub>2</sub> emissions. Sweden still remains the top CO<sub>2</sub> emitter per vehicle in the EU. The next few years will determine if the trend can continue to accelerate, and have a true impact on the regime. Some notable Niche 2 activities and indicators such as increased car service, reductions in number of young attaining driving licence, and successful congestion charges support the image of active ongoing pre-development. However, dependence on cars is still evident, with most of the increase in travel demand satisfied by cars. Within Niche 3, there are positive trends, but so far few indicators supporting the suggestion that increased use of ICT for home-shopping and home-working contributes to reduced travel demand. In terms of slow modes, no substantial increase is visible and considering population growth the sector is in decline. There are also drivers acting against Niche 3 development, such as continued urban sprawl. In summary, although there is a growing awareness of this potential, few policies effectively foster a Niche 3 development, with the trial of congestion charges in Stockholm as a notable exception.

In the UK, the empirical evidence suggests a slower growth in Niche 1 activities than in Sweden. Nevertheless, sales of low-emission and (to a lesser extent) alternative fuel/engine vehicles are increasing and diesel cars remain very popular. As the biofuel infrastructure and industry develops this will facilitate market growth further in this area. The evidence for Niche 2 activities is somewhat ambiguous: while rail travel, car clubs and car shares are becoming more popular (as congestion and parking become more problematic), urban public transport use (e.g., buses) is somewhat declining while private car use continues to increase. Niche 3 data is similarly ambiguous: while home working and shopping are increasing, walking and cycling (slow modes) are declining. The political context in the UK - transport, energy and climate policies - may provide more support for development of all three niches, particularly if more powers are devolved to local authorities to implement schemes such as the London Congestion Charge.

Summing up, pre-development of several Niche 1 technologies is ongoing, while other novel technologies (notably biofuels in Sweden; and low-emission vehicles in UK) are already reaching the take-off phase. Niche 2 shows positive developments, but is still very much characterised by pre-development. Finally, developments of ICT in Niche 3 may support sustainable transport, yet slow modes are in decline.

## **6 Ongoing and future Niche accumulation within and between Niche 1, 2, and 3**

Merging the analysis of the three discussed niches on novel technologies, a product to service shift, and trends in cultural and behavioural change, a basis for a more integrated analysis of future sustainable pathways for transport is established. In this section we try to highlight some key ongoing and potential niche-accumulation and hybridisation processes between the niches, and how such development contributes to the understanding of pathways to more sustainable transport.

### **6.1 Niche accumulation within the alternative fuel sector and importance of Niche 2 development**

The current first generation of bio-fuels (ethanol, methane, and bio-diesel) paves the way for a second generation of more efficient synthesised biofuels such as DME and FTD (See Table 2), and energy carriers such as Hydrogen and Methanol. Furthermore, experiences with the gaseous fuel methane in terms of NG and Biogas and experiments with hydrogen-rich fuels such as Hythane (Natural gas enriched with hydrogen), are an important interim step toward wide-scale use of hydrogen as an energy

carrier. Potential use of old methane infrastructure for Hydrogen supply and experience of gaseous fuels in general in terms of on-board storage, safety, and refuelling technologies, constitutes learning and potential technological add-on within Niche 1. There is also compatibility between bio-fuel development and the current (fuel/vehicle/auto-mobility) regime (Bomb et al., 2006). Similarly, as previously discussed, hydrogen and FC technologies are aligned with (developed within) the regime and early niche applications with respect to these technologies, such as fuel cells for idle electricity generation in trucks (<http://www.powercell.se>), could pave the way for initial infrastructure build up.

## **6.2 Importance of Niche 1 and 2 co-evolving**

The growth of new technologies and alternative fuels are ensured by a range of policy incentives, tighter regulations on particulate emissions, climate change policies etc. However, crucially, taxi fleets and public transport fleet experiments create initial infrastructure build-up and initial demand for new technologies. Furthermore, both car sharing schemes and rental cars can act to further promote new technologies. This is indicated in ongoing developments in Sweden where one of two actors in commercial car sharing uses environmental friendly cars only<sup>6</sup>, larger taxi companies continuously act as forerunners in procurement of alternative fuel and engine systems, and Toyota have implemented the subscription business model of the highly efficient Aygo model. That car services are in fact able to decouple engine size from travel service to some extent is also supported in the study by Prettenhaler and Steininger (1999). Even though impact of this trend so far is relatively small, this co-evolution between Niche 1 and 2 acts as an important driver for new technologies and will do so also in the future. A continued product to service shift, strengthening car services procurement and car sharing could speed up diffusion of future technologies. Seemingly, alternative means of purchasing car services encourages new low cost and thus fuel efficient technologies.

## **6.3 Information Technology as a driver in all three niches**

By itself the car industry is unlikely to push for broad market introduction of alternative novel technologies. Regulation, developments in other sections, notably ICT, and market demand (e.g., for functionality, branding, and new services) are key drivers for innovation as the car manufacturing industry has entered a mature state (Köhler et al., 2007; Seidel et al., 2005). In particular, ICT and demand for additional functionality may lead to innovation in vehicles as mobile power platforms (e.g., Kurani, Turrentine, Heffner, and Congleton, 2003), in turn creating new support for electric drive trains found in HEVs and BEVs, or FCVs. In the transport service niche, ICT enables new functionality in simplifying car sharing and car pool coordination. ICT is also a key driver in our third niche studied, offering communications solutions for potentially reducing transport need per se, but more importantly, restructuring culture and enforcing urban lifestyles through growing use and interests in ICT throughout life and reducing importance of car ownership.

As ICT acts as a driver in all three niches discussed, innovations associated with one of our discussed niches, could affect development in one or both of the others. Hybridisation and accumulation of ICT solutions between these different niches could be a driver for further development within the niches.

## **6.4 Electric drive train development**

An electric drive train could support new functionalities and create opportunities for niche accumulation. From a technological transition point of view, hybridisation and technological add-on between HEV, FC and alternative fuels are relevant here, and each of the technological options discussed in the literature constitutes innovative elements that enable further expansion, also for other related technological options in turn. With a growing share of the car fleet using an electric drive train, other opportunities for niche-accumulation and hybridisations could emerge. Research highlights HEV

<sup>6</sup> Sunfleet - <http://www.sunfleet.com/>

as an interim step to a plug-in HEV version acting as a purely electric car for longer distances before engaging the ICE. Furthermore, there is potential for plug-in cars to act as a buffer to energy system demand peaks (Kempton and Tomic, 2005). Finally, such niche accumulation could act as important first steps toward more advanced and automated electrified transport systems. With a large share of cars equipped with an electric drive train, and standards being developed, electrified highways, dual mode systems and other more futuristic options are one step closer to being realised (e.g., see Elzen, 2005).

### **6.5 Lifestyle change niche affecting other niches**

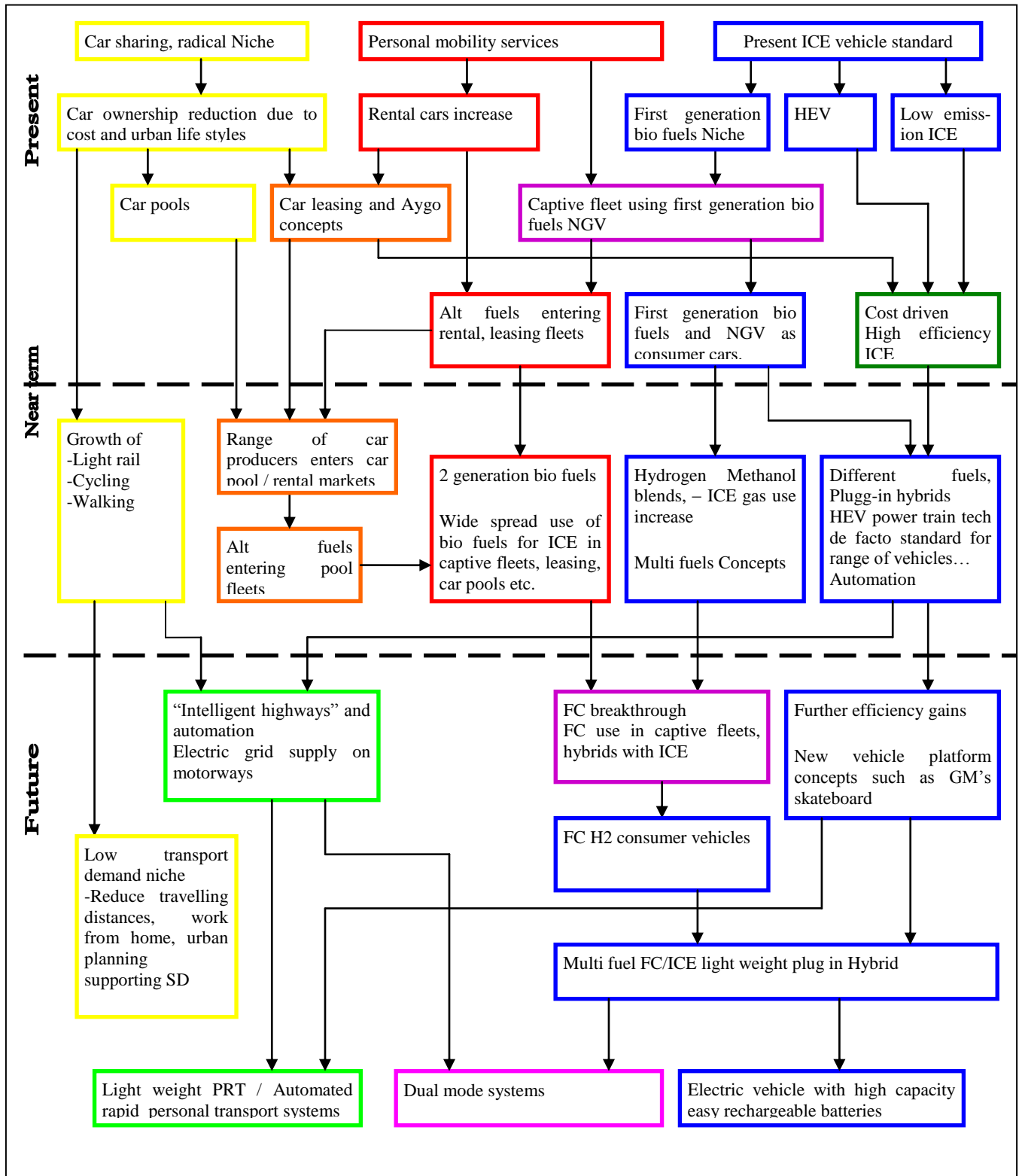
Behavioural and cultural changes within Niche 3, reinforced through wider landscape pressures and weakening of the transport regime, could act to reduce transport demand slowly in the mainstream through processes of social learning and imitation (Bandura, 1971). Hence, development internal to a radical Niche could spread values and environmental concerns to other consumers groups and encourage car manufacturers to speed up investments in new technologies through learning about innovations (cf. Smith, 2005). Existing links can also be exploited to develop more coherent networks of actors: for example, as mentioned, Niche 3 has obvious links with the product-to-service niche (Niche 2), which - in contrast to the current regime - also attaches little value to vehicle ownership.

### **6.6 Future niche accumulation and radical innovations**

The ongoing and potential niche-accumulation processes discussed above highlight pathways to more sustainable transport solutions and use. In the following figure we have tried to illustrate both ongoing developments and some extended niche-accumulation and hybridisation possibilities between the discussed niches that could help introduce sustainable transport options. The purpose is to illustrate niche-accumulation and hybridisation processes that enable development and growth within and between the three niches. Illustrated pathways (arrows) and solutions (boxes) in the lower half of the figure are not to be interpreted as predictions but rather as possibilities that could enable more radical future sustainability solutions, considering evidence of similar ongoing and past processes. All three niches include potential 'end states' i.e. solutions that offers sustainable means of transport.

The figure is divided in three. The top section is ongoing; the middle section is near term development; and the lower section is possible longer-term niche development. Niche 1 is coded in blue boxes, Niche 2 in red and Niche 3 in yellow. When important (ongoing or potential) hybridisation in between them occurs, boxes are coded in respective mixes of colours.

Figure 11. Ongoing, near term and future niche-cumulation within sustainable transport



## 7 Conclusions

In this paper, we have outlined a number of serious and persistent problems in the current transport system, which suggest a need for a ‘transition’ - radical systemic change - towards sustainable transport. Furthermore, we have proposed three alternative niches which may lead us towards a more sustainable transport future in Europe, and examined evidence of the development of these niches in two European countries: UK and Sweden.

### 7.1 Theoretical implications

We believe that discussions of pathways to sustainable transport benefit from transition concepts such as niche and regime because they highlight important relationships between societal actors and trends which contribute to innovation and future development. Furthermore, temporal concepts of pre-development, take-off and acceleration have enabled us to explore the dynamics and potential of different innovations.

Although we have focussed on niche development as a mechanism for transition to sustainable transport, we acknowledge that there may be circumstances in which transitions occur with minimal or no involvement of niche activities (Geels and Schot, 2005; de Haan and Rotmans, 2006). The historical evidence indicates, however, that niches - whether in symbiotic or antagonistic relationship with the regime - typically play a role in most transitions as they represent the source of radical innovation. Furthermore our discussion of the current transport regime's responses to landscape pressures indicates their reliance on niche innovation to adapt adequately. However, although we have highlighted various commonalities between and within our three niches, we have also found that actors within each niche do not necessarily have the same interests or compatible activities. In Niche 2 and 3 in particular, our empirical evidence highlighted several diverging trends which indicates these niches are unlikely (yet) to offer a coherent or stable alternative to the incumbent regime. This finding may indicate a weakness in our definition of these niches (and that alternative boundaries should be drawn around the transport innovations discussed), or that these groups will constitute more stable and inter-dependent networks over time. Indeed, since the regime may be more or less aligned or stable over time, instability or inconsistency within the niches need not undermine the validity of our analytical framework.

### 7.2 Determinants of sustainable transport and implications for policy making

What have we found to be the determinants, or necessary conditions, for emergence and growth of sustainable transport niches? Firstly, they are determined by *landscape* pressures - environmental (e.g., climate change), economic (e.g., oil prices, automotive markets) and cultural (value/behaviour change) - which in turn impact on policies at national and European level. At the *niche* level, there is interest in exploiting opportunities arising from these trends (for example amongst agricultural and emerging biofuel industries). *Regime* actors are also beginning to respond to these pressures, and exploit technological opportunities and new markets (e.g., biofuels, HEV), and gearing up investments in even more radical technologies (e.g. hydrogen fuel cell vehicles); although there is evidence of misalignment and tensions between this group of heterogeneous actors. The regime is limited, however, in its capacity to respond to landscape pressures: for example, existing refuelling infrastructure and automotive expertise is not compatible with hydrogen transport technology development.

Such barriers to a transition can be partly avoided through ‘hybridisation’. New hybrid solutions have both the existing standard and the advantages of new solutions (e.g. HEV and flexi fuel solutions). Similarly, accumulation of concepts and solutions between the niches opens up further radical development (e.g. product to service shift combined with new technologies).

Retaining the diversity of niches is important: combined policy and incentives, tax levels, and R&D encourage breadth of niche development. Different technological solutions are developed in parallel and finally a series of developments enables one of the technologies to break through. This is consistent

with the notion of Strategic Niche Management (Kemp, Schot, and Hoogma, 1998), and notably the conditions for development within Niche 1 are now in favour of a breakthrough finally challenging the regime that was very stable in 1998 when Kemp, Schot and Hoogma analysed the transport sector.

It has been shown that CO<sub>2</sub> emission reduction is less costly and more efficient if renewable energy primarily is used in other sectors than for road based transportation. (Azar et al., 2003; Hammerschlag and Mazza, 2005). These conclusions strengthen the arguments that it is dangerous to impose radical change, potentially building up new lock-in effects, with technologies using renewable energy where it is not as efficient as possible. In the end the transport sector has to undergo a wider transformation in order to become sustainable. However, as we have discussed in this article we argue that a regime change in the transport sector toward sustainability is best done when options are still kept open, with a wide range of Niches adding up and co evolving, using niche independent policies that foster such development.

Such policies must be seen to be effective by citizens if they are to be accepted and change attitudes and behaviour: the London Congestion Charge was not widely supported until it was introduced and seen to work. The same trend in acceptance could be seen during the experiment period for the Stockholm Congestion Charges. Policy measures that are less visible, such as fuel taxation, may not be as effective since their impact is less direct and less obvious. Furthermore, congestion charging is an example of a policy that supports development in all three Niches: in Niche 1 – through exemption of tax for novel technologies; in Niche 2 – since the charges constitute an incentive for shifting to public transport; and finally in Niche 3 – through cost increase for unnecessary travelling inducing reduced travel demand. We identify two ways in which effective policies supporting a transition could be introduced. Firstly through gradual accumulation of initiatives guiding consumers toward alternative choices. In Sweden a range of such incentives and taxes has encouraged change since late 1990 when climate change became a prioritised policy issue and the first commercial alternatives to petrol cars become available. A similar process is taking off in the UK. Secondly, a single, more visible, and initially more controversial policy measure such as congestion charges can be decisive and have a broad range of impacts over different sectors than the primary one targeted, fostering wide niche development in unexpected sectors. The impact of the Stockholm Congestion Charges on environmental car sales in Stockholm has been notoriously underestimated.

Finally, we conclude that the role of European policy has not been straightforward. In many respects, the EU has been a driver of UK environmental policy development; however, it has in some aspects hampered development in Sweden – for example, through not including the transport sector from the start in the CO<sub>2</sub> trading scheme. A recent committee assessed the possibility to press ahead unilaterally, but concluded it would be difficult within the present agreement and with uncertain economic impacts on Sweden's economy, being the sole forerunner (Statens Offentliga Utredningar, 2005b, p70). A key role for Europe is to act on issues where lack of harmonisation among member states opens up for critique the often argued 'cost of being the forerunner'.

### **7.3 Achieving multiple sustainability goals**

Sustainability in road transport also means relative sustainability in other sectors (cf. Whitmarsh and Wietschel, 2006), and indeed wider changes within society. Furthermore, since sustainable transport is a contested notion, it is important to foster participatory and integrated approaches to policy-making. No one policy can achieve the range of sustainable transport criteria outlined earlier; rather cross-sectoral policies and multi-stakeholder dialogue are required.

In this paper we have firstly addressed the three niches separately, and then discussed future co-evolution among them. It is unlikely that any one niche alone will be able to achieve sustainable transport: each contributes to different aims. For example, technology alone may not be able to provide the required emissions reductions to mitigate climate change (CST, 2001); furthermore, it does not

address problems of congestion, obesity, and social exclusion, although it may provide the most economic opportunities of the three niches.

Much more radical solutions are needed in order to reach a sustainable transport future. It is impossible to project such solutions, but we have tried to outline some potential pathways and argued for the importance of supporting the breadth of solutions. A future sustainable transport sector probably includes both reduced demand through reorganisation of travelling patterns, alternative lifestyles and consumption patterns, and radical technical solutions.

#### **7.4 Further work**

The empirical findings from this research will be applied in simulation models of transitions to sustainable transport, currently being developed within WP9 of MATISSE (see Bergman et al., 2006). Potential “end states” of a sustainable transport transition will also be further examined, particularly drawing on stakeholder visions (e.g., Whitmarsh and Wietschel, 2006).

## 8 References

- Ahman, M. (2001). Primary energy efficiency of alternative powertrains in vehicles. *Energy*, 26(11), 973-989.
- Appleyard, D. (1981). *Livable Streets*. Berkeley, CA: University of California Press.
- Azar, C., Lindgren, K., et al. (2003). Global energy scenarios meeting stringent CO2 emissions constraints - cost-effective fuel choices in the transportation sector. *Energy Policy*, 31(961-976).
- Bandura, A. (1971). *Social Learning Theory*. Morristown, New Jersey: General Learning Press.
- Bergman, N., Haxeltine, A., Whitmarsh, L., Köhler, J., Schilperoord, M., and Rotmans, J. (2006). Modelling transition patterns and pathways. *Manuscript in preparation*.
- Black, C., Collins, A., and Snell, M. (2001). Encouraging walking: the case of journey-to-school trips in compact urban areas. *Urban Studies*, 38(7), 1121-1141.
- Bomb, C., McCormick, K., Deurwaarder, E., and Kaberger, T. (2006). Biofuels for transport in Europe: lessons from Germany and the UK. *Energy Policy*(in press).
- Bulkeley, H., and Rayner, T. (2003). New Realism and local realities: transport planning in Leicester and Cambridgeshire. *Urban Studies*, 40, 35-55.
- BURF. (2006). Biluthyrningsbranschens Riksförbund. Retrieved 2006-10-26, from [www.burf.se](http://www.burf.se)
- Cairns, S., Sloman, L., Newson, C., Anable, J., Kirkbride, A., and Goodwin, P. (2004). *Smart Choices - Changing the way we travel*. London: Department for Transport.
- Caroline J. Rodier, R. A. J., David R. Shabazian. (1998). Evaluation of advanced transit alternatives using consumer welfare. *Transportation Research Part C*, 6, 141-156.
- Christian Bomb, K. M., Eqout Deurwaarder, Tomas Käberger. (Article in press). Biofuels for transport in Europe: Lessons from Germany and the UK. *Energy Policy*.
- Cedersund, H.-Å., and Henriksson, P. (2006). En modell för att prognostisera ungdomars körkortstagande. *VTI: 44*.
- Dahlström, B. (2006). Press secretary, Toyota Sweden AB. Stockholm.
- de Haan, J., and Rotmans, J. (2006). Pillars of change: A dynamical theory of societal transitions. *Manuscript in preparation*.
- (2003). *Digest of Environmental Statistics*. London: HMSO.
- DEFRA (Department for Environment Food and Rural Affairs) (2006). *Climate Change: The UK Programme 2006*. London: HMSO.
- Department for Transport. (2000). *Transport 10 year plan*. London: TSO.
- Department for Transport. (2004). *Making Car Sharing and Car Clubs Work: Final Report*: Department for Transport: [www.dft.gov.uk](http://www.dft.gov.uk).
- Department for Transport. (2005a). *Home Zones: Challenging the future of our streets*: Department for Transport: [www.dft.gov.uk](http://www.dft.gov.uk).
- Department for Transport. (2005b). *Transport Statistics Great Britain, 31st Edition*. London: TSO.
- Department for Environment Food and Rural Affairs. (2005). *UK Government sustainable development strategy*. London: Stationery Office.
- Department of the Environment Transport and the Regions. (1998). *A New Deal for Transport: Better for Everyone*. London: TSO: [http://www.dft.gov.uk/stellent/groups/dft\\_about/documents/page/dft\\_about\\_503890.hcsp](http://www.dft.gov.uk/stellent/groups/dft_about/documents/page/dft_about_503890.hcsp).
- Dosi, G. (1984). *Technical Change and Industrial Transformation*. London: Macmillan.
- Edenhall, Y. (2005). Bilpooler rullar på som alternativ. *Svenska Dagbladet*, p. 66.
- Enoch, M. P., and Taylor, J. (2006). A worldwide review of support mechanisms for car clubs. *Transport Policy*, 13(5), 434-443.
- Elzen, B. (2005). Socio-technical scenarios: A new method to explore transition paths towards sustainable mobility. Paper presented at the 6th Open Meeting of the Human Dimensions of Global Environmental Change Research Community, Bonn, October 9th-13th.
- European Commission (2001a). *European transport policy for 2010: time to decide. White Paper*. Brussels: European Commission.

- European Commission (2002). *Environmental technology for sustainable development. COM (2002)122*. Brussels. Available from: [http://ec.europa.eu/environment/docum/02122\\_en.htm](http://ec.europa.eu/environment/docum/02122_en.htm): European Commission.
- European Commission (2006a). *CARS21 A Competitive Automotive Regulatory System for the 21st century: Final Report*. Luxembourg: Office for Official Publications of the European Communities.
- European Commission. (2006b). *COM(2006) 463 final: Implementing the Community Strategy to Reduce CO2 Emissions from Cars: Sixth annual Communication on the effectiveness of the strategy*. Brussels: European Commission: [http://ec.europa.eu/environment/co2/pdf/com\\_2006\\_463\\_en.pdf](http://ec.europa.eu/environment/co2/pdf/com_2006_463_en.pdf).
- European Environment Agency (2005). *The European Environment - State and Outlook 2005*. Copenhagen: European Environment Agency.
- European Environment Agency (2006). *Transport and environment: facing a dilemma. TERM 2005: indicators tracking transport and environment in the European Union*. Copenhagen: European Environment Agency. Available from: <http://europa.eu.int>.
- Freeman, C., and Louçã, F. (2001). *As Time Goes By*. Oxford: OUP.
- Geels, F. W. (2002). Technological transitions as evolutionary reconfiguration processes: a multi-level perspective and a case-study. *Research Policy*, 31(8-9), 1257-1274.
- Geels, F. W. (2005a). Processes and patterns in transitions and system innovations: Refining the co-evolutionary multi-level perspective. *Technological Forecasting and Social Change*, 72(6), 681-696.
- Geels, F. W. (2005b). *Technological Transitions and System Innovations: A Co-evolutionary and Socio-Technical Analysis*. Cheltenham: Edward Elgar.
- Geels, F. W., and Schot, J. (2005). Taxonomy of transition pathways in socio-technical systems. Paper presented at the *Paper presented at workshop by the ESRC Sustainable Technologies Program*, London, 12th May.
- Gibbons, M., Limoges, C., Nowotny, H., Schwartzman, S., Scott, P., and Trow, M. (1994). *The new production of knowledge: the dynamics of science and research in contemporary societies*. London: Sage.
- Gibson, R. B., Hassan, S., Holtz, S., Tansey, J., and Whitelaw, G. (2005). *Sustainability assessment: Criteria, processes and applications*. London: Earthscan.
- Giddens, A. (1984). *The Constitution of Society: Outline of the Theory of Structuration*. Berkeley: University of California Press.
- Glaister, S. (2002). UK transport policy 1997-2001. *Oxford Review of Economic Policy*, 18(2).
- Goodwin, P., Cairns, S., Dargay, J., Hanly, M., Parkhurst, G., Stokes, G., et al. (2004). Changing travel behaviour. Paper presented at the *Presentation given at the Bloomsbury Theatre*, London.
- Gröna Bilister. (2006). *Miljobilenz Varld: September 2006*. [http://www.gronabilister.se/public/file.php?REF=6da37dd3139aa4d9aa55b8d237ec5d4a&art=321&FILE\\_ID=20060904133559\\_1\\_3.pdf](http://www.gronabilister.se/public/file.php?REF=6da37dd3139aa4d9aa55b8d237ec5d4a&art=321&FILE_ID=20060904133559_1_3.pdf).
- Hammerschlag, R., and Mazza, P. (2005). Questioning hydrogen. *Energy Policy*, 33(16), 2039-2043.
- Hekkert, M. P., Hendriks, F., et al. (2005). Natural gas as an alternative to crude oil in automotive fuel chains well-to-wheel analysis and transition strategy development. *Energy Policy*, 33(5), 579-594.
- Hoffman, P. (2001). *Tomorrow's Energy: Hydrogen, Fuel Cells and the Prospects for a Cleaner Planet*. Boston: MIT Press.
- Hotopp, U. (2002). *Labour Market Trends Report: Teleworking in the UK*. London: ONS.
- Inglehart, R. (1990). *Culture Shift in Advanced Industrial Society*. Princeton, NJ: Princeton University Press.
- Jakobsson, C., Fujii, S., and Garling, T. (2000). Determinants of private car users' acceptance of road pricing. *Transport Policy*, 7(2), 153-158.
- Jeong, K. S., and Oh, B. S. (2002). Fuel economy and life-cycle cost analysis of a fuel cell hybrid vehicle. *Journal of Power Sources*, 105(1), 58-65.
- Johansson, B., and Ahman, M. (2002). A comparison of technologies for carbon-neutral passenger transport. *Transportation Research Part D - Transport and Environment*, 7(3), 175-196.

- Jordan et al. (2006). *An institutional analysis of current uses of ISA related tools in their 'real world' policy context - Deliverable 2.3, MATISSE.*
- Kemp, R., Schot, J., and Hoogma, R. (1998). Regime shifts to sustainability through processes of niche. *Technology Analysis and Strategic Management*, 10(2), 175.
- Kempton, W., and Tomic, J. (2005). Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy. *Journal of Power Sources*, 144, 280-394.
- Kurani, K. S., Turrentine, T. S., Heffner, R. R., and Congleton, C. (2003). *Prospecting the Future for Hydrogen Fuel Cell Vehicle Markets*. Davis, CA: Institute of Transportation Studies, University of California.
- Köhler, J., Whitmarsh, L., Michie, J., and Oughton, C. (2007). Can the car makers save the planet? In T. Foxon, C. Oughton and J. Köhler (Eds.), *Innovation in energy systems: Learning from economic, institutional and management approaches*. Chapter in preparation.
- Lave, L. B., and MacLean, H. L. (2002). An environmental-economic evaluation of hybrid electric vehicles: Toyota's Prius vs. its conventional internal combustion engine Corolla. *Transportation Research Part D*, 7, 155-162.
- Lucas, K. (2006). Reconciling environmental and social concerns: transport. *ESRC Environmental Inequalities Seminar 2*, University of East Anglia: Norwich, 5<sup>th</sup> July.
- MacLean, H. L., and Lave, L. B. (2003). Evaluating automobile fuel/propulsion system technologies. *Progress in Energy and Combustion Science*, 29(1), 1-69.
- Malmstöm, S. (2006). Responsible for car sharing at SunFleet.
- Markusson, P. (2006). (pp. Carsharing consultant. Engaged in creation of roughly 30% of car sharing schemes in Sweden).
- McDowall, W., and Eames, M. (2006). Forecasts, scenarios, visions, backcasts and roadmaps to the hydrogen economy: a review of the hydrogen futures literature. *Energy Policy*, 34, 1236-1250.
- Mont, O. (2004). Institutionalisation of sustainable consumption patterns based on shared use. *Ecological Economics*, 50(1-2), 135-153.
- Nenseth, V. (2005). Urban sustainability - paced by urban actors? Paper presented at the *Paper presented at the 7th Nordic Environmental Social Science Conference*, Gothenburg, Sweden. June 15-17, 2005.
- Nieuwenhuis, P., and Wells, P. (1997). *The Death of Motoring? Car making and automobility in the 21st century*. New York: John Wiley and Sons.
- Nilsson, M., and Küller, R. (2000). Travel behaviour and environmental concern. *Transportation Research Part D-Transport and Environment*, 5(211.234).
- Norton, A., and Leaman, J. (2004). *The Day After Tomorrow: Public opinion on climate change*. London: MORI Social Research Institute.
- Office for National Statistics. (2002). *Internet access: Households and individuals*. <http://www.statistics.gov.uk/pdfdir/intacc0702.pdf>.
- Office for National Statistics. (2005). *Labour Market Trends Report: Home Based Working using Communication Technologies*. London: ONS.
- Office for National Statistics. (2006). *Percentage of adults who have used the Internet in the 3 months prior to interview by purpose of access*. [www.statistics.gov.uk](http://www.statistics.gov.uk).
- Ory, D. T., and Mokhtarian, P. L. (2005). When is getting there half the fun? Modeling the liking for travel. *Transportation Research Part A: Policy and Practice*, 39(2-3), 97-123.
- Pede, G., Iacobazzi, A., and al. (2004). FC vehicle hybridisation: an affordable solution for an energy-efficient FC powered drive train. *Journal of Power Sources*, 125(2), 280-291.
- Rogers, E. M. (1995). *Diffusion of Innovations* (4th ed.). New York: Simon and Schuster.
- Romm, J. (2006). The car and fuel of the future. *Energy Policy*, 34, 2609-2614.
- Prettenthaler, F. E., and Steininger, K. W. (1999). From ownership to service use lifestyle: the potential of car sharing. *Ecological Economics*, 28(3), 443-453.
- Regeringskansliet. (2006). *Moderna transporter. Regeringens proposition 2005/06:160*. Retrieved from.
- Rotmans, J., Kemp, R., and van Asselt, M. (2001). More evolution than revolution: transition management in public policy. *Foresight*, 3(1), 15-31.

- Sandén, B. A., and Jonasson, K. M. (2005). *Competition and co-evolution among contenders: The development of alternative transport fuels in Sweden 1974-2004*. Göteborg, Chalmers University of Technology: Chalmers Publication.
- Seidel, M., Loch, C. H., and Chahil, S. (2005). Quo vadis, automotive industry? A vision of possible industry transformations. *European Management Journal*, 23(4), 439-449.
- SCB. (2005). Företagens användning av datorer och Internet 2003.
- Semelsberger, T. A., Borup, R. L., et al. (2006). Dimethyl ether (DME) as an alternative fuel. *Journal of Power Sources*, 156(497-511).
- Shaheen, S. A. (1999). *Dynamics in Behavioral Adaptation to a Transportation Innovation: A Case Study of Carlink—A Smart Carsharing System*. University of California, California.
- Skatteverkets meddelanden. (2005). Skatteverkets information om värdering av bilförmån att tillämpas vid beräkning av skatteavdrag och arbetsgivaravgifter för beskattningsåret 2006 samt vid 2007 års taxering. *SKVM 2005:31*.
- Skinner, I., Fergusson, M., Kroeger, K., Kelly, C., and Bristow, A. (2004). *Critical Issues in Decarbonising Transport: Tyndall Centre Technical Report 8*: tyndall.ac.uk.
- Smith, A. (2005). 'Innovation for Sustainable Development: Some Lessons From Green Niches', Paper for the 6th International Conference of the European Society for Ecological Economics, 14-17 June 2005, Lisbon.
- Smith, A., Stirling, A., and Berkhout, F. (2005). The governance of sustainable sociotechnical transitions. *Research Policy*, 34, 1491-1510.
- Statens Offentliga Utredningar. (2005a). *SOU 2005:10. Handla för bättre klimat - Från införande till utförande*. Stockholm: Fritzes Offentliga Publikationer.
- Statens Offentliga Utredningar. (2005b). *SOU 2005:51, Bilen Biffen, Bostaden. Hållbara laster - smartare konsumtion*. Stockholm: Regeringskansliet.
- Steg, L., Vlek, C., and Slotegraaf, G. (2001). Instrumental-reasoned and symbolic-affective motives for using a motor car. *Transportation Research Part F: Traffic Psychology and Behaviour*, 4(3), 151-169.
- Strategy Unit. (2001). *Transport Strategy Review*. London: TSO.
- Strelow, H. (2006). *Statistics in Focus, September 2006: Passenger transport in the European Union*. Eurostat website: [http://epp.eurostat.ec.europa.eu/cache/ITY\\_OFFPUB/KS-NZ-06-009/EN/KS-NZ-06-009-EN.PDF](http://epp.eurostat.ec.europa.eu/cache/ITY_OFFPUB/KS-NZ-06-009/EN/KS-NZ-06-009-EN.PDF).
- SUMMA. (2005). *SUMMA: Final Publishable Report. Version 2.0*. Leiden: RAND Europe.
- Svensk Författningssamling. (1994). Lag om skatt på energi. *SFS 1994:1776*.
- Svensk Författningssamling. (1999). Inkomstskattelag. *SFS 1999:1229*.
- Svensk Författningssamling. (2003). Förordning om statliga bidrag till klimatinvesteringsprogram. *SFS 2003:262*.
- Svensk Författningssamling. (2004a). Förordning om myndigheters inköp och leasing av miljöbilar. *SFS 2004:1364*.
- Svensk Författningssamling. (2004b). Lag om trängselskatt, *SFS 2004:629*.
- Svensk Författningssamling. (2005a). Förordning om ändring i förordningen om myndigheters inköp och leasing av miljöbilar. *SFS 2005:1228*.
- Svensk Författningssamling. (2005b). Lag om skyldighet att tillhandahålla förnybara drivmedel. *SFS 2005:1248*.
- Svensk Författningssamling. (2006). Vägtrafikskattelag. *SFS 2006:227*.
- Svenska Petroleum Institutet. (2006). *Statistik*. <http://www.spi.se/statistik.asp?art=60>.
- Swedish Institute for Transport and Communications Analysis. (2000). Information- och kommunikationsteknik i Sverige.
- Swedish Institute for Transport and Communications Analysis. (2006a). *Statistics (internet)*. [http://www.sika-institute.se/Templates/FileInfo.aspx?filepath=/Doclib/2006/ss\\_2006\\_5.pdf](http://www.sika-institute.se/Templates/FileInfo.aspx?filepath=/Doclib/2006/ss_2006_5.pdf).
- Swedish Institute for Transport and Communications Analysis. (2006b). *Fordon vid årsskiftet 2005/2006*.
- Swedish road administration. (2002). *Bildelning i praktiken - En kartläggning av organisation och funktion hos svenska bilkooperativ 2002:90*. Stockholm.
- Swedish Road Administration. (2006a). *Safe traffic - Vision Zero on the move*. Report 88325

- 
- Swedish Road Administration. (2006b). *The road transport sector 2005 - Special report*. 2006:22E (No. 2006:22E).
- Taylor, A. (2006). Bio-Ethanol: an Environmental Opportunity? Paper presented at the *School of Environmental Sciences, University of East Anglia*, Norwich, 9th June.
- Toyota. (2006). Aygo product information. Retrieved 10-08, 2006, from [http://tims.kape.se/webbase/intranet/pdf/specs/ayg\\_pf\\_web.pdf](http://tims.kape.se/webbase/intranet/pdf/specs/ayg_pf_web.pdf).
- Transport for London. (2006). *Central London Congestion Charging: Impacts monitoring Fourth Annual Report*. London: Transport for London.
- Turnpenny, J., O'Riordan, T., and Haxeltine, A. (2005). *Developing regional and local scenarios for climate change mitigation and adaptation; Part 2: Scenario creation*: Tyndall Working Paper 67: tyndall.ac.uk.
- Urry, J. (1999). *Automobility, Car Culture and Weightless Travel: A discussion paper*. Lancaster, UK: Department of Sociology, Lancaster University.
- van den Hoed, R., and Vergragt, P. J. (2004). Institutional change in the automotive industry: or how fuel cell technology is being institutionalised. *Greener Management International: The Journal of Corporate Environmental Strategy and Practice (GMI)*, 47, 45-61.
- Verplanken, B., Aarts, H., van Knippenberg, A., and Moonen, A. (1998). Habit versus planned behaviour: A field experiment. *British Journal of Social Psychology*, 37, 111-128.
- Whitmarsh, L. (2005). *A study of public understanding of and response to climate change in the South of England*. Department of Psychology, University of Bath, Bath, UK: Unpublished doctoral thesis.
- Whitmarsh, L., and Wietschel, M. (2006). Sustainable transport visions: what role for hydrogen and fuel cell vehicle technologies? Manuscript submitted for publication in *Energy and Environment*.
- Wietschel, M., Hasenauer, U., et al. (2006). *Development of European hydrogen infrastructure scenarios - CO2 reduction potential and infrastructure investment*. *Energy Policy*, 34(11), 1284-1298.

**Published by**

SERI Nachhaltigkeitsforschungs und -kommunikations GmbH  
Garnisongasse 7/27, A - 1090 Wien  
Tel.: 01/9690728-0, Fax.: 01/9690728-17  
[www.seri.at](http://www.seri.at), [office@seri.at](mailto:office@seri.at)

Download available <http://www.matisse-project.net>