



Commission for
Rural Communities

Tackling rural disadvantage

**Thinking about
rural transport**

The implications of
technological change
for rural transport

A 'think-piece' in collaboration with
University of the West of England

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1

1 Synopsis

This report (one of a series) was commissioned by the Commission for Rural Communities (CRC), to help inform strategic development of rural transport policies. It focuses on assessing the impacts on rural transport of emerging technologies in the transport and related sectors over the next 15-20 years, indicating the likelihood and desirability of various alternatives emerging against a number of 'drivers' for change: upward pressures on transport costs as a result of fuel prices, the need to respond to climate change, continuing centralisation of services; greater availability of cars, and growing numbers of older drivers. Technology for both private and public transport modes is assessed, including alternative fuels (biofuel, electricity or hydrogen), ICT developments, and new technology for 'public transport'. Implications of any requirements for new infrastructure are also considered, as well as the debates around the Stern and Eddington reports on climate change and transport respectively.

Scenarios for mobility levels are found to lie on a continuum from fluid mobility, in which local sourcing of fuel permits continued high levels of individual mobility and generates jobs and 'exports' to urban areas, through to increasing friction of distance, describing a technologically-deprived and mobility-poor future. Within this broad context, new technology for public transport provides opportunities for better services, and in addition, developments in ICT could remove the need for some travel. However, it is unlikely though that these changes will reverse the huge disparity between public and private means of travel, unless a further significant increase in fuel costs occurs, whilst substitutive ICTs could encourage greater migration into rural areas, boosting rural economies, but at the same time increasing the disparity between those affluent enough to be able to maintain their own private transport and those reliant on public alternatives.

In practice, the more positive visions may be tempered by constraints such as the opportunity cost of growing fuel crops rather than food, and the introduction of industrial scale production facilities into rural areas. Considering the other extreme, whilst the technology may develop sufficiently and quickly enough to avoid the most severe mobility-poor scenarios, such solutions may not be as appropriate or readily available for rural areas as they are for the urban counterparts. The latter areas also have more 'lower technology' options, being able to adapt more easily to greater dependence on public transport, walking and cycling. Even if some rural areas do experience greater spatial isolation from their urban neighbours, however, lower transport intensity might have community benefits by encouraging a re-investment in local services and facilities, leading to more self-sufficient production and consumption patterns.

The costs of new infrastructure may be important in determining how new technologies develop in rural areas. Any new infrastructure development that is intended to cover a dispersed population will invariably cost more per user. Looking beyond the 20 years, towards

the possible 'hydrogen economy' it can be seen that this offers a major cost challenge, and it may be that this proves to be prohibitive for rural areas, and in fact other solutions are more applicable for maintaining mobility. Given the range of areas which are considered rural, particular scenarios are likely to lead to different outcomes even in adjacent areas, depending on relative affluence, location and population.

One general finding relating to the timeframe considered for this study is that 15-20 years is probably too short a perspective in which to expect radical change in transport and transport technology; what is perhaps more likely in this period is a sharpening of pressures and the emergence of a range of responses and technological trials within rural areas, with some of these becoming more influential toward the end of the period. It is recommended that further work to inform policy should consider a longer timeframe, include quantitative scenario analysis, with this informed by empirical qualitative data collection with key informants.

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2 Introduction

The Commission for Rural Communities (CRC) has initiated a number of small-scale "think piece" studies to inform strategic development of its rural transport policies. The Centre for Transport & Society at the University of the West of England (CTS) has undertaken one of these studies, assessing the impacts on rural transport of emerging technologies in the transport and related sectors over the next fifteen to twenty years.

The resulting paper describes and reviews some of the existing knowledge on these issues, and indicates the likelihood and desirability of various alternatives emerging. Technological developments for both private and public transport modes have been assessed, considering their likely progress to 2025-2030. Specific developments that were examined included:

- The implications of a possible alternative fuels revolution (biofuel, hydrogen or local-distributed production of electricity), and specifically examining whether local sourcing of transport energy was likely.
- A consideration of how ICT / broadband technologies might impact on the need to travel in rural areas.
- The potential for new 'public transport' technologies for booking, scheduling and payment to alter the viability of existing delivery modes, including conventional bus services and Demand Responsive Transport (DRT). Consideration will be given to the possible spin-off applications of smartcards to be introduced for concessionary fares.

Particular strengths and weaknesses presented by rural areas were taken into account, such as the relative availability of land for new infrastructure on one hand, but the relatively diffuse nature of consumer demand on the other. Infrastructure implications of a switch away from the current dominant road fuels have also

been considered, where necessary reviewing the infrastructure requirements for new sources of energy and if there may be potential to adapt existing infrastructure.

The report has also considered links from these 'future scenarios' for rural transport to the two recent independent strategic reviews for the UK Government: the Stern Review on Climate Change and the Eddington Transport Study. Where possible any implications arising from this for rural areas are also discussed.

Report Structure

The next section of this report 'sets the scene', exploring what 'rural' means, if specific transport problems can then be identified in these areas, and a consideration of what alternative public transport may offer at present. The following section focuses on the 'drivers for change' in rural areas which will affect the demand for transport and travel in rural areas over the coming decades. The fourth section then considers the new transport technologies likely to be forthcoming in the next 15-20 years, as well as changes to existing transport and communication technologies that may impact on rural travel during that period. It also looks at the implications of these changes for rural areas, from economic, social and environmental perspectives – with a focus on any special characteristics of rural areas which may help, or hinder, transport and travel. Finally, some conclusions are drawn from the above, and some suggestions as to possible scenarios for rural areas and transport through to 2030 are outlined.

3

3 Rural areas and transport – the current situation

The concept of rurality

In order to better understand how any specific technology might impact on rural areas and communities, it is useful first to understand what the term rural implies in this context. As identified by Moseley *et al.* (1977), "there is no unambiguous way of defining rural areas". By using different criteria (*i.e.* social, economic, demographic or geographic), it is possible to produce a variety of different results, although it is suggested that "Socio-economic factors" are often favoured in preference to purely spatial definitions (Root, Boardman & Fielding 1996).

Twenty-five or more definitions of 'rural' were identified in a 1993 report (Barnes 1993), but no overall consensus identified. Other studies identified that the term is actually used to classify a variety

of physical areas, which serve a number of different purposes. For example as dormitory locations for urban areas, as recreation and wilderness areas, and as employment centres (agriculture and rural industries for example). One rural typology introduced in a report looking specifically at transport in rural areas (Sloman 2003), came up with the following:

- Villages in prosperous commuter belt within an hour of a city (*i.e.* Manchester)
- Dispersed settlements around a market town (*i.e.* mid-Wales, Lincolnshire)
- Tourist 'honey-pot' areas (*i.e.* Lake District).
- Remote villages and/or isolated settlements (*i.e.* Northumberland, or highlands of Scotland)

As can be seen though, some areas that are classed as rural are readily accessible from urban areas, and thus have become desirable places to locate, both for housing and for business. Particular examples of this form of rurality are areas that attract commuters, but also those areas which lie in the corridors between successful urban settlements (Banister 2005). This link to urban spaces is important, as rural areas do not exist in isolation. They all have some dependence on services and employment opportunities in urban areas (large or small), and it is the level of access to these that in part determines rural travel needs, and accessibility problems (Moseley *et al.* 1977). What is perhaps more relevant is the distinction to be made between those rural areas which are 'accessible' and those which are 'inaccessible' (Root, Boardman & Fielding 1996).

What is apparent from this consideration of the term 'rural' is that it has a wide variety of meaning, both in terms of its physicality, and in respect of the travel needs within it. Transport solutions within rural areas are both shaped by the characteristics of the area, but also by the technology available. For example, widespread access to the private car has most certainly impacted on location decisions of (many) people currently living in rural areas, and "*may have been the crucial determinant of the new mobility*" (Banister 1989).

The fact that there is no single definition means that the impact of new technologies may vary across the rural typology. It is also likely that the drivers of rural travel (discussed below), will vary as well. However, for the purposes of this report, a simple categorisation of 'rural' developed by Cullinane and Stokes (1999) will be used. This offered a definition of rural as being: related to the countryside, and defined in terms of size of settlement. Thus whilst a rural area is synonymous with the countryside, it will still include settlements (small towns and town fringes, villages, and hamlets), as well as dispersed populations. The UK government also adopts this approach, with a population of 10,000 people or more considered to be 'urban' (ONS 2008). Consequently, for the purposes of this report, rural will be taken to equate to 'non-urban' areas and it will be this definition that the impacts of change will be considered against.

Transport in rural areas

Mobility in all of the different types of rural area discussed above is currently dominated by the private car, seen as the “*perfect mode of travel*” (Banister 1989). It could perhaps now be considered to be a ‘*pre-requisite*’ for living in a rural area. However, there are those who don't enjoy this level of mobility. Although only 18% of rural households don't have a car, a much larger proportion of the rural population, some 30%, do not have access to one. This may be as a result of being in a car-less household, or because they cannot drive, or do not use the car as a driver (Banister *et al.* 2005). This doesn't though translate into public transport use. Low income households in rural areas spend more (as a proportion of income) on travel, and they may be dependent on public transport services. But, in any given income group, rural residents make about half the level of use of bus and rail compared to their urban counterparts (*ibid*).

This lack of mobility can impact on all aspects of rural life, for example, access to employment, education and health care and also upon the viability of rural businesses. Lack of transport can be a key factor in social exclusion in rural areas, and those people without access to a transport can be subject to a number of social and economic problems as a result. Although many people in rural areas ‘get by’, opportunities for things such as employment and education can be much reduced as a result of a lack of mobility (Macdonald, Heaney, Smith & Breakell 1995). In a report specifically considering access to employment and education in rural areas, a quarter of students thought that ‘transport’ would have an impact on their decision on what to do when leaving school, and over 60% of unemployed people considered transport was a limitation on seeking employment and training. This was a particular issue for those without private transport, and a problem for women (Macdonald, Heaney, Smith & Breakell 1995).

The current mobility afforded by the private car can also be seen to be contributing to a wider set of problems for rural areas in respect of declining local access to services, facilities and employment opportunities. Not surprisingly, providers of services and employment are taking the opportunity afforded by the greater mobility of the majority of people in rural areas to centralise and up-scale to achieve economies of scale, but often on sites outside of settlements. This has resulted in an even greater reliance on the car – illustrated by the fact that whilst some 20% of England's population live in rural areas, around 60% of vehicle distance travelled is in rural areas – much of it travelling into and between urban areas (Sloman 2003).

The public transport alternative

Notwithstanding financial support from the government and local authorities, public transport has been in decline in rural areas for many decades. Further reductions in services have been seen since the privatisation of the system in the 1980s, with journeys in England outside of metropolitan areas falling from 1.6 billion in 1985/86 to 1.3 billion in 2006/07 (DfT 2007). This whilst access to bus services in rural areas had actually improved, with the proportion of households within a 13 minute walk of an hourly bus service improving from 38% to 54% over the period 1995/97 to 2006 (DfT 2007)¹.

The low density of users in some rural areas has meant that it is no longer commercially viable to operate regular fixed route services where demand patterns are dispersed and low. Although the introduction of free travel for older people in 2006 has resulted in an upturn in journeys by bus, the reimbursement regime for operators is such that some rural routes have actually been withdrawn as a result of the numbers of free travellers carried.

As discussed above, some rural dwellers will not have access to a car, and for these people public transport is an essential alternative. In many instances local authorities still support rural services, including through DRT and Community Transport (CT) initiatives. These only provide a limited alternative though, and the high cost of subsidising DRT services expose them to the risk of being withdrawn (particularly so since the ending of the Rural Bus Challenge scheme which pump primed the development of many of them). Even where there are public transport services, not everyone will be able to access them, particularly in more remote rural areas.

Summary of current rural transport situation

As has been seen above, the private car dominates rural mobility, and this is reflected in the levels of household access to the car. Partly as a result of this, and because of the diffuse nature of the rural population, it is often not economically viable to run public transport to the same levels seen in urban areas, making this a less viable alternative for those with out access to a car. There are some solutions in this area, such as DRT, but more often than not in limited niches. One interesting aspect of discussing how new technologies may impact on rural transport will be if any of them offer alternatives to the current dominance of the car.

1 For comparison, at least 95% of households in medium-sized or larger urban areas (areas with a total population of more than 25,000) were within a 13 minute walk of an hourly or better bus service, falling to 86 % of households in small urban areas (3,000-25,000 population).

4

4 Drivers for change in rural transport

As well as understanding the current position and state of transport and travel in rural areas, it is also worth considering what some of the drivers for change may be over the next few decades, as they may well impact on the technologies available and chosen by rural areas to deliver mobility. There are seven 'drivers' that might reasonably be foreseen to have an impact on rural transport demand in the future, which are summarised below. Some of these are likely to counteract and contradict each other, and may combine to induce greater or less change.

Costs of travel. Longer distances are often travelled in rural areas in order to access basic opportunities and needs, things such as employment, education, health care, *etc.* Thus rural travellers are more exposed to increases in fuel and transport costs. Oil prices have exceeded \$100 a barrel in recent months, in response to various factors exacerbating supply, but high levels of fuel costs are likely to be an ongoing feature. Continuing growth in demand for fuel resources from the developing economies in China, India and South America will add to price pressures. In addition, if the theories of 'peak oil' are correct (that is we are at or near to the maximum supply of oil available), then diminishing availability will add to the upwards pressure in the future. Rising fuel costs will also impact on public transport, leading to higher fares, and on business costs, including the expense of delivering goods to rural areas. These growing fuel costs are also increasingly outside of local control, with the EU expecting that 90% of oil and 80% of natural gas will need to be imported by 2030 (European Commission 2005).

At the same time as fuel costs are likely to rise, there is going to be a growing need to address climate change, and reduce emissions from transport. It is expected that the passing of the Climate Change Bill in 2008 will produce a statutory framework for emissions reductions – potentially achieved through fiscal means such as carbon taxes, probably including the existing graduated vehicle excise duty and fuel excise duty, but possibly involving others as well.

Another area of possible cost which may become relevant in rural areas is road pricing. Although congestion is less common in rural areas, so there may be less need to charge rural motorists, car journeys which begin in rural areas may terminate in charged urban areas, and rural residents may have fewer alternatives to paying the charge than their urban counterparts. Another cost for motorists which is beginning to move towards 'distance-based' charging is insurance, with a number of companies piloting schemes where customers pay by the distance they travel and other factors such as time of day and type of road used (with single carriageway roads typical of rural areas generally rated as higher risk than dual carriageways). Again as a result of the longer distances travelled in rural areas, this might prove to be a disincentive, albeit at the margin, to travel.

Ageing Population. The population in rural areas in England is generally ageing, that is the average age is rising. Research has suggested that the average age at which people stop driving used to

be sometime in their early-to-mid 70s. This may be getting older, but at the same time so are people in rural areas. This lack of personal mobility may be compounded by the lack of adequate public transport, further exacerbated by the impacts of concessionary travel on services. This may lead to a decrease in travel (particularly by car).

Levels of car ownership. The highest level of car access in households is found in rural areas, and this level is still growing. Numbers of older people who still drive is also growing, and the share of driving licence holders in higher age groups is also increasing. This may lead to an increase in travel by car. Uncertainties remain, however: although the number of older people with access to cars is growing there is, at least for the present, a marked difference between men and women, with the latter living longer but less likely to be driving in older age.

Loss of local services. As discussed above, the availability of services and facilities in rural areas has been diminishing over recent decades, and this process is likely to continue whilst transport is both available and reasonably cheap relative to disposable income (as at present). This process of centralisation becomes self-reinforcing, as location demands mobility, and mobility facilitates location. This process will encourage travel.

Urban to rural migration. Another trend in recent decades has been migration of people from urban to rural areas, and the converse. Those seeking the rural idyll, either for their families, or increasingly to retire to the country, are often replacing younger rural residents who can no longer afford the costs of purchasing a property in increasingly desirable (and affluent) rural areas. These incomers are more able to cope with the costs of mobility, although of course there is still a population of less well-off rural residents caught between the higher costs of mobility and the lack of opportunities close by. The urban migrants are also more likely to want to continue to commute to urban areas for employment or social purposes. All of this is likely to increase personal travel, and undermine public transport.

Availability of public transport. Commercial pressures since bus de-regulation have meant that operators are increasingly unlikely to provide as many services in rural areas as they do in urban ones. Primarily this is the result of the lower density of population in rural areas, and lower levels of demand. The current regime of public subsidy for public transport in rural areas has not encouraged innovative responses to mobility needs; in fact the current English concessionary bus scheme for older and disabled people may actually have led to the removal of some services². DRT and CT are still providing some solutions, but only in limited areas,

2 Since 2006, older and disabled people in England have been able to travel for free on buses in their local area. In a number of instances (examples have been seen in rural Lincolnshire, Sussex and in Devon), bus routes which have been principally carrying this type of passenger have proved to be no longer economically viable, and operators have either withdrawn, or threatened to withdraw them unless extra support was provided.

and sometimes for restricted social groups. The diminishing public transport alternative may be reducing travel for some groups in rural areas, but by encouraging travel by private car could be increasing travel overall.

Stern & Eddington. The Stern Review made clear the need to address emissions of greenhouse gases now, to avoid significant economic costs from climate change in the future. This applies equally to transport, an area now responsible for over a quarter of emissions in the UK. Measures aimed at using more sustainable forms of transport (or reducing demand for travel) that follow from this, and the forthcoming Climate Change Act, may reduce levels of travel.

In contrast, the Eddington Report is looking to deliver solutions that maintain economic effectiveness and productivity, primarily by making more effective use of existing transport infrastructure and networks - in some instances including new infrastructure. This might suggest potential increases in travel as a result of this greater efficiency, although the report also makes it clear that 'pricing' the use of the network is key to making it work efficiently. This, particularly in the form of road pricing, is likely to be a disincentive to some travel, especially for those less well off and with fewer access and mobility choices.

5

5 Technological change and rural transport to 2030

As was established above, the vast majority of travel in rural areas is currently undertaken by private car, and this is unlikely to change significantly over the next 15-20 years: a view shared by the RAC Foundation in their enquiry into transport over the next 50 years. This concluded that the car would continue to be the 'main means of transport' over this period (RAC Foundation 2002). Notwithstanding this outlook though, there are increasing pressures on using current oil-based fuels for transport, both environmental (climate change, air quality) and economic (cost and fuel security). Part of the response to these pressures will undoubtedly be to use 'technology' to improve resource use, to alleviate some of the demand, or to make more affective use of existing alternatives. However, the most fundamental response over the longer term is likely to be an attempt to reduce the current dependence on fossil fuels by moving to alternatives.

In a recent report for HM Treasury on low-carbon cars (King 2007), the conclusion was drawn that technology was available now that could bring a 30% reduction in emissions of CO₂ over the next ten years, and that developing technologies would deliver a 50% reduction by 2030, and zero emissions at the tailpipe by 2050. The technologies underlying this finding were; improvements in efficiency in the short term, and then a move to a sequence of

alternative fuels over the medium to long term. Because of the pressing need to respond to the climate change issue, there is a high probability that the technology route-map identified by the King Review is likely to materialise. Thus it is the changes identified in the King Review through to 2030 that form the core of the options discussed in more detail below;

- Existing Technologies/Fuels that could lead to greater resource efficiency / reduced emissions.
- Biofuels (Biodiesel, Bioethanol and Biogas).
- Electric Vehicles.

The final 'new' transport technology identified in the King Review is the introduction of Hydrogen as a fuel source, although it is not thought to offer a compelling and significant replacement technology until 2050. A similar view is taken in a US study considering vehicle technology over the next 25 years (Schafer, Heywood & Weiss 2006). This concluded that vehicles using improved internal combustion engines (ICE) and hybrid technologies would deliver similar reductions in energy use over the next 20 years or so as hydrogen fuel cell vehicles promise in their initial form (creating hydrogen from natural gas, so delivering limited decarbonisation benefits). Consequently, although hydrogen is addressed below, it is considered more in the light of the impacts it may have in the longer term, particularly in respect of infrastructure requirements.

As well as reviewing these alternative fuel options, two other areas that could impact on the demand for and provision of travel in rural areas; public transport, and ICT solutions, are also considered.

All of the technological changes discussed could have an impact on rural transport. This may be in terms of the costs of transport and travel, and its availability, or the social and environmental effects that may arise from the change. Consequently, each of the technological changes is reviewed below in respect of these impacts and effects. Particular reference is given to those aspects of rural areas that perhaps offer the easiest distinction with urban areas: the generally higher population density and the different pattern of land values. Whilst not all rural land is cheap and available – properties in particular rural locations may exceed the market value of those in some towns and some areas have statutory protection in planning law – agricultural land without planning permission tends to be low cost. Particularly where the requirement is for the routing or siting of energy grid infrastructure or the growing of energy crops, rural areas may have distinct advantages over urban areas.

Change in existing technologies

One option which is readily available over the next 15-20 years is to improve the efficiency of existing modes of travel (beneficial to people in rural, as well as urban areas). This option was considered in detail by the King Review, which proposed that fuel efficiency could be improved by as much as 30% within ten years, just by using technology, vehicles and fuels that are current (or near-current). It was suggested by King, that many of the potential improvements were being considered for the next 'car model cycle', and in some cases were actually being introduced in the current model cycle. Table 1 below lists some possible benefits, or dis-benefits, of pursuing this route.

Table 1:

Improvements in existing technology.

Benefits:	Disadvantages:
<ul style="list-style-type: none"> • Produces 25%-30% less CO₂ than current vehicles and reduces other pollutants. • Reduced resource use, and potentially cost of transport. • Continues 'known' technologies and existing infrastructure. • Helps with 'fuel security'. 	<ul style="list-style-type: none"> • Still tied to hydrocarbon fuels, fuel scarcity / security issues in future. • Still produces emissions and pollution.

Applying this approach would help reduce CO₂ emissions and go some way towards addressing fuel security, and by reducing fuel use could potentially reduce costs of travel. It would however in most instances entail 'turnover' of current vehicles for more efficient models. The improvements could be delivered at a relatively low cost in relation to the cost of vehicles in general, particularly if they were applied in volume production. Some of the potential costs and efficiency benefits are illustrated in Table 2 below. Whilst the focus of the King Review was on CO₂ emissions, these were delivered by reductions in fuel use, so are of equal interest when considering other factors such as scarcity of supply and cost. As well as new technology, there are other opportunities to make vehicles more efficient, for example through reducing weight, improved aerodynamics and energy-saving tyres (available off-the-shelf for most vehicles today).

Table 2:

Vehicle efficiency savings, and indicative costs of implementation

Technology	Efficiency saving	Cost per vehicle (£)
Variable valve actuation	5-7%	175-250
Downsizing engine capacity with turbo-charging or supercharging	10-15%	150-300
Dual clutch transmission	4-5%	400-600
Stop-start	3-4%	100-200
Stop-start with regenerative braking	7%	350-450
Electric motor assist	7%	1000
Reduced mechanical friction components	3-5%	Negligible
Weight reduction	10%	250-500
Low rolling resistance tyres	2-4%	50-100
Improved aerodynamics	2-4%	–

Source: King Review (2007) *From a number of sources, including the International Energy Agency (IEA), Institute of European Environmental Policy (IEEP), California Air Resources Board (CARB), Ricardo.*

The improvements proposed above are against a typical current petrol car, and it is not expected that all of the improvements could be added to all cars (with each additional measure of course the relative impact will be reduced). It was thought feasible that these changes could be delivered in new vehicles over five to ten years. There may also be an issue with the types of vehicle that are needed by some rural citizens though (e.g. 4x4), and whether these are likely to be well-represented by more fuel-efficient variants.

Whilst not all of the changes suggested above will be appropriate for all vehicles, it is possible to see some improvements which might prove more beneficial in rural areas. For example more efficient aerodynamics and less 'rolling resistance' might return more fuel-efficiency on less congested roads, and over the longer distances travelled. There may also be some changes less relevant to rural drivers, (stop-start for example as a result of less congestion), but overall a 30% efficiency saving should be feasible for new models against current ones. It was predicted that this might add £1,000-£1,500 to the cost (assuming volume production). At this level of cost to the 'consumer', the payback could be as little as three years for a driver travelling 10,000 miles per annum, and quicker for those undertaking a higher mileage or if fuel costs rise. There could be further inducement to migrate to these more efficient vehicles if the vehicle excise duty (VED) mechanism rewarded the change with lower annual rates (particularly if rates for less efficient vehicles continue to rise).

The potential impacts on rural areas, and transport of delivering efficiency gains through deployment of these existing technologies are summarised in Table 3 below.

Table 3:

Impacts on rural areas of improvement in existing technology

Economic impacts:

- Reduced costs of travel, but will require 'capital' expenditure on new vehicles.

Environmental impacts:

- Reduced emissions and pollution, potentially reduced rural noise pollution.

Social impacts:

- Those that cannot afford more efficient 'new' vehicles doubly penalised by rising fuel costs, and 'carbon taxes'.
- New technology may be less applicable for vehicles in rural areas.

- Introducing efficiency improvements will add to the cost of vehicles, although of course there will be a benefit in reduced running costs. As most elements discussed above are not available as a retro-fit, this will mean that to gain the benefit of more efficient vehicles, people will need to acquire new vehicles. This could be an issue for those less well off in rural areas, who will also not have the public transport infrastructure more prevalent in urban areas as an alternative. Rural dwellers tend to need to travel longer distances as well, so will potentially be doubly penalised if fuel prices continue to rise as a result of scarce oil. Other cost pressures such as carbon-based taxation, and road-pricing would only exacerbate this. It may be some years before new models filter through to the second-hand markets, but in the meantime some sections of the rural population could find their mobility constrained by cost.
- In terms of environmental impacts, improvements to existing technology should provide air quality benefits as a result of more efficient engines, as well as the expected emissions reductions. The air quality benefits will probably be felt more in urban and congested areas, although improvements in noise levels that may also follow would be beneficial in rural areas. These sorts of technological development are unlikely to add any increased demand for land to that already used for transport in rural areas.

It is worth sounding a note of caution in respect of efficiency improvements though, as vehicle manufacturers have previously struggled with meeting EU efficiency targets. The voluntary agreement between manufacturers and the EU in 1996 to reduce emissions to an average of 120g/km CO₂ by 2010 at the latest is now most likely to be 'increased' to 130g/km CO₂ for 2012 (FOE 2007). An interim target for 2008/09 of no more than 140g/km also looks unlikely to be achieved (the average figure for the UK in 2006 being 162g/km CO₂). It is also the case that if efficiency improvements are introduced ahead of increases in fuel prices, then this could actually increase levels of travel, particularly by private vehicles, as travel costs will be lower. This might be more of a problem in rural areas than urban as a result of the greater capacity available on rural networks, and the longer distances that people need to travel.

Wider use of existing fuel alternatives

As well as applying known technology to existing transport to address problems of emissions and cost, there is also potential to increase the use of existing alternative hydrocarbon fuels. Liquid Petroleum Gas (LPG) and Compressed Natural Gas (CNG) are both already available and in use in the UK. Their use to date has been relatively limited (particularly CNG), but there is potential for an increase in use over the next 15-20 years, perhaps as a precursor to similar technologies using biomass based fuels.

Table 4:

LPG ('Autogas')

General Benefits of LPG:

- Produces 25%-30% less CO₂ than equivalent petrol car *.
- Significantly less pollution than diesel vehicles (NOx and particulates) **.
- Can be used in a 'dual-fuel' vehicle that can also take petrol as backup.
- Conversion is relatively straightforward, costing around £1,600 for a car or light van.
- About 60% of UK LPG is a by-product of the natural gas extraction process.

Disadvantages of LPG:

- Still a hydrocarbon fuel, refined from either natural gas or crude oil
- Emission benefits no better than switching to diesel.
- Requires bulky/heavy on-board tanks for the fuel which reduce the range in comparison to petrol/diesel.
- Additional cost to convert existing vehicles
- Price of fuel needs subsidy to offset extra costs of conversion
- Requires special safety procedures as is heavier than air

Future direction:

- Will be subject to similar pressures to other hydrocarbon-based fuels.
- May provide route-map to biomass based gas fuel.

* Road fuel gases and their contribution to clean low-carbon transport. EST. 2003

** The 'BoostLPG' website, LP Gas Association (LPGA)

Worldwide, LPG is a well established fuel, used in over eleven million vehicles. Some four million of these are in Europe (particularly in Italy and The Netherlands), but just 140,000 in the UK. There is an extensive re-fuelling infrastructure available – approximately 1,300 filling stations in the UK (Boost 2008), although many of these serve urban areas, or are located on inter-urban corridors. Currently, tax concessions mean that LPG is about half the price of petrol and diesel (although savings are more like 40% when performance is considered).

The second existing fuel technology which may provide opportunities for further development is Compressed Natural Gas (CNG).

Table 5:

CNG

General Benefits of CNG:

- Slightly lower CO₂ life-cycle emissions than petrol or diesel.
- Some (limited) air quality improvements over conventional fuels.
- Can be distributed to refuelling stations through the natural gas grid

Disadvantages of CNG:

- A hydrocarbon fuel.
- Cost of converting car engines, and need for bulky/heavy on-board tanks for fuel.
- Poor range at typical compressed volumes in comparison to petrol/diesel.
- Refuelling overnight, or via high-tech and high-cost filling stations.
- Better suited to larger commercial vehicles because of the weight of fuel tanks.
- Needs subsidy to encourage use.
- High energy cost of compressing gas to usable volumes giving range

Future direction:

- Will be subject to similar pressures to other hydrocarbon-based fuels.
- May provide route-map to biomass based gas fuel.

In other European countries there is much greater take-up of gas powered vehicles (buses, commercial vehicles and cars). Sweden is expected to have 200 plus 'gas' filling stations by 2009 (BRG 2008), and Germany 1,000 filling station by the same year. In response to this growing demand, a number of European manufacturers now offer gas-powered vehicles, with new models introduced regularly. Currently though, there is a lack of common standards and regulation across the EU, which may hinder further development of this fuel. There is potential however for CNG to become a 'route' to the use of biogas at a later stage.

More recently, another 'liquefied gas fuel' has begun to be marketed by the oil company Shell. 'Gas to Liquids' (CTL) fuel is a synthetic liquid fuel derived from natural gas that burns more cleanly than conventional fuel. In trials carried out by Shell in Germany, cars produced 91% less carbon monoxide emissions, 63% less hydrocarbons and 26% less particulates in their exhaust than they would have if running on regular diesel. The fuel is produced using similar technology to that used for biofuels, and Shell now believes it is viable to produce and market it. The liquefied gas is compatible with current diesel engines, and is already on sale in Europe as part of a diesel blend. Whilst this fuel appears to offer air quality improvements which will be particularly important in urban areas, it makes less of an impact on greenhouse gas emissions, and relies on the existing hydrocarbon fuel infrastructure for supplies. What might be more significant in the longer term would be whether the technologies being developed are transferable to biogas and biomass fuels.

As with the introduction of technology to support greater efficiency above, there are likely to be a number of impacts on rural transport of a significant use of these 'alternative' hydrocarbon fuels. These are listed in Table 6, and discussed below.

Table 6:

Impacts on rural areas of greater use of LPG / CNG

Economic impacts:

- Reduced costs of travel as a result of current fuel subsidies, but will require 'capital' expenditure on new vehicles / conversions.
- 'Bridging' technology to biogas and then hydrogen, reduced investment in infrastructure as a result.

Environmental impacts:

- Reduced emissions and air pollution potentially reduced rural noise pollution.
- New infrastructure will require land

Social impacts:

- Ideal fuels for use in captive fleets, such as public transport, so could reduce costs for travellers, but;
- if costs of new infrastructure fall on rural areas, this may actually raise costs and penalise those less well-off.
- Users exposed to volatility in oil prices.

- The cost of converting or buying purpose-built vehicles could be high, and could disadvantage the less well-off rural areas. These costs are partly as a result of fuel storage systems, but also the relatively low volumes of vehicles being manufactured to date (mainly left-hand drive). This could of course change if significant numbers of consumers (in the UK) pursued this option.
- Air quality benefits will probably be felt more in urban and congested areas, although improvements in noise levels that may also follow would be beneficial in rural areas. There are potential air quality benefits from using LPG and CNG powered buses in urban areas, but this would be of less value in rural areas.
- Greater use of LPG and CNG may require land for new infrastructure, particularly if there is a widespread move to these fuels as a precursor to future use of biogas. This might entail new pipelines and production plants, but this new infrastructure, particularly for CNG, could be costly (Foley 2002). If these costs represented an additional level of charge for supplying rural areas then it could further exacerbate the (higher) costs of transport in rural areas.
- CNG Infrastructure costs could be seen as investment for future biogas, and then hydrogen networks – priming rural areas for these later technologies.
- The lack of stability in the price of fuels derived from or linked to oil, as illustrated by the price of natural gas in the domestic energy market in recent years, could leave rural areas with very expensive transport costs should oil prices rise significantly.

Alternative (fuel) technologies

The primary technological change in transport over the next 20 years as identified by the King Review (King 2007) is a move to alternative fuels, and three of these were identified as being likely to replace petrol and diesel.

- **Biofuels**. Either as a 'blend' with petrol/diesel fuels and used in existing vehicles and hybrids, or as a fuel in its own right.
- **Electricity**. In the form of battery vehicles, and plug-in hybrids.
- **Hydrogen**. Either as a gas fuel in an internal combustion engine (ICE), or in the longer term in a 'fuel cell' vehicle.

The first two 'new' fuels (biofuels and electricity) are likely to be in widespread use over the next 20 years or so, but the third (hydrogen) is unlikely to make a big impact on personal transport until the middle of the century – and only then if some key technological breakthroughs are made. A fourth, some might say 'maverick', fuel source is compressed air which has been proven in test vehicles, but has yet to make a significant breakthrough into the commercial market. To an extent, it can be considered alongside electricity as a fuel source, as to date most proposals for 'refuelling' compressed air vehicles have used electricity as the power source for both onboard and off-vehicle compression of the air used as a fuel. There is no reason, though, why biofuels or other renewable sources of energy couldn't perform the same function.

For all of these alternatives, however, it is worth noting that certain fuels lend themselves more to particular environments and uses. For example, fully electric cars may be better suited to short city journeys due to their limited range and long recharging times. Vehicles using gaseous fuels such as biogas and hydrogen need to be able to accommodate larger and heavier tanks, requiring larger vehicles – but offering greater range as a result. These may then be better suited to the longer distances commonly travelled in rural areas.

Biofuels

Perhaps the most obvious replacement fuel for both private and public transport vehicles, and one which is beginning to be more widely used already, is biofuel. This is a fuel made from a plant source, most commonly the diesel alternative, biodiesel, and the petrol substitute, bioethanol. A third type of biofuel is biogas, which as its name suggests is not a liquid fuel, but a gas, Akin to the LPG and CNG alternatives available from fossil fuels described above. Table 7 summarizes the benefits and issues related to the liquid biofuels (biogas is discussed separately below).

Table 7:

Liquid Biofuels

Benefits:

- The only 'renewable' transport fuel option that can be commercially deployed today.
- The only supply-side measure currently available to decrease the reliance of road transport on fossil fuels.
- Can offer significant CO₂ savings compared with petrol and diesel.
- Offers reduced dependence on oil.
- Can be blended with petrol or diesel and used in a conventional vehicle engine.
- Can be grown on set-aside land without contravening set-aside rules.

Disadvantages:

- Slightly lower 'energy density' than petrol and diesel, and lower range.
- Blends above 5-10% need engine modification, although this is relatively inexpensive.
- Major use could leave supply exposed to agricultural risks such as weather, pests and diseases.
- Could compete for land with food production.
- The logistics of dealing with large scale production, including the transport of fuel crops to 'refineries', particularly if production is centralised.
- Some Biofuel (biomethanol) is corrosive and needs careful handling by consumers, and appropriate systems/materials in vehicles.

Future direction:

- Move to more productive second and third generation fuels.

Biofuels are categorised as first, second and third generation. The first generation fuels are being grown now, and are specific crops such as wheat, sugar beet and rapeseed. The technologies used to produce these fuels have been relatively simple, meaning that capital costs for producers have been low. Europe produces most of the world's biodiesel (particularly Germany), whilst major producers of Bioethanol are located in North and South America (particularly Brazil). It is these fuels that the UK government has encouraged to be grown to meet the current Renewable Transport Fuels Obligation (RTFO) target of 5% of transport fuel by 2010. It is widely accepted, though, that the relatively low levels of fuel production seen with these sorts of crops mean that any aspiration to produce more than the 5% target would require too much land, and create a conflict between use of farmland for food production and fuel production. In fact the UK government has recently (February 2008) announced a review of biofuel policy as a result of potential negative environmental, social and economic impacts.

Second generation biofuels use a wider range of feedstock than the first generation, and new processing techniques are being developed that could extend the range further. New biological processes are being developed that could convert wood, straw and even municipal waste into ethanol (and potentially hydrogen), and thermochemical processes that could produce a range of synthetic fuels from biomass-derived gas. Although some of these new technologies have reached a demonstration stage, the costs are still high, and a crucial element to the viability of all of these second generation technologies will be the availability of low cost feedstocks. Third generation fuels include the use of algae, and are still at the research stage, although demonstration plants are

beginning to be built. These technologies offer as much as 70-100 times the fuel outputs for the same land area as first generation fuels.

The UK has a growing biofuel industry, in 2007 there were five biodiesel plants in the UK, (growing to eight during 2008), with four bioethanol plants also planned. By 2010, total production capacity is expected to be between 4-5% of the UK's road transport fuel usage, in line with the RTFO. There are currently no second generation biofuel plants in planning or construction in the UK. Rural processing could in principle be encouraged by the low 'energy density' of biofuel feedstocks, making transport over long distances to processing plants costly. However, larger plants are currently needed to achieve economically competitive fuels. These need plentiful supplies of feedstock, achieved at present by building processing plants at, or near, ports, to make the most of imported (and cheaper) material (AEA 2007).

The cost effectiveness of biofuels is currently dependent on the price of conventional fuels. Until recently the former have generally been more expensive than petrol and diesel using current technologies, although fuel sourced from developing economies can be significantly cheaper than fuels from the UK and Europe, because of lower labour costs and better climates for feedstock growth. Biofuels from countries such as Brazil are considered to be competitive at an oil price greater than US\$60 a barrel (comparing energy content). In Europe, ethanol from wheat and biodiesel from oil seed rape are competitive at oil prices starting at US\$70 a barrel, as feedstock costs are higher in temperate areas such as the UK (E4Tech 2006).

It is possible to see a number of impacts on transport and rural areas of a wider move to the use of biofuels in the future, summarised in Table 8 below.

Table 8:

Impacts on rural areas of increasing use of biofuels

Economic impacts:

- Income for growers / producers.
- More employment opportunities in production, and possibly processing.
- Local production of fuels could 'secure' fuel supplies for rural transport.
- Reduced costs for travellers by avoiding 'carbon' taxes.

Environmental impacts:

- Increased water use, fertiliser / pesticide use, monoculture.
- Reduced CO₂ emissions (over lifecycle of crop/fuel).
- Some air quality problems, particularly if travelling to urban areas.

Social impacts:

- Competition for land leads to increasing costs of food.

- Increasing use of biofuels in rural areas could provide an economic benefit for those areas if it translates into greater production of fuel feedstocks. The UK government Biomass Strategy (Defra 2007) suggests that up to 1 million acres of land could be growing biofuel and energy-crops by 2020 (equivalent to 17% of UK arable land), as well as production from woodland and waste products, although it accepts that going beyond

this level (5% of transport fuel) could be a problem. This could provide a welcome fillip to rural economies.

- Biofuel production in rural areas also has the potential to create employment. The Sustainable Development Commission (SDC) estimated that approximately two 'on-farm' jobs would be created per 1,000 tonnes of biodiesel, and over 60 jobs for each 100,000-tonne processing plant. For bioethanol the figures were higher, five jobs on farm and 80 or more jobs in processing (SDC 2006).
- Reduced CO₂ from vehicles would help avoid potential carbon taxes for users – keeping down transport costs (private and public).
- There are environmental benefits, and costs for rural areas from growing biofuels. An agricultural monoculture, more pesticide and fertiliser and greater water use in growing and processing the fuel are dis-benefits, but much reduced CO₂ from vehicles would help with meeting carbon reduction targets from transport. In the future, a significant amount of biofuel could, potentially, be produced from feedstock without significant land requirements (e.g. in vats using agricultural and municipal waste or algae). These developments would be expected to reduce the life-cycle CO₂ emissions of biofuels significantly, and the amount of land required.
- One area where biofuels do not perform so well is in respect of air quality (where they are thought to potentially create more NO_x and particulate emissions). In fact it could be foreseen that there might be problems for rural commuters in congested urban areas with strong air quality management regimes. This may work in the favour of rural communities though in decreasing the desirability of biofuels in urban areas, and reducing competition for them.
- For rural transport users to make use of these fuels there will need to be a rural infrastructure for delivering them. Liquid biofuels can largely use the existing petrol/diesel infrastructure with some modifications, although the lower 'energy density' of biofuels would mean more deliveries to achieve the same energy availability as petrol and diesel. As a consequence of the development of biofuels, it is possible that the manufacture of fuels could become more 'dispersed' than current oil refining (Eyre 2002), helping to remove the current 'premium' paid for fuel in rural areas compared to urban counterparts.
- One further issue for the use of biofuel for transport in rural areas is competition for its use. Motorised land transport will be competing with the power, heat, food, clothing, cosmetics and, potentially, aviation and maritime sectors. This may make the price too high for transport users. Aside from cost, the UK Government's Biomass Strategy (Defra 2007) showed that car transport is currently one of the least cost-effective uses of biomass in saving CO₂. In particular, wood biomass is more efficiently used to produce heat than electricity (Prag 2005).

This suggests that, if the focus is on the largest and most cost-effective impact on CO₂ emissions, then biomass should not be used extensively for transport fuels until either potential savings from these other sectors have been exhausted, or until the marginal cost-effectiveness in road transport is greater than in other sectors.

Another form of biofuel available for use in vehicles is biogas produced from biomass using technology such as anaerobic digestion (AD).

Table 9:

Biogas

Benefits:

- Can be commercially deployed today.
- Local generation, on-farm and community based
- Upgraded biogas (biomethane) contains 97–98 % methane, which allows it to be mixed with natural gas and distributed in the existing natural gas grid.

Disadvantages:

- Lower energy densities than petrol and diesel and lower range.
- Biogas needs costly processing to remove impurities before use.
- Has to be stored at high pressure in vehicles, meaning high compression costs and heavy fuel tanks.

Future direction:

- Use of wider range of source material, *i.e.*, municipal waste, sewage?
- The technology could be developed and used for hydrogen-powered vehicles.

The National Farmers Union (NFU) has produced a guide to the production of biogas which highlights the potential of this process for both generating energy, and producing transport fuel from controlled decomposition of animal and food wastes (NFU 2008). Use of AD may be further encouraged by the EU Directive on animal by-products that require greater control over wastes, especially methane emissions from animal waste (Prag 2005). The latter is a substantially more potent greenhouse gas than CO₂ (some 25 times more potent), and by using it as a transport fuel, it is possible to avoid not only emissions from the use of a conventional fuel, but also to avoid the impact of the methane as well.

Small-scale systems can be implemented on individual farms, whilst larger operations could use materials from several farms, or wastes from rural communities. There is much more experience of this in European countries such as Sweden and Germany. In fact, in two Swedish cities biogas is transported in the existing natural gas grid. This means that use of the gas is not limited to the production area, it can be used anywhere along the grid, for example at roadside filling stations (Biogas West).

Aside from the impacts seen in liquid biofuels above, there are some other, primarily economic, impacts of a more significant use of biogas in rural areas in the UK.

Table 10:

Impacts on rural areas of increasing use of biogas

Economic impacts:

- Infrastructure costs could be significant, and may need government support to encourage take-up.
- Better suited to 'captive fleets' for example buses and commercial vehicles.
- Possibility of very localised / community production of fuels.

Environmental impacts:

- Climate change positive, as it removes methane emissions

- Infrastructure costs for a network could be significant. However, the rapid expansion of biogas production and distribution in Germany and Sweden illustrate that a similar expansion could happen in rural areas in the UK if the appropriate pricing were in place (Germany fixing their pricing regime until 2020 to provide long-term stability), and would be achievable within the 15-20 year timeframe of this review. Such an expansion could prove economically beneficial to rural areas, providing extra income for farmers and communities (if community waste is also processed for gas).
- Such an expansion would also offer rural areas a greater control over transport fuel resources and more fuel security. There are issues though in respect of the diversion of organic matter away from being used as a fertiliser, and whether there would be competition for the biogas as a domestic fuel or source of electricity.
- It might prove more beneficial in the short term to use biogas as a fuel in public transport fleets, as the infrastructure required to deliver biogas in these fleets could be simpler, and less costly. This might help manage costs in public transport in rural settlements.

Electric vehicles (battery / hybrid)

The second energy source expected to become more prevalent in vehicle technology in the next two to three decades is electricity. This has many attractive properties as a transport fuel, and is likely to feature in two forms: first, battery powered vehicles, and second, hybrid-electric. The former, although rapidly improving, may still have a shorter range than petrol and diesel vehicles, and are perhaps better suited to the urban environment where they could provide significant air quality benefits. Hybrids have greater range, and perform more like conventional vehicles (but much more efficiently) and are more likely to offer a solution to replace conventional petrol and diesel vehicles (E4Tech 2006).

Table 11:
Electric Vehicles

Benefits:

- Zero emissions at the point of use, providing major local air quality benefits.
- If produced from renewable sources, then low or even zero CO₂ emissions.
- Can also use biofuels in hybrid electric vehicles to maximise environmental benefit.
- Efficiency: 75-80% of original electricity generated can be delivered to the vehicle with a plug-in hybrid (Romm & Frank 2006).

Disadvantages:

- Energy storage and corresponding vehicle range remain relatively limited compared with petrol or diesel vehicles.
- Extra weight of batteries reducing performance.
- Battery charging time is still high relative to most consumer expectations, unless fast charging is used, requiring more complex and more costly charging stations.
- Transfers pollution to power stations / creates demand for more power stations
- Need to run ancillary equipment (heating, air conditioning) places a significant or unfeasible load on battery.

Future direction:

- 'Plug-in' hybrid, and diesel hybrid.

Battery powered vehicles have in the past suffered from the weight, bulk and poor range of traditional lead-acid batteries. Next generation technology such as lithium-ion batteries (as used in mobile devices such as laptop computers) is expected to provide a substantial improvement in cost and performance, potentially boosting range to 400kms or more. Pure electric vehicles being developed currently appear to fall into two camps, the low-cost urban 'runabout' (such as the G-wiz), and expensive electric sports cars (Tesla Roadster). The former is small and has limited range, making it relatively impractical for rural use, and the latter is costly to purchase.

Several major manufacturers are though beginning to design and introduce vehicles that take advantage of new technologies around electric vehicles, and it is conceivable that a breakthrough in battery technology will be made in the next 20 years that will revolutionise electric vehicles. Other technological improvements which help performance include moving to electric motors within each wheel (hub motors) as opposed to one central engine, which can offer weight reduction and mechanical simplicity benefits. However, the lengthy recharging time is still an issue for most consumers, and there are potentially fewer opportunities to provide commercially viable plug-in recharging points in more dispersed rural areas.

Hybrid vehicles use an electric motor in conjunction with a conventional ICE, or more likely in the future a fuel cell, to improve efficiency and hence reduce fuel use and emissions. These appear to offer great promise; Toyota is expecting to sell 0.5 million hybrids a year in the USA within 2-3 years. A further development of this concept is the 'plug-in' hybrid. Like conventional hybrids, these vehicles combine an ICE with an electric motor to maximize fuel efficiency, but they have larger batteries that can be recharged by plugging into an electrical supply. This provides a greater store of electrical energy than that generated 'onboard' by current hybrids through techniques such as regenerative braking.

Plug-in hybrids can be run on electricity for short trips, and on their ICE for longer trips (when the battery is flat the vehicle runs on the ICE). The combination can drastically reduce fuel consumption, offering approximately two-to-three times the fuel efficiency of current hybrids (such as the Toyota Prius). In America it has been suggested that there will be hybrid models of most vehicles available by 2020, and that this is when a 'market transition' to hybrid technology will occur (Romm & Frank 2006). This is earlier than expected in Europe, where vehicles are already more fuel efficient than US models.

Others consider that hybrid systems are just a transition technology, on the way to hydrogen as a widespread fuel source, and will not be a long-term solution without a significant breakthrough in battery technology. It is accepted though that if fuel cells are delayed, then hybrid vehicles using biofuels could make a major contribution to CO₂ emissions reduction (E4Tech 2006). There is also a school of thought that the extra costs implicit in the hybrid approach (two engines plus batteries), and the lack of space to grow enough biofuel (particularly 'first generation' fuels); mean that actually transport will need to be 'grid-connected' to provide affordable mobility (Gilbert & Perl 2006). This solution, in the form of electric trains, metros, trams, and trolley buses for example, provides transport that is propelled by electric motors directly connected to a remote power source, as opposed to actually needing a fuel source on the vehicle. This isn't only restricted to public transport, as it could also be deployed for individuals in the form of 'Personal Rapid Transport' (PRT), that is systems using smaller vehicles maybe carrying two or four passengers³. Whilst a pervasive argument can be seen for the adoption of grid connected systems in urban areas, it is difficult to see how this could be extended to serve the majority of rural areas, particularly those locations more remote from urban centres, although there might be potential where rural areas lie on inter-urban corridors.

The potential impacts of a widespread move to electricity as a fuel in rural areas are highlighted in Table 12 below.

Table 12:

Impacts on rural areas of increasing use of Electric / Hybrid-electric vehicles

Economic impacts:

- Potential for increased generation of renewable energy in rural areas – creating income for landowners, and access to energy supplies for rural communities.
- Using electricity to power a car would be cheaper than petrol and diesel (especially if cars are charged overnight when electricity demand is lower and there is spare capacity).

Environmental impacts:

- Reduced 'tailpipe' emissions and pollution.
- Reduced noise pollution.
- Use of land for renewable energy generation.

Social impacts:

- Could facilitate greater access and travel to urban areas, as electric vehicles may escape congestion and air quality restraints, as well as avoiding carbon-based taxes.

3 The first commercial example of PRT is currently scheduled for implementation at Heathrow airport over the next two years.

- One important feature of a move to electric vehicles in rural areas is the potential ability to generate transport fuel *in situ*, particularly from renewable energy. Sources of energy such as on-shore wind, and biomass are largely reliant on open land either to grow crops or for the effective siting and operation of wind turbines, making rural areas more appropriate as locations. It is also the case that the most effective use of this energy would be local, thus avoiding losses over power lines. A wider issue though will be competing uses for the electricity. If the renewable sources are grid connected, then this conflict may be resolved by the price achieved from the grid as opposed to the value as a transport fuel.
- The large-scale uptake of pure electric cars would require the wide availability of charging points. Given that electricity is already supplied to all except the UK's most remote rural locations, this should be relatively straightforward to implement. Vehicles can already be recharged from the garage or from the street using a cable, and in addition charging points in car parks could effectively increase range. This is obviously less viable in rural areas than urban, but for those people travelling to urban destinations to work or access education, healthcare etc, then they could make use of urban facilities anyway. 'Fast charging' requires more complex and considerably more costly charging stations and would require very aggressive policies for infrastructure to be put in place (E4Tech 2006), perhaps less likely to be implemented in rural areas as a result, and a potential deterrent to wider use.
- There are environmental benefits from using electric vehicles: they provide zero-emissions at the tailpipe, and remove the other air pollutants commonly associated with petrol and diesel engines. They do of course move the emphasis back to the power station that is generating the electricity. If this is a conventional fossil fuel source then there will still be emissions and pollution – and the negative impacts of fuel extraction and processing. Pure electric vehicles are also much quieter than conventional vehicles and would greatly reduce rural noise pollution from transport.
- Hybrids using biofuels offer the opportunity for rural areas to generate both the fuel sources being used relatively simply, and depending on oil prices, cost-effectively. It is feasible to see rural fuel networks developing, much as is happening in Sweden now with biogas, and allowing a degree of self-sufficiency in rural areas for both public transport and private vehicles. This combination could also be seen as a way of making the most of biofuel, whilst the transition to third-generation fuels is still underway – accepting that there will not be adequate land available to grow enough first generation – and possibly second generation – fuels to supply global transport needs.

Hydrogen

The third new fuel technology that is expected to offer a replacement for petrol or diesel vehicles is hydrogen – particularly as a fuel for use in fuel-cell⁴ vehicles. These offer a potential low-carbon replacement for the longer-term (2050+), partly as a result of the wide range of possible hydrogen sources (E4Tech 2006). The technological barriers still needing to be addressed though make it unlikely that it will be a significant alternative in the period to 2030 (King 2007). Consequently, hydrogen is covered here briefly, in order to give some indication of how private and public transport may develop. More specifically what impacts might start to be seen by 2030 in rural areas as we begin to move towards a transport system that uses hydrogen more widely. It is also feasible to use hydrogen in an ICE engine, but this is less fuel efficient, and not thought to be a solution for the long term.

Table 13:

Hydrogen

Benefits:

- Zero emissions at point of use, only by-product of combustion is water.
- Can provide fuel for efficient fuel-cell technology, or be used less efficiently in an ICE.
- Fuel cells can utilise hydrogen from any source, including hydrocarbon fuels, such as natural gas and methanol.

Disadvantages:

- There are no natural sources of hydrogen so it must be produced in energy-intensive chemical reaction (reforming), from water, coal, oil, gas or biomass.
- Reforming from fossil fuels produces pollutant waste products.
- Poor public acceptance of hydrogen vehicles to date on perceived safety grounds.
- Will need completely new refuelling infrastructure and production plants.
- Lack of international standards and regulations which may hinder implementation
- Relatively inefficient use of renewable energy – only 20%-25% of original energy delivered to vehicle.

One particular avenue of interest for rural areas is producing hydrogen from biomass, and over the next 15-20 years these techniques could become more prevalent. Again, this is an area that is being explored in other European countries, such as Sweden, as part of their biogas development programs. It is understandable that Sweden is seeing the route to hydrogen as one which involves compressed gas fuels now, moving to biogas, and then hydrogen in the future, as it may offer the opportunity to reduce the need to provide further generations of new infrastructure, particularly in dispersed rural areas.

4 A Fuel Cell is an energy conversion device that can convert hydrogen into electricity without combustion by use of an electrochemical process. Similar to a battery, but in a fuel cell the fuel and oxidant are stored externally, enabling them to continue operating as long as the chemicals are supplied.

Table 14:

Impacts on rural areas of increasing use of hydrogen vehicles

Economic impacts:

- Potential for creation of hydrogen fuels 'locally'.
- Significant costs for new infrastructure.

Environmental impacts:

- Reduced 'tailpipe' emissions and pollution (depending on fuel source).
- Reduced noise pollution.

Social impacts:

- Costs of infrastructure may mean that dispersed rural populations need to wait for local infrastructure. This could reduce the ability to travel in rural areas if the only alternative is costly petrol / diesel.

- Hydrogen would require major new supply infrastructure to be developed, and/or local production facilities, *i.e.*, to provide for the 'reforming' of hydrogen from natural gas, for example, or biogas. This cost may cause initial roll-out to be concentrated on urban areas and inter-urban corridors (motorways *etc.*) to allow operators to recoup their investments. It might also encourage initial use of hydrogen in captive⁵ bus and car fleets as an intermediate step. A large supply network is only likely to be developed if hydrogen emerges as a fuel that can be widely supplied at a reasonable financial and CO₂ emission cost, and if developments in other technologies do not provide more cost-effective alternatives. Even then, a complete replacement for the current refuelling infrastructure is not likely to be necessary until hydrogen vehicles constitute a major part of the national fleet. A much less dense network could still be used to cover a suitable area, though, without providing high levels of competition in the short term, similar to the network of LPG stations today. It is thought that the initial infrastructure could be either centralised or decentralised in nature (that is producing hydrogen locally using gas or electricity from the national grids), although in the longer term a centralised infrastructure is thought to be more cost-effective and to deliver greater CO₂ emission reductions (E4Tech 2006).

Technological change in public transport

There are of course opportunities to use the alternative fuel technologies discussed above in public transport vehicles, with similar benefits, although sometimes with subtly different design and operation issues. It is likely that some of the benefits, such as less air pollution, may prove to be of greater benefit to urban rather than rural areas. In contrast, in the areas of communication technology and computing, changes may be seen that particularly improve the performance of public transport in rural areas. For example;

5 *I.e.* fleets refuelled from one or a small number of dedicated depots, minimising the infrastructure needs.

- The widespread use of the internet, across most groups in society (although not all), presents opportunities for online booking and availability checking for services such as Community Transport (CT) and Demand Responsive Transport (DRT) services.
- Advances in scheduling software and on-bus Information and Communications Technology (ICT) could mean that services respond to customer demand much more dynamically and flexibly, thereby encouraging greater use. These technologies may also enable a move towards smaller-scale public transport solutions, such as DRT and / or shared taxis.
- The expansion of broadband facilities into rural areas is also providing greater opportunities for the public to access these services. The introduction of wireless broadband across phone networks increases the potential, as does the growing availability of applications such as ticketing and money transfer on phones.
- Improvements in scheduling and on-board ICT systems might also create opportunities for services to link-up more effectively. If, for example, buses on a network 'know' where other vehicles are, and when they will reach particular destinations, it may be possible to provide better integration between services, and other transport providers and modes. This is helped by the growing availability of spatial positioning systems (GPS and the new European equivalent Galileo), and their integration into phones and other devices.

Table 15:

Benefits and issues with technological change in public transport

Benefits:

- Potential for locally produced fuels. Improved fuel security.
- Reduced environmental impacts, although possible air quality issue with biofuels
- ICT improvements could lead to more effective routing, and a service more tailored to customer needs.

Disadvantages:

- Extra costs from some alternative fuels, and new technology.
- Possibly restricted route network, shorter range if constrained by 'centralised' refuelling with alternative fuels.
- Not everyone has access to ICT solutions (internet, mobile phone)
 - those without a car may be less likely to have internet access for economic and age-cohort reasons.

'Smartcards' are also currently being introduced for older and disabled people for use in concessionary fare schemes on public transport, which will require operators to fit smartcard-reading technology to buses and trains. This could open up opportunities for other passengers to take advantage of the technology to improve their experience of using public transport – removing the need to carry change, and offering the ability for passengers to access season and multi-use discounts, as has already been seen in London with the 'Oyster' card. In some areas this technology is being extended to other modes of travel, such as taxis, as well. Similar functionality is being trialled in mobile phones offering the same

sorts of benefits, and both technologies are helping operators to tailor services better to specific markets.

The movement towards some of these technological changes could be hastened – if considered desirable – by changes to regulatory and fiscal regimes for public transport. For example, how local and central government support is delivered to operators might encourage moves towards alternative fuels, helping insulate rural passengers from the cost pressures of rising oil prices.

Table 16:

Impacts on rural areas of technological change in public transport

Economic impacts:

- Reduced costs of travel for travellers and reductions in operator costs from more efficient networks.
- Extra costs from new technology for operators (and travellers?).

Environmental impacts:

- Reduced emissions, pollution and possibly noise.

Social impacts:

- Better public transport network, more integrated and seamless travel.
- Service more flexible, and better suited to customer needs.

- Increases in the use of public transport as a result of improved technology are more likely to be focussed on services such as DRT and CT in those rural areas with dispersed populations. Extra services here will be unlikely to have major requirements for land, or produce significant impacts on the environment in respect of air quality or emissions.
- Assuming that the deployment of alternative fuels happens as quickly, if not more quickly, in commercial vehicles, then similar environmental benefits to those expected in private vehicles may accrue over the next 15-20 years. For some smaller vehicles with relatively short commercial lives (taxis for example), this turnover to new technologies may happen in a relatively short timescale. Vehicles likely to be in service for longer periods may benefit from the retro-fitting of new technology. Buses powered by gas are in widespread use in some countries, and electric power has been used for many years – although perhaps this is better suited to urban areas. Hydrogen fuel-cell vehicles are running in a number of cities, including London, but primarily as demonstrations of the technology at present, as high costs are involved.
- There would seem to be opportunities for public transport to take advantage of the ability to generate fuel locally, particularly biogas, with 'local' digesters capable of producing gas for fuel. In Sweden there are already settlements running their public transport on gas, and others planning to move to biogas. A demonstration biogas infrastructure is being set up on the Dalbo Plain, involving on-farm as well as centralised production facilities (Energi & Miljo 2008). Longer-term local renewable energy could be used to generate electricity, and hydrogen. Whilst pure electric public transport is probably unlikely to have much potential in rural areas because of the dispersed

nature of the population, hybrid or fuel-cell vehicles could offer a mechanism for using the local fuel close to the production facility. Use of these new technologies is actually more likely to happen first in these captive fleets, as operators can take advantage of the benefits of new fuels by managing their own systems and storage.

- The other technological driver for change in public transport – advance in ICTs – is likely to make the service more attractive, but unless the costs of alternative private transport become significantly greater it is difficult to see any substantial move back to public transport. For those with no alternative of course, what will be more important will be whether the costs of new technology in public transport will continue to be supported by local and central government through the various public subsidies.

Information and communications technology (ICT)

An earlier report for the CRC (Craig & Greenhill 2005) identified a number of potential scenarios for how computing and communication technology (ICT) might develop in rural areas through to 2020. These scenarios had a range of outcomes, but a number of key directions could perhaps be foreseen. These were that the new technologies will be exploited more by those who are more affluent, and that 'services' will be more readily available in areas where these more affluent rural-dwellers are concentrated. The less well-off, and perhaps older, rural residents may experience less improvement in accessibility and/or other benefits from these new technologies. This can be expected to lead to changes in demand for transport.

The speed and breadth of take-up of new technologies could be partly encouraged by the rising costs of travel, and further increases in costs and disincentives to travel (e.g. road pricing, carbon taxes) over the next few decades could accelerate this.

For some, the greater availability of ICT functionality and networks in rural areas will open up opportunities to access services remotely, and support those who wish to tele-commute, perhaps accelerating migration into some rural areas. The movement of more affluent groups into rural areas may be a boost for rural economies, encouraging spending on local services and in local shops for example. This migration though is likely to still be predicated on the ability to travel by private car(s), taking advantage of alternative fuels as considered above. Another potential factor relating to new ICTs will be the opportunity it provides for rural businesses to access urban markets, potentially without the need to travel.

Table 17:

Impacts on rural areas of technological change in ICT

Economic impacts:

- More people working in rural areas, leading to more economic activity, and potentially a driver for re-localisation of some services.
- Workforce catchment areas extend into rural areas.

Environmental impacts:

- Reduced travel: less pollution, noise, congestion *etc.*, although this may be offset by greater 'leisure' travel, travel outside of commute times by 'tele-workers'.

Social impacts:

- As greater use is made of ICT solutions, so avoiding travel, there may be a reduction in services required locally as people choose e-services, *e.g.*, continued pressure on the viability of Post Offices if most functionality is available on-line. This might exacerbate loss of facilities in rural areas.

- Reductions in the amount of travel as a result of tele-commuting, and online shopping appear to be beneficial to the environment in respect of emissions, but even these solutions have a footprint, for example domestic energy use whilst people work from home (*e.g.* heating and lighting), or the energy used in home delivery.
- As improved 'electronic' links from rural areas make it easier for tele-commuting, so the desirability of rural areas for affluent urban 'escapees' increases – this may also increase levels of travel when these people do need to commute.
- ICT changes may lead to 'virtual' catchment areas for workers, as regular commuting is replaced by tele-commuting. However, very few employment opportunities will result in no travel needing to be made, and this might actually result in an increase in longer-distance travel (even if occasional).
- It is possible that ICT solutions may just displace travel to another time in the day, or free people up to make different journeys. Journeys that may have been made as part of the commute in the past may now be made separately (the school run for example), so there may actually be increases in shorter journeys at the same time as a reduction in longer ones. It is worth noting though, that any substantial reduction in demand for travel, particularly public transport, could undermine the case for, and the economic viability of, small-scale localised generation of fuels such as biogas.
- The infrastructure needed to make ICT solutions work comes at a cost, and this may be higher per user in rural areas than urban areas, because of the lower density of population, reducing opportunities for businesses to recoup investments. This was seen on the slower roll-out of rural broadband, and may impact on future technologies in the same way. This could make the benefits of new technology the preserve of the rural affluent, whilst those less well-off are still constrained to use high-cost private transport.
- Greater use of ICT to resolve transport needs could also mean that there is less need for distributed services such as Post Offices, as more services move online, which penalises those without ICT access – perhaps in more remote rural areas, or the less well-off sections of rural communities.

6

6 Conclusions

A vision for rural transport over the next 15-20 years

Upward pressures on prices for oil and gas-based transport fuels are likely to continue over the next two decades as a result of the continuing global demand and competition for resources, and as a result of the impact of the widely predicted 'peak oil' scenario. There will also be an increasing need to respond to climate change, driven by the successor to the Kyoto Accord, due in 2012. In the UK, the forthcoming Climate Change Bill will set legislative targets for CO₂ reductions – including from transport. Concurrent with these pressures to reduce unsustainable travel, it can also be seen that the other drivers for mobility in rural areas (centralising of services, increasing access to a car, a larger number of older drivers *etc.*) will encourage mobility and travel. The net result will be a need to move to more sustainable transport solutions, although this is unlikely to result in any move away from the majority of travel being by private motor vehicle.

Bearing this in mind, the choices available over the next 15-20 years seem to be threefold, more efficient travel, new technologies, and avoidance of the need to travel. There is a view, that in the longer-term (2050 and beyond) hydrogen-fuelled vehicles, along with electrically powered vehicles, are likely to become the norm and will offer the potential to resolve many transport related issues. Accepting that these latter options are longer-term, there is still some debate as to which technology, or technologies, may prove most attractive in the medium term. Greater efficiency is in theory relatively easily available. Existing fuels can reduce emissions and pollution – but keep us locked in to hydrocarbon fuels and the associated problems they bring. For many it is biofuels that appear to offer a solution in the short to medium term, although there are still sustainability issues to address. They are, however compatible, with existing vehicle technologies, and in many ways look and behave like the fuels we currently use. UK and EU efforts to date have sought to use these across all road transport, but it is obvious that 'first generation' fuels can not provide more than 5-10% of this resource without causing significant environmental (and social) problems. What does appear to be possible though, as is starting to be evidenced by other European countries such as Sweden and Germany, is that local fuel infrastructures can be developed that can use local resources and provide fuel to public and private transport. Because of the possible 'penalty' of transporting bulky raw material for these biomass-based fuels smaller-scale production could become more effective closer to source, offering rural areas the ability to produce their own transport fuel and possibly the opportunity to become suppliers for other areas.

It is also possible to see that the different transport needs of rural and urban areas may actually lead to a greater divergence of transport technology than is just evident in particular niches

today. Low pollution, 'mass' transport, particularly in urban areas, is probably better served by moving to systems powered by electricity. Longer distance travel, less suited to public transport solutions in low-density rural areas will be better served by biofuels, and possibly longer term by plug-in hybrids, co-fuelled by biofuels. There will, of course, be infrastructure issues with any change, although greater use of liquid biofuels could co-exist with existing distribution structures fairly readily. Any significant moves towards biogas will require new infrastructure – but again potentially overlaid on an existing distribution network.

In order for hydrogen to develop as a commercially-viable solution for transport fuel, the problems of how to sustainably source and compress it will need to be addressed. If and when these are resolved there may be opportunities for localised production of hydrogen, perhaps using small-scale renewable energy solutions. This could speed the introduction of hydrogen as a transport fuel in rural areas, as the costs of deploying a widespread infrastructure are likely to prove an issue for some time. Ultimately, in a market context, whether hydrogen in fact becomes an important fuel may depend on how other solutions such as biofuels and direct consumption of electricity in vehicles develop. If these alternatives can offer equivalent or greater benefits, or they have achieved a sufficient foothold as transport fuels, then hydrogen may become a less attractive goal than some currently predict.

Implications for mobility and transport in rural areas

It is possible to see a number of scenarios developing in rural transport, and rural areas, as a result of technological change over the next 15 to 20 years. These range from the community-based production of transport fuels, and the ability to continue the high levels of individual mobility currently seen, through to a technologically-deprived and mobility-poor future.

The timeframe to 2030 is probably too short to expect radical change in the dominant transport technologies; what is perhaps more likely is the acceptance that responses to pressing problems, such as climate change and peak oil, will require a variety of responses, with rural areas employing the policy options and developments that suit them best. Consequently it is possible to see a number of technologies developing in parallel, rather than there being a widespread move to a single alternative with a corresponding shift in behaviour.

By creating their own fuels, rural areas could become 'transport rich', and benefit economically as a result. It is even possible that fuel could be 'exported' to urban areas, akin to the supply of food, although the poorer air quality performance of some biofuels may deter their extensive use in more densely-populated areas. The greater energy security is of course predicated on the ability to produce adequate fuel without relying on 'unsustainable' imports of feedstocks or finished fuels, and there not being more effective uses

of this energy. It is also possible to see that taking this route could create pressures on existing rural activity – such as food production – and development pressures to build more (industrial scale) processing plants in rural areas.

Technological change in ICT could encourage greater migration into rural areas, boosting rural economies, but at the same time increasing the disparity between those affluent enough to be able to maintain their own private transport and those reliant on public alternatives. New technology in public transport does though provide opportunities for better use of the network (and facilitates a more personal delivery of it). In addition, developments in ICT could also remove the need for some travel. It is unlikely, though, that these changes will reverse the huge disparity between public and private means of travel, unless a further significant increase in traditional fuel costs occurs – which itself may hasten the implementation of other new technologies.

All things considered, given the range of worldwide market pressures, it can be expected that transport costs will increase over the next 20 years and the fundamental impact of this may actually be reductions in travel from rural to urban areas, and within rural areas to access services and facilities. The impact could be much more significant than for urban communities, where the density of population and proximity to services and facilities would mean that electrically-powered public transport and walking and cycling could provide essential mobility. In more dispersed rural areas this would be less achievable, and as a result communities could become more isolated from their urban neighbours. This relative fuel-poverty might though prove beneficial in other ways, encouraging a re-investment in services and facilities for rural communities, halting the centralisation of recent years. It could also extend to employment opportunities, with virtual workforces distributed through rural areas making the 'commute' unnecessary. This more positive framing of decentralisation of both fuel supply and industry then echoing the Huxleian vision of strong, self-sufficient communities built on local and diverse networks of skilled production and consumption (Schumacher, 1974).

The costs of transport infrastructure could also have a major bearing on how transport develops in rural areas. As has been seen in the past with rural broadband networks, the low density of consumers and the size of the network required mean that it is urban areas that see the first investments, and possibly lower costs. Any new infrastructure development that is intended to cover a dispersed population will invariably cost more per user. Looking to the long term, towards a possible significant use of hydrogen it can be seen that this offers a major challenge in respect of the costs of new infrastructure, and it may be that this proves to be prohibitive for rural areas, and in fact other solutions are more applicable for maintaining mobility.

Finally though, throughout all of the possibilities considered above it is important to bear in mind that 'rural' is not a single classification, and that these scenarios may play out differently depending on

the relative affluence, location and population of an area, and that different scenarios may even coexist in adjacent rural locations. What is clear, though, is that there is no single technological change on the horizon that will address the range of transport issues likely to be relevant for the next 15 to 20 years. It is also evident that there are some significant decisions to be made about what the rural environment is best used for, and whether in order to achieve resilient rural communities in the future there is a need to think about more sustainable responses to some of the identified drivers for mobility and transport.

Recommendations for further research

The present report was produced based on interpretation solely of secondary sources. Moreover, the short duration of the review meant that it cannot be considered exhaustive in terms of detail, although its breadth is likely to prove relatively robust. It is hence recommended that follow-on work be undertaken to extend the detailed literature review work.

More importantly, however, a key finding is that a 'transport revolution' in rural areas is unlikely to occur within the 15-20 year time frame examined to date. However, for the period beyond 20 years literature review is likely to be a less relevant methodology, as the pace and nature of change is more speculative, and is less likely to have been reported yet in peer-reviewed or official publications. It is therefore suggested that the follow-on work include primary qualitative research with key informants. This could take the form of a Delphi methodology, in which opinions are elicited from expert informants and then represented to informants as a collective synopsis, with at least two iterations of the process being applied. This enables informants to learn from each other, and to comment on an emergent consensus view of likely future change.

The qualitative data could in turn inform scenario analysis involving a quantitative dimension, considering, for example, different levels of future fuel prices, biofuel planting, and rates of provision of wind energy production capacity.

7

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