Getting in the Right Lane
Low Carbon European Transport Beyond 2050

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1. The Context

The EU is committed to taking the lead in moving towards a low carbon future with a challenging target of an 80% reduction in CO_2 emissions by 2050 (on 2000 levels)[1]. Transport in the EU27 currently accounts for over 25% of carbon emissions, and this sector must take responsibility for cutting its levels of emissions. Aviation and shipping also need to be included in this target, even though the allocation mechanisms are not yet well defined. The actual targets are likely to be even higher, as population will grow within the EU to 2050, and as the potential for further growth in travel is likely, as there is at present a strongly link between travel and economic growth.

This study reviews the available secondary material on investigating sustainable futures for transport, to set out the options available and the challenges that need to be met. It presents a synoptic view of the transport market, the opportunities available, and the role that the EU should play in leading the debate and in taking effective action. The key actors are also identified, together with the barriers to successful implementation of the 80%+ reduction in carbon use in the transport sector.

The report covers five main topics:

1. The scale of change required to reach the 80%+ carbon reduction target in transport, covering both the targets themselves and the use of 5 year budgets for change;
2. The potential pathways – to cover both technologies and behavioural change. This will also include new visions for transport, and the view that transport should be seen as a service provider, and not on the conventional modal basis;
3. The key actors and policy strategies – to cover leadership and commitment, as well as the need for new incentives to facilitate change;
4. Barriers and inertia, covering the need for strong immediate action, and the issues of vulnerability, security and resilience;
5. A set of key recommendations and priorities for action at the EU level.

[1] This target has been confirmed at the G8 Summit in L'Aquila (July 2009) and there is also a commitment to a maximum 2C rise in global temperatures (see annex 2).

2. *The Scale of Change*

Throughout this paper, the assumption is made that transport needs to take its fair share of the 80% reduction target. This is particularly difficult as there has been a substantial and continuous growth in transport demand since targets were first introduced for CO_2 reductions from 1990 (Table 1). This means that any reduction is going "against the tide" of growth, and so far transport has made no contribution. This issue is particular problematic in the air and maritime sectors, where growth rates of over 4% per annum and 3% per annum respectively are evident.

Table 1: Key transport emissions data for the EU27 and levels indexed to 1990 (2005)

$MtCO_2e$	Transport	Road	Civil Aviation	Waterways	Rail	Other
1990	960.1	716.6	84.5	133.1	14.6	11.2
2000	1174.0	864.7	136.3	153.8	9.7	9.6
2005	1277.4	922.6	151.4	184.5	8.5	10.4
2006	1300	926	158	197	9	10
1990	100	100	100	100	100	100
2000	122	121	161	116	66	86
2005	133	129	179	139	58	93
2006	135	129	187	148	62	89

Source EEA (2007) and reported in DGTREN (2008)
Notes: 2000-2005 increases have been 9% overall, +7% road, +11% air, +20% waterways, -12% rail, and +8% other. The 2006 figures are provisional.

The second issue is the expected growth in population in the EU27 over the next 50 years, meaning that the available amounts of carbon have to be divided among more people, making the actual target 83%. This means the per person transport emissions levels need to be reduced from 2.44 tCO_2e (2000) to 0.43 tCO_2e (2050) – or 2.04 tCO_2e to 0.35 tCO_2e if the dates taken are 1990-2050.

Thirdly, the estimates of the scale of change over the 50 year period needs to be set against the expected growth (see annex), where emissions levels per person are likely to almost double from 2.44 tCO_2e to 4.02 tCO_2e, so the real change needed is a Factor 10 reduction (i.e. from 4.02 to 0.43). Embedded within these figures are assumptions that there will be some efficiency gains (+4.7%) in all modes of transport, so any other gains need to be in addition to those already assumed in the forecasts.

Finally, none of these figures include international aviation and maritime transport, which as we shall see are two of the main growth areas in the recent past and they are likely to continue to be major contributors to CO_2 emissions over the next 50 years.

One of the limitations of the target setting is to establish a pathway to that target. Ideally, it would be important to introduce some "quick hits" where substantial savings are made immediately in the transport sector (the ideal path in Figure 1), but in practice this has not taken place. The pathway being followed is much closer to the current path (Figure 1) where all the major savings are left to the last period. The pathway should at least follow the steady path (Figure 1) over the full time period to 2050, so that not all the difficult actions are left to the last few years.

The UK Committee on Climate Change has set 5 year budgets for the period 1990-2025 to suggest a profile of change that seems to follow the current trends (Figure 1). The implications of this strategy are illustrated in below, where the pathway for transport emissions in London has been calculated and summarised (Table 2).

Figure 1: Diagrammatic view of three pathways to the 2050 80% target

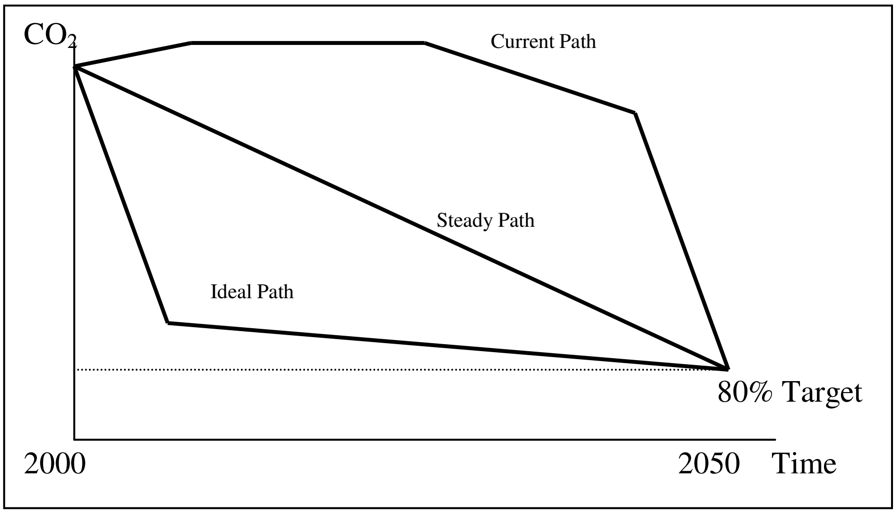

Table 2: Carbon Budgets for London

London 2027: This information box is based on a comparison of the planned reduction profile with a uniform reduction over the whole period (1990-2025), with the calculations based on the methodology of 5 year allocations developed by the Committee on Climate Change (Dec 2008) report. There are also actual figures for 18 years, so that the deficit can be easily calculated for the period 1990-2005.

1. Assuming a uniform reduction, the total amount available over the 38 years (1990-2027) is 259 $MtCO_2$ for transport in London.
2. The actual amount used already (1990-2008) is 168.3 $MtCO_2$. The amount available for the next 20 years (the first 4 budget allocation periods) is about 90 $MtCO_2$ – so the current remaining allocation per year is 4.5 $MtCO_2$ (under 50% of the current actual levels). Each year, this figure gets reduced if the allocation is not met.
3. At the current levels of CO_2 emissions in transport for London, the total allocation (259 $MtCO_2$) will be used by 2018, some ten years before the target date.
4. Even with the pathway being proposed (the slow path: 5%, then 10%, then 30%, and then 60% reduction in each 4 year budget period), there will be a deficit of 56 $MtCO_2$ by 2027.
5. With a fast path approach (10%, then 30%, then 45%, and then 60% reduction in each 4 year budget period), the deficit will be 36 $MtCO_2$ by 2027.
6. To reach the target requires immediate fundamental action and a pathway of 45%, then 55%, then 60% and then 60% reductions are needed over the four budget allocation periods.

Using the cumulative approach and budgeting for 5 years means that it is already impossible to reach the 60% reduction levels set for transport in London. It is possible to achieve the target itself, but this ignores the “additional” carbon emitted over the period because of the pathway adopted. It is essential to make immediate substantial cuts if this problem is to be overcome. The "slow path" being adopted in London leaves a substantial (22%) carbon deficit for transport in London (2027).

Source: Author's calculations (2009)

The arguments for immediate action are powerful as we cannot afford to leave all decisions until later, as there will be an even greater deficit given the budgets that have been allocated. In London, it has been estimated that the budgets allocated to 2027 (259 $MtCO_2e$) will all have been used by 2018. This argument is strongly supported by the climate science evidence (Anderson, 2008 and Metrological Office, 2008), where the slow progress made so far towards the targets set, have been highlighted as endangering subsequent actions. As time passes, the CO_2 deficit increases and even if targets are reached, millions of tonnes of additional CO_2 will have been placed in the atmosphere.

There are also many external factors that influence the process, and it seems that there has been considerable increase in the volatility of the economic context within which the debates on climate change are taking place. Transport is almost totally dependent on oil, and the world price of oil has fluctuated between $40 and $140 a barrel over the last year[2]. It is uncertain as to how that might change in the short or longer term, as its price has an impact on travel demand and on alternative technologies (including alternative fuels). In addition, there is also the question over the availability of oil, which again influences the price of travel, and alternative technologies.

Looking at the future of oil, Gilbert and Perl (2008) claim that World oil production will peak in 2012. They are not alone in this view, even though it is extremely difficult to obtain accurate figures from many of the producers on their reserves. Simmons (2005) came to the same conclusion in 2003 through his detailed analysis of available information on Saudi Arabia's reserves that account for about 25% of the World's total. The main criticism of "peak oil" is that with higher prices and improvements in technology, new fields will be found, more oil will be recovered, and oil shales and tar sands will become economic. But the problem here is the speed at which change is needed and the levels of investment required to bridge the gap between cheap oil and expensive oil, and the suitability of low grade oil for transport.

Central to Gilbert and Perl's case are two claims. The first is that oil use is about three times as high as the rate of new discovery (p124), and the second is their dependence on two key graphs in the book (Figures 3.7 and 3.8), where much is made of the Uppsala Projection (Aleklett and Campbell, 2003), with some additional material from the more established International Energy Agency (IEA) reports. Aleklett (2008) uses a depletion model to forecast peak oil production of 90 Mbpd in 2011, with production declining to about 50-60 Mbpd in 2030 and demand being maintained at about 80 Mbpd. The message is clear, even if the numbers are uncertain (Table 3).

Gilbert and Perl (2008) go through the alternative energy sources (p146), and they are strongly critical of hydrogen for its inefficiency and losses through the numerous transformation processes (57% losses even with the most favourable assumptions). The

[2] Oil prices are again rising steadily and have increased by 50% over the last three months to $72/bbl (April–June 2009)

focus then switches to the three types of electric vehicles, based on battery technology, plug in hybrids with some on board generation, and grid connected vehicles. It is suggested that an increase of 15-40% would be need in electricity generation to facilitate a complete switch in the passenger car fleet in a high income country, but this energy will have to be generated from renewable sources.

Table 3: The Debate on Peak Oil

Peak Oil: The IEA in their World Energy Outlook (2008) have upgraded the annual rate of decline in output from the world's existing oil fields from 3.7% to 6.7%. This estimate was based on a comprehensive study of decline rates, covering the 800 largest fields.

"Although global oil production in total is not expected to peak before 2030, production of conventional oil….is projected to level off towards the end of the projection period."

This statement was clarified by IEA's Chief Economist – "In terms of non OPEC, we are expecting that in 3-4 years time the production of conventional oil will come to a plateau, and start to decline…. In terms of the global picture, assuming that OPEC will invest in a timely manner, global conventional oil can still continue, but we still expect that it will come around 2020 to a plateau as well…. I think time is not on our side here."

From George Monbiot, Guardian 14th April 2009

More recently, there has been the meltdown in the financial systems, with huge sums of money being pumped into the banking and other sectors. World recession has short term implications for travel demand, but there may be important lessons for future more efficient ways for communications and travel. It may also give the opportunity to invest heavily in new and clean technologies, so that after recession it is not a continuation of the same system and trends, but there is progress made through a transition to a low carbon future. New initiatives, such as the current (2009) UNDP-GEI project on the potential for the Green Economy, are one way to move in this direction.

Also within this wider picture are issues relating to the scale of migration and wider population movements into the EU, and there may be problems induced by climate change resulting form the distribution of water and other resources. These migrations may be for humanitarian as well as economic reasons. There may be substantial second round effects that have major transport and other implications, as climate change is causing the World to change now, which will require both mitigation and adaptation.

There has been a tremendous growth in long distance travel for social purposes to meet friends and relatives. This international travel has been facilitated by the new mobile technologies, mass media, greater internationalisation of education, the availability of cheap transport, and the globalisation of economic and social activities. Twenty years ago, people's networks were local, national and EU based, but today they are totally global. Many of these factors impact first on the wealthy and those who have the knowledge to use the new technologies. But in time this will gradually cascade to the lower income groups, as they also take up the opportunities to travel the world. There are substantial social and equity issues that also need to be addressed.

Conclusion: The nature and scale of the problems being addressed has been totally underestimated. Transport has become a major producer of CO_2 yet it has made no contribution to reduction targets and it has continued to increase both its absolute and relative shares of total emissions. Most of the analysis that has been carried out has been based on optimistic arguments about the potential for technological solutions to social problems, and where any debate has taken place on real behavioural change, this has been deemed to be politically unacceptable. This is a classic set of arguments for inaction, and in the meantime nothing changes, as levels of traffic demand and emissions continue to increase.

Even if the 80% target was met, there would still be a substantial CO_2 deficit as two key contributors (international air and sea) are not included in the current debate. Transport is extremely vulnerable to external factors, as it is totally dependent on oil for its energy. These arguments make a powerful case for immediate action across all transport, including international transport, both in terms of carbon reduction and energy security.

3. The Potential Pathways

Travel has been divided into five mutually exclusive forms of travel, one covering short distance city passenger travel (<150km), another covering long distance passenger (>150km), and others for air travel, sea and freight. Much of the research on transport and climate change has concentrated on the city (e.g. Banister, 2005), but this market is relatively stable and there are good opportunities here for change. It is in the other markets that substantial increases in travel are taking place, and this is also where there are far fewer opportunities available for reductions in carbon based energy use.

Figures for the EU27 illustrate the scale of this problem (Table 4). City travel accounts for more than 98% of passenger trips and about 80% of distance (1990). Long distance travel and air travel in the EU27 countries account for 20% of distance, but only 2% of trips. It is in these non urban travel markets that the low carbon alternatives are much harder to envisage, let alone implement.

Table 4: Travel per person in the EU27

Travel per Person EU27	1990	2000	2005	2025	2035	2050
City and <150 km	9000	9700	10000	12400	13000	14900
Long distance >150km	1500	1600	1650	2100	2200	2500
Air	500	670	760	1370	1620	2100
Freight	3800	4500	4900	6750	7400	8600
Sea	2500	2800	3100	4000	4500	5200

Notes: Long distance is over 150 km and all distances here are given as averages per person in the EU27. The passenger figures are in km per person per year and freight figures are tonne km per person per year – see figures in the Annex. The top three rows are in kilometres per person and the bottom two are tonne kilometres per person. Freight in the ETAG report assumes 80% of tkm is >150km, so the figures have been grossed up and the maritime sector added, but it only covers internal and intra EU movements. For passenger travel, aviation is separated and rail is divided 15% long distance and 85% short distance, with the same division being used for car and motor cycles. Public transport has been added to city transport. International aviation and maritime transport outside the EU27 are not included.
Source: Based on own calculations and data from ETAG (2008) and Eurostat (2008).

The main point to make here is the scale of change needed to reduce travel levels by 80% in 2050. If no increase in efficiency was achieved then distance would have to be reduced to 2400 km (on 2000 levels), rather than the forecast level of 19500 km – this is more than a Factor 8. The corresponding freight figures would be 1460km (on 2000 levels), rather than the forecast level of 13700 tkm – this is more than a Factor 9. The key question here is how far technology can help in achieving such a change, and how much would depend on travelling less and relying on the most efficient forms of transport. Recent evidence suggests that improvements in the new car stock efficiency levels have averaged at about 1.4% per annum over the last 10 years in the UK (SMMT, 2008). At this rate, it will take the full 53 year period (1997-2050) for the new car stock to get to 90gCO_2/km – this is only Factor 2. The mandatory targets being introduced in the EU27 is one way to accelerate this process, but it still means that more policy measures need to be used.

For *city transport* there are many options for substantial reductions in carbon use, perhaps even to a zero level by 2050. The aim here would be to only allow "clean" cars[3] in cities, with pollution free public transport, and lease or hire cars (taxis) available where (or when) public transport was not available. All city freight distribution would be provided in the same way by clean and quiet vehicles. Such a future would probably be based on renewable electricity. Power could be transmitted through wires (Gilbert and Perl, 2008) rather than through on board storage. This would mean getting round the problem of weight penalties (from batteries), and the need to look at the extensive use of rare metals (e.g. lithium and cadmium) for the technology. There would need to be a substantial increase in the generating capacity from renewables. The use of hydrogen may be technically possible at this time on a commercial scale, but the sourcing and handling of that hydrogen also needs to be addressed, and it must be carbon free. On board reformation of hydrogen still have potential weight, size and resource implications, but above all hydrogen must be made a more efficient energy carrier. It is likely that hydrogen could be best used in larger vehicles, such as lorries and buses. The potential for nanotechnology may be considerable, but at present the research here is embryonic.

Technology on its own cannot achieve changes of the scale needed. As stated earlier, there would need to be a Factor 8 or 9 times decrease in carbon being used, so in addition to moving away from carbon based technologies, there would need to be other complementary actions in terms of city planning (densification, mixed use development, and the concentration of activity around transport accessible locations), as well as substantial behavioural change. One possibility here would be to move towards greater use of walk and cycle, and public transport, perhaps with a series of intermediate modes – electric scooters and skateboards – for slow speed movement around the urban areas.

Rather than ownership, vehicles could be leased, so that the best possible form of transport would be used for each particular purpose. There would also be an incentive for manufacturers to provide a range of vehicles that would reflect the highest possible zero carbon technological standards. Consumers would pay for and demand the most suitable

[3] "Clean cars" is a relative term here and would be used differentially over time. For example, clean in 2010 might be <110 gCO_2/km, whilst in 2020 it might be <80 gCO_2/km etc. The value would need to include the full well to wheels allocation to take account of how the biofuels or electricity were generated.

form of clean transport available. This would get away from the concept that one vehicle is suitable for all types of activities. There would be an increase in specialisation and the use of the best vehicle for each particular journey – a form of customisation.

Within cities, the possibility of zero carbon transport system is based on local access and proximity, leading to high levels of walk and cycling, and short distances. Space is allocated to people and not to transport. The vision here is to design cities of a high quality for people. These clean quiet and safe environments would provide the secure neighbourhoods within which communities can develop with high levels of social cohesion. This vision is both environmentally and socially fair.

Long distance travel on land covers both passenger and freight transport. For the passenger sector, space on the motorway network could be allocated to long distance coaches to give them priority, as they are the most fuel efficient means to travel between cities, particularly for those that do not have direct rail services. These coaches could have electric power, taken from the grid (like an express trolley bus). For rail, there are substantial opportunities to switch to renewable electricity and to expand capacity to take up demand from road and air. Again, transport is viewed as a service that provides an opportunity to carry out activities across modes and at a reasonable speed. All the arrangements would be carried out online or through personal communications devices that would help to organise the complete journey, including all interchanges and the ticketing.

The high speed rail (HSR) network would be seen as the main means for intercity travel within and between EU countries, and in providing access to airports and the local transport network. The service based approach might not be organised as a city centre to city centre network, but one that allows interchange at highly accessible points to the local network, for example where the rail network might link to the bus network or to the local car hire networks.

A similar future can be conceptualised for freight distribution, but with a heavier emphasis on using the waterways, as well as the road and rail networks. Hybrid trucks using renewable electricity (from over night top-ups) would be standard, but again they could be linked to the local electricity network. Incentives are needed to ensure load matching and a minimal amount of empty running, together with optimal speed control and routing.

One issue here is the relatively low proportion of total freight costs that are transport related, so much of the distribution system is transport intensive with long supply chains. Freight may be the most appropriate sector for carbon allowances and a cap and trade system that was applied nationally in the EU. As with the passenger sector, the overriding concern over travel time reduction and speed needs to be reviewed, as these carry a carbon penalty. Concepts of efficiency should be rethought, so that time minimisation as a scheduling strategy is replaced by one that minimises carbon use. This would have important implications for the location of warehouses and distribution networks, and the optimum strategy would include the use of the more energy efficient freight modes (rail and water). Supply and distribution chains need to be shortened through local production and consumption.

Aviation and maritime transport are two growth sectors where there may be less opportunity for major changes, as many of the vessels and planes now in operation may still be in use in 2050. But these two transport sectors must be high on the list for action, as they both have substantial growth potential. Aviation produces about 0.730 $GtCO_2$ per annum (2005), and this is likely to increase to between 2.4-2.9 $GtCO_2$ by 2050 (CCC, 2008 and IEA, 2009a). There is less clarity on the science of high level emissions, including contrails (water vapour) emitted at high levels, and so the total impact may be much higher (Andersen, 2008). Technologically, the options are limited to using different fuels (e.g. biokerosene) and flying slower.

Measures would include full cost pricing that internalises the externalities of air travel, incentives to use the most fuel efficient planes, strict emissions standards, and increased efficiency of flight paths with less delay at airports. Together, all of these measures might stabilise emissions from the aviation sector, but there would be little impact on the need to move towards zero carbon emissions. The only way to achieve this would be to reduce the total amount of air travel substantially.

Within the EU, the best pathway would be to look at travel as multimodal with international links being provided by a limited number of super airports in Europe. These mega airports would be fully integrated into the HSR network for long distance travel, and the local rail network would be used for transfers to the city centres.

Global shipping presents a similar scale challenge as aviation, with about 1 $GtCO_2$ emissions[4] (2005) and strong growth expected to 2050. About 80% of the emissions are from global trading and 20% from local trading. This figure might increase to between 2.4 and 3.2 $GtCO_2$ by 2050 (CCC, 2008, p324 adjusted for IMO, 2009), even if there are substantial efficiency gains. As with many of the growth assumptions, it has been assumed that the global economy would be growing by 2-3% pa, but even with more uncertain economic growth, there will still be an increase in emissions unless the business model changes.

The technological options are all feasible and can be introduced relatively quickly – these are possible quick hits. They include novel design improvements to reduce resistance and increase propulsion efficiency, reductions in wind resistance (superstructures), shifts to larger ships, better management and maintenance regimes, slower speeds, alternative fuels (liquefied natural gas), biomass energy and wind power (skysails). The Committee for Climate Change (2008, p328) states that emissions could be halved by 2050, but even with these innovative technologies, emissions would still increase[5].

Conclusions: Technology on its own cannot provide the total solution, as there are too many risks and uncertainties, and the scale of change requires actions that reduce trip distances and the numbers of trips. A service based approach to travel could provide door-to-door travel, but by the most efficient (in carbon terms) combination of transport

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[4] IMO MEPC (2008) Updated study on greenhouse gas emissions from ships, Phase 1 Report 58/4/INF.8

[5] Note that international maritime transport uses low grade bunker fuel with high levels of sulphur and PM, and these have consequences for premature death and associated health costs – in the US these are estimated at 60,000 deaths and $330 B in health costs (US EPA and James Corbett, University of Delaware, 2009). A car emits about 100g of SO_2 in a year when travelling 15,000km, but a 86,000KW diesel engine operating for 280 days a year emits 5,200t of SO_2.

(for passenger and freight movements). Load factors on all forms of transport are critical to carbon efficiency, so load matching and sharing for travel must be the standard. The potential for change in each of these sectors need to be matched up with the Images of the future in the EU27. The three Images developed in the ETAG (2008) project give a clear indication of the range of possible futures, given certain assumptions about the driving forces of change, even though they were primarily developed for long distance travel (>150 kms) and they excluded international maritime and aviation.

Table 5: Three Visions of EU27 in 2050

Three Images for 2050			
	Image I **High-tech Europe**	**Image II** **Slow and reflexive-lifestyles (world)**	**Image III** **Economic pressure + expensive energy**
Key drivers	**Science and Technology**	**Behaviour**	**Economics and energy**
General Framing			
Governance	EU is strong and cohesive, it has a leading role in the world and as well in climate policy; rest of the world is fragmented; UN is weak; India, Russia and China and some American countries are global key-players. EU has established efficient regulations to combat climate change. EU policy strongly promotes energy efficiency and renewables; not only because of climate change but also because of energy security and economic competition.	There is a very strong UN that is supported by all important nations and organisation around the world. The UN has established highly efficient regulations to combat climate change Brussels has a lot of power in Europe, but national states are still very important.	Weak EU, weak UN, there are nearly no regulations to combat climate change. Low degree in international governance; international regulations are dominated by different trade agreements. Strong local identity and regional/national governments. EU is a loose network of European nations and does not exert strong power. Targets are only reachable because of very high energy prices.
Economy and innovations	Relatively rich Europe Very high growth in GDP (2.4%) + intensive research funding. Efficient and CO2-lean energy technologies are very advanced and basic pillar of economic growth Medium degree in international division of labour Cheap mass products are popular EU economic strength is mainly based on growth in the high-tech sector.	Moderate GDP growth (1.7%) initially (but high potential). Medium degree in international division of labour High quality regional products are dominating There is a tendency to export knowledge instead of goods (Dematerialisation).	Extremely high energy prices triggered by running out of oil (oil price ~ 250 €/bbl) Low growth in GDP (0.7%) ; Medium degree in international division of labour; Considerable technological progress triggered by competition Mixture of cheap mass products and regional products; National state trade barriers.
Population	Slightly growing because of people living longer and migration from many regions of the world "Internationalisation" of society	Population is slightly decreasing; people live longer; migration to and from other parts of the world	Significantly decrease since migration between the continents is hampered by political and cultural barriers. Immigration mainly restricted to well-trained (economically useful) people
Society / Standard of living	Comparatively homogeneous standard of living throughout Europe at a high level;	EU: Strong middle classes Global: More even distribution	Very heterogeneous society with very rich and very poor people living in Europe; middle class is

	Global: "extremes" are visible; poor and rich regions do exist	of wealth.	very weak Global: non-homogeneity
Life styles	Consumption-oriented lifestyles; "fast" is important; fast travelling; fast food, fast carriers; cheap mass products are popular, but there is a market for luxury and status products	"Reflexive" slow-lifestyle Slow-food; slow travelling Global networks are important for travel patterns	Consumption-oriented "fast" lifestyles; international networks are not that strong
Social values	Individualistic. Trust in democracy + information. Price important in consumption. Status symbols are important. Extremely high degree of trust in technology and the potentials of technological progress. There is a very optimistic view on technologies.	Strong focus on quality of life, on health, well-being, recreation, on safety and on the different routes to achieve these goals. Influences from Asian-Indian philosophical elements are visible; Counter-movement related to the stress-dominated life style in the beginning of the century; Critical view on technologies	Individualisation, competition, pursuit of happiness, strong affinity to private property and status symbols
Framing of Energy and Transport system			
Energy generation and distribution	Very advanced High-tech is widespread in the energy sector High share in renewables; broad mix of renewable sources; everything is used including oceans (tidal, waves,) Advanced batteries as well as hydrogen for energy storage Distributive power generation + European-North-African Super Grid. Imports of energy are well diversified and coming from all parts of the globe. CCS Technology is established CNG is important; also for the generation of hydrogen	Electricity as the backbone of the energy system Efficient international regulations were able to slow down emissions, energy and oil consumption; Alternatives to oil have been pushed and triggered by the same incentives and implemented successfully all over the world. Comparatively low energy demand CCS Technology is established and allows usage of domestic coal	Very high energy prices; energy is used as a geopolitical instrument; energy efficiency is high because of high prices. All nations are as independent as possible. Different fuels dominate in different parts of the World. Flexibility in feedstock is highly important and biomass is very important; because of the extremely high oil price. Natural gas and coal are the dominant fossil resources, and renewable energy is central. Ideas for a "supergrid" abandoned as too much international cooperation is needed. No CCS since this would be a purely political market based on international agreements
Fuels and propulsion technologies **(Emission factors)**	Different fuels and propulsion system are used. Battery Electric Vehicles (BEV) and as well as Hydrogen + fuel cells are important. Biofuels and CNG (mixed with biogas) are important	BEV are dominating propulsion technology for passenger cars in Europe; long distance trucking is running on second generation biofuels and CNG.	Advanced Biofuels with some hydrogen and CNG
Development of transport infrastructure	Highly sophisticated intelligent infrastructure. There is a dense and high-quality European network of roads, tracks, rivers + motorways of the sea. In many urban areas the transport networks are supplemented by large tunnel	Advanced and intelligent infrastructure; some bottlenecks do still exist; strong focus on safety; Dynamic speed control	No harmonised development of infrastructure in Europe > a lot of bottlenecks, especially for railways.

	systems.		
Intelligent transport system (ITS) and Telematics	ITS is widespread Passengers: there is a lot of intermodal travel including train and aviation in the transport chain. Advanced information and booking systems are well established. Freight: Logistics are optimised by ITS and ICT. The freight sector is pushed by harmonisation of standards.	ITS is widespread Very successful program for harmonisation of international standards has been established. Also inside the EU the level of harmonisation is high.	ITS is moderate Strong market penetration of ITS. Standardisation still is a serious problem. Train transport suffers most from this situation.
Road Pricing schemes	Widespread Used to finance infrastructure Used to optimise transport flow	All-encompassing, related to CO2-output High occupancy lanes where ever possible	Most countries have their own pricing system; foreign trucks are disadvantaged
ICT	ICT is dominating international relations; inside the EU people tend to behave like living in one country, many people have friends everywhere in the EU, people are visiting each other relatively frequently.	High levels of cyber and virtual mobility; accessibility instead of mobility ICT substitutes travel > less travel; need for travelling is reduced because of video conferences, online shopping, teleworking etc.	ICT plays an important role in everyday life. It is an important form of communication.
Impact on transport volumes (and efficiency factors) Figures relate to 2050 baseline			
General	Sophisticated but expansive transport system with high growth rates but lower than in the baseline	High degree in decoupling and substitution of transport	Transport growth is hampered by high energy prices, international trade barriers and low GDP growth
Passenger transport in general	- 20%	- 35%	- 50%
Freight transport in general	- 20%	- 35%	- 50%

Based on ETAG (2008)

4. The Key Actors and Policy Strategies

The starting point must be to build on existing initiatives, but to make sure that they are introduced on an accelerated timetable so that real change can be seen. This requires strong leadership and mandatory agreements with all major actors, together with strong penalties where agreements are not met. Table 6 gives a summary of some of the measures that are now being taken within the EU (to 2020). In total these measures may stabilise CO_2 emissions from transport at their current levels (optimistic), but even here stabilisation is based on all these initiatives and targets being achieved, and the current growth rates in aviation and shipping being modified.

Table 6: Actions and Debates in the EU27

New cars: Legally binding emissions regulations set for all new cars - under 130 gCO_2/km (2012-2015), with some burden sharing for heavier cars and reductions for eco innovations. Fines set at €95 for each g/km over this level – equivalent to a price of €500 per tonne of CO_2. New Euro5 standards (2009) require an 80% reduction in particulate matter (PM) in new diesel cars and

particulate filters, and the Euro6 (2014) will reduce NO_x by 68% in all new diesel cars.

Legally binding requirements for a maximum 95 gCO_2/km for all new cars by 2020, together with similar measures for vans and HGVs – the average stock levels will be 150 gCO_2/km, 240 gCO_2/km and 750 gCO_2/km respectively, giving a reduction of 15%, 13% and 12% on 2005 levels. Greatest potential for lean burn ICE engines, electric city vehicles and some further development of plug in and other forms of hybrid technology. There is a general target for 20% of all energy to be generated from renewables in 2020. Note that the VW Beetle has the same energy efficiency now (2008) as it did in 1948 – 7.5litres per 100km.

Eco driving and the enforcement of speed limits: This is the main demand side measure to reduce fuel use and emissions.

Biofuels: The targets set for 2010 were for 5.75% of all fuel to be from biofuels, but there are doubts about the carbon benefits and the quantity of fuel needed. This target will not be met as the 2005 target of 2% was not reached (1% achieved in 2005). The new target for biofuels in 2020 is 10%. It is likely that aviation and shipping may be premium users of biofuels, not road and rail transport.

The IEA (2009a and b) view is that transport's share of biofuels will be 40%, with an equal split between shipping, air and land transport. It tries to address the question of allocation of biofuels between sectors and concludes that transport will have a premium role and be able to pay more for the biofuels. There is less debate over the form of biofuels (1st, 2nd or 3rd generation), and on the wider implications of such an increase in production on demand for land (and prices), on the food supply situation, and on the nitrogen cycle, as there are important consequences if nitrogens are used as fertilisers – the global warming value of N_2O is 300 times as great as CO_2. The reliance on biofuels in the shipping and aviation sectors is seen as the only way to reach CO_2 reduction targets, but this is a high risk strategy as it depends on many unknowns (IEA, 2009a).

Aviation: Assumptions about new planes having a 1.5% per annum efficiency gain through lighter air frames, more efficient engines and better operations – but here the investment cycles are long and it is difficult to retrofit planes.

Aviation within the EU and international flights arriving or leaving will come within the new ETS from 2012 (Emissions Trading Scheme). The number of pollution permits allocated to airlines would be capped at 97% of average greenhouse gases emitted in 2004-2006, and this will be lowered to 95% (2013-2020) with 15% of the allowances being auctioned.

Shipping: Again long investment cycles, but considerable potential for more efficient designs, larger vessels and the use of liquefied natural gas and wind power (skysails).

The current path is one of little change in the short term, perhaps waiting for the "magic" technological solution that will be in full operation by 2050. All the measures are small scale and incremental, rather than having a clear recognition of the scale and nature of change required.

Visions of the future of transport in the EU27 that are sustainable – this means that the transport system should be using 20% of the carbon (2000 levels) in 2050. These futures need to be conceptualised in conditions of increasing uncertainty, such as in the three Visions outlined in Table 5. This makes conventional forecasting more problematical, and it also challenges the robustness and the ways in which scenario construction takes place. Attention needs to be given to the flexibility of solutions and to the avoidance of path dependence:

- Global and regional population growth need to be recognised along with the likely patterns of migration. It would need to include structural changes and an ageing population;
- Volatile and high oil prices, including the necessity for transport to diversify its energy sources to reduce the carbon content of transport energy, and to move towards a range of different supply options;
- Negative or low economic growth over a sustained period of time – followed by economic growth that is moderated by the capacity of the planet. This is sustainable growth (see paper by Werner Rothengatter) hinted at in the Lisbon Strategy (2000) where the EU was to become the most competitive and dynamic knowledge based economy in the World;
- Climate change impacts and the need to invest in both mitigation and adaptation. This includes the increasing frequency and severity of natural events and the means to maintain global (and regional) patterns of activity. There are links here with the food and water, covered in the land use and biodiversity themes;
- General robustness in all systems to deal with the increasing frequency and severity of unpredictable events.

With these levels of uncertainty, it needs to be recognised that the base situation is in a continuous state of flux, as changes are taking place continuously. Future visions need to be robust and flexible, and amenable to adaptation.

Most of the thinking in reports and futures has been on the supply side. But it is clear that changes in technology will not on their own get us anywhere near the targets that are being considered. Even with the strongest implementation, they will get us about 30% of the way to the 80% target for 2050 (Hickman and Banister, 2009). The analysis here (the range of international VIBAT projects – www.vibat.org) points towards the continued expectation that the distance travelled will continue to increase, and that the most energy inefficient forms of transport will continue to dominate.

There must be complementary actions on the demand side, but this needs to be more than enforcement of speed limits and ecological driving. All forms of transport must become substantially more expensive and users should pay more than the full social and environmental costs of travel. This means that travel costs will increase by at least a 3-4 times to internalise these costs, for both passenger and freight transport. The full internalisation of costs would cover the full costs of carbon (set at a realistic price that reflected the long term as well as the short term damage), together with the health costs (in addition to those relating to accidents). This would include the costs of premature death and morbidity, as well as the loss of output resulting from illness caused by transport-related pollutants.

Pricing should feature as a strong market indicator, and this would mean an EU27 wide system of road pricing, together with substantially higher costs for using cars in the city. Air travel and shipping costs will also need to be increased by even more than the costs for road travel. Table 7 gives a listing of some of the measures that need to be considered if transport is to move towards a low carbon pathway.

Table 7: EU27 Action Checklist

City Transport	Cars to be an average of 50 g CO_2/km, using ultra lean burn small ICE engines – high load factors and leased for each specific purpose – the end of the all purpose car. Public transport to be at least twice as efficient as cars per passenger km – using electricity based on a street distribution system to reduce weight penalties – some potential for hydrogen with on board reformation. Substantial parts of the city could be car free, as all facilities would be available locally and there would be networks of cycle routes and paths for pedestrians. Separation of traffic in cities according to speed. Public transport would be universally available, operating at low speeds – densification, mixed land use and highly accessible services and facilities. Network society with universal access to videoconferences and video phones, plus the ability to work at home or at a local centre – high levels of virtual mobility. Personal carbon allowances – considered but may be too problematic to introduce – so carbon allowances for companies. Intermodality a reality with all journeys being viewed in their entirety – integration and information permits this – based on real time and PDAs. All speeds in cities low (max 30km/hr) and controlled by GPS.
Long Distance Land Travel	Technological efficiency – mandatory standards for all vehicles. Priority for efficient modes – bus and rail – allocation of space for buses on motorways. Integrated total journey planning – slower and more reliable transport. Substitution through telecommunications and technology. Shorten supply chains with knowledge transfer and local production. Local distribution networks and use of technology to source products. Road pricing on all motorways, based on environmental charges that relate to the CO_2 emissions of the vehicle and load factors. Carbon tax on all fuel and long terms commitments and guidance to manufacturers on expectations for achieving low carbon transport. Investment in renewable energy to power the transport system – electric vehicles and a grid system for power distribution. EU vignettes to be extended to all long distance travel as an interim step to a full EU road pricing scheme. All speeds lower (max 80 km/hr) and controlled by GPS.
Aviation	Technological efficiency – design of planes (and size), engines (turbo props and geared turbofans), fuels (biokerosene and biomass to liquid fuels), and operations – note the long lead time and lifetime of airplanes. Limit access of polluting planes to EU airports – low emissions zone for all EU airspace.

	Slower air travel and full cost pricing of all fuel (including tax and VAT) to reflect the carbon emissions and radiative forcing effects. No new airport capacity in the EU – encourage holidays nearer to home and promote video conferencing activities and remote working. Global agreement on carbon emissions in the aviation sector to reduce CO_2 levels by 80% in 2050 through the use of a cap and trade system. If a global agreement is not possible, then there should be an EU wide system (see CEC,2009). National accounts to include all international aviation, based on an agreed accounting procedure that would allocate proportions of the carbon to countries that were either the origin or the destination of the flight.
Sea Transport	Technological efficiency – design of vessels (and size), propulsion systems, energy use and fuels (clean diesel), use of wind (skysails) – note the long lead time and lifetime of ships. Limit access of polluting ships to EU ports – low emissions zone for all EU coastal waters. Slower sea travel and full cost pricing to reflect the carbon emissions. No new port capacity in the EU. Reduce length of supply chains by introducing a carbon charge related to distance travelled for all freight. Global agreement on carbon emissions in the shipping sector to reduce CO_2 levels by 80% in 2050 through the use of a cap and trade system. If a global agreement is not possible, then there should be an EU wide scheme, as the EU is a large international market (see CEC, 2009). National accounts to include the carbon produced in countries that supply goods to EU markets – at present much of the carbon has been outsourced overseas. For example, the Oslo Centre for International Climate and Environmental Research estimate that over 30% of China's emissions are due to their exports being consumed overseas (Guan et al., 2009).
Organis-ational Changes	New EU wide organisation (DG CLIMATE) that has explicit responsibilities for the setting of emission standards, for allocating incentives to firms and people to reduce their carbon impacts, for allocating the permits for cap and trade, for setting up the auction system, and for setting prices to promote the EU wide road pricing system. This organisation have responsibilities that would cut across all three forms of transport (land, air and sea), with particular emphasis on the growth areas of long distance transport, and international travel and trade. It would set the overall targets (and the interim budgets), and it would monitor progress towards the achievement of real reductions in CO_2 emissions, and it would fine governments and companies for non achievement of targets.
Key Generic Comple-mentary Measures	Huge investment in renewable energy in Europe, both nationally and locally. Alternative fuels to include renewable electricity and biomass. More generally taxation could be based on consumption rather than production – and linked directly with the carbon content of the product – raising the price of emissions through higher prices for fuels, combined with a carbon tax, and a

	dividend that could be used to encourage hybrids, lean burn small engines and renewable electric vehicles. Incentives for people to opt for the most efficient vehicles, as in the Netherlands in 2002 (but abolished in 2003) and the French Bonus-Malus scheme (This scheme has helped to achieve a 9 gCO_2/km reduction in 8 months in 2008). But here there must be clear consistency in policy objectives that are followed over a period of time. End of transport as a source of financing for general exchequer revenues, but more to fund the low carbon transport infrastructure (and the necessary research) – return much of the taxation raised from the transport sector to transport to help the switch to low carbon futures. European fuel duty escalator or road pricing to move from charging the full costs of travel (including environmental and carbon costs) and placing most costs on use of transport rather than the ownership of the vehicle – switch from fixed to variable costs. Charges and prices related to carbon emissions and load factors. Slowing of all travel down – with the encouragement of less travel and combining activities to reduce total distance travelled – greater appreciation of quality of movement and not the quantity of movement – shifting to slower more efficient modes of transport to ensure greater reliability – and active transport.

Policies in combination – much thinking and analysis in transport has concentrated on single policy actions (e.g. on pricing), rather than looking to see whether combinations of policies are more effective in achieving objectives. The possibilities for mutually supporting policies means that the benefits can be "locked in" and the potential rebound effects minimised.

It is only through policy packaging that the scale of the change envisaged can be achieved. It also provides the (only) mechanism for positive messages to be combined with measures that are seen to be negative (e.g. higher prices or taxes). This approach increases the acceptability both by the public and by politicians. There is empirical evidence (e.g. on the built environment) that measures in combination tend to be additive (see the new EU FP7 OPTIC project). There is also the possibility that additivity may become multiplicative when certain thresholds are reached and "snowballing[6]" takes place.

Participation and involvement – throughout the process of change it is essential that there is full engagement and participation by all stakeholders, so that they know what is happening and that they can present their views. Such an approach ensures the highest levels of support for measures, and it leads to the potential for outcomes to match up more closely with expectations. This process of engagement needs to be continuous, both in the debate about the scale of the problem, and what options are available, but also after implementation through monitoring and feedback to the stakeholders. This gives much greater legitimation to what is being done, and it also gives ownership to those that are affected by the changes.

[6] Snowballing refers to situations where the rate of change accelerates as peoples' perceptions change and they respond positively to change – for example, when cycling reaches 20-30% of road users. This is sometimes known as a tipping point.

Wherever possible, the messages given should be positive with incentives being promoted to encourage change – too often the discourse has been one of negative messages. All travellers and freight operators need to pay the full costs of their transport and there should be no subsidies, except perhaps to certain individuals for clearly specified reasons. Evaluation needs to embrace all aspects through a whole systems analysis that covers life cycle costs (cradle to grave), and includes the energy costs of fuels, vehicles and infrastructure. The combined effects of transport, energy, carbon dioxide and other emissions, accidents, health and distributional implications, all need to be included, as well as the congestion costs.

Information is needed for politicians and others on the energy and carbon savings of different actions and how they compare with each other. This would go much further than the labelling of items to cover comparative figures (that could be approximate). Such a priority came out of the discussions on the ETAG project with the MEPs, namely that even well informed people have no real idea of the implications (good and bad) of the decisions that they make (Table 8).

Table 8: Information and Engagement

Information – this needs to be made available at all levels:

1. Relating to the implications of Climate Change at the global scale – although 2C seems quite small, the impacts are substantial – see summary from Mark Lynas in Annex 2;
2. To politicians and other decision makers on the impacts of policy measures in combination over a period of time so that "quick hits" can be identified, and so that the scale of change needed can be addressed;
3. To individuals and firms to give them information on the effects of their actions or decisions on purchases, travel and even small effects such as car sharing and walking to work.

This process is not a one way flow of information but part of a process of engagement and involvement, with feedback and ideas from "bottom upwards". It is a key educational role that needs to be embedded as part of school and university curricula.

Clearer understanding is needed of how individuals and firms can be better engaged in the process of environmental decision making, so that they can take more responsibility for their actions and can begin to lead the debate rather than just follow it. This means new thinking on the allocation of power away from the centre and to give people the right incentives to change their behaviour – this is not just the economic incentives, but a clearer understanding of individual (and firm) decision processes. It also means that firms and individuals must make decisions that are based, not just on their own utility, but on the environmental (climate change) imperative and their moral responsibility to act. The consumption led society needs to change to one that values the resources used in terms of their impact on the environment.

Our understanding of the links between how people should make decisions and how they do make decisions needs careful investigation. Rationality in the decision maker's view may be very different to rationality in terms of the user's view.

5. *Barriers and Inertia*

Many of the potential barriers have been stated above in terms of the huge range of different stakeholders in transport and the effect that real change has on all types of activity. There are also problems relating to claims about the importance of transport in national and regional economies, and the crucial role that it plays in the globalised economy. Debates relating to the need for real cross sectoral roles need to be more clearly identified and responded to (including the role of the public and private sectors). Transport works at the interface of all sectors of the economy and seems to "escape" taking on real responsibilities for action.

Globally by 2050, it is clear that between 50-60% of all carbon emitted could come from transport, with land transport accounting for 20-22%, and air a further 15-18% and shipping another 15-20%, even if some fairly optimistic assumptions are made about efficiency gains, as shown in Table 9.

Table 9: Growth Paths for Transport 2050

	2005	2050
Land transport	7.1 Gt CO_2 (22%)	3.2 – 3.6 Gt CO_2 (20-22%)
Air transport	0.730 Gt CO_2 (2.2%)	2.4 – 2.9 Gt CO_2 (15-18%)
Shipping	1 Gt CO_2 (3.1%)	2.4 – 3.2 Gt CO_2 (15-20%)
Global Total	**32.564 Gt CO_2**	**16 Gt CO_2 (100%)**

Based on information from CCC (2008), IEA (2009a and b) and IMO (2009) – All figures are approximate and there are also issues relating to radiative forcing and water vapour, as well as emissions of N_2O and other GHG. The figures assume that the global levels will be a 50% reduction, but that the levels of reduction in the Developed Countries should be at least 80%. It should also be noted that there are already substantial efficiency gains assumed in the aviation and shipping figures for 2050 – aviation efficiency is assumed to improve by 1.5% pa from now to 2025, giving a CO_2 reduction figure 45% lower than business as usual and then not to increase any further to 2050. For shipping the assumptions are that efficiency will increase by 40% per tonne-km by 2050. These figures are consistent with those produced by Crist (2009) and the IMO (2009).

Although there are substantial barriers, it is really the inertia within the system and the tendency (not just in transport) to make decisions that are inconsistent with each other. For example, decisions are made on environmental grounds to build more energy efficient housing developments with provision for local travel and good public transport accessibility, but at the same time decisions are made to promote more air travel by increasing airport capacity.

The underlying message here is that travel in the rich countries of the world will have to be reduced, and where travel is essential the most efficient (in carbon and energy terms) form of transport will have to be used. This clear message has not been clearly recognised by decision makers at all levels, where there is still the belief that we can continue to increase the amount of travel as in the past. The challenging policy objectives on an 80% carbon reduction can only be achieved by travelling less not more.

In addition, there needs to be a much clearer recognition that it is long distance travel where the growth is taking place, and this is where most reductions are needed. This applies both to the passenger sector, with the growth in air travel and long distance land travel, and to freight, where long supply chains and outsourcing have followed on from the availability of cheap transport. The information box here gives some indication of these issues, even though it only relates to car travel in the UK (2006). About 80% of journeys (under 10 miles) account for 37% of CO_2 emissions (Table 10). Reduction efforts need to be concentrated on the growth areas, namely the longer distance journeys.

Table 10: Distribution of Travel and CO_2 Emissions for Cars in the UK

Journeys under 5 miles	19% of emissions	10.5 $MtCO_2$	57.6% of trips
Journeys 5-10 miles	18% of emissions	10.2 $MtCO_2$	21.0% of trips
Journeys 10-25 miles	26% of emissions	14.8 $MtCO_2$	14.9% of trips
Journeys 25-50 miles	15% of emissions	8.5 $MtCO_2$	4.2% of trips
Journeys over 50 miles	23% of emissions	13.0 $MtCO_2$	2.4% of trips

Based on CCC (2008) and UK National Travel Survey (2006) Table 3.4

Total distance travelled by car, for 658 annual car journeys, is 9109 kms person per year.

There are many good examples of actions that can be taken in urban areas and the opportunities here for low carbon futures are very positive, particularly where distances are short, where there is good public transport, and where there are good networks for cycling and walking routes. There seems to be a complete avoidance of the more important debate over long distance travel by road, air and sea for both passenger and freight movement. Even with the optimistic assumptions embedded in the forecasts, more than 50% of the total global emissions will come from the transport sector in 2050 (Table 10). The role of the EU27 must be to take the lead in the international debates over how emissions levels for long distance travel can be substantially reduced.

Much more emphasis should be given to demand management measures, rather than the almost complete reliance on greater efficiency on the supply side. Greater efficiency is important, but all policy measures must be presented in combination to achieve the agreed reduction targets. At best, it would seem that in growth markets (long distance travel by land, air and sea), technological improvements can only maintain carbon emissions levels at their current levels. The evidence over the last twenty years (since 1990) in transport illustrates the enormous difficulties of actually reducing carbon emissions.

6. Comments and Conclusions

Transport is essential to economic and social wellbeing, yet at present it is making no contribution to GHG reduction targets. In the EEA32, there has been a 32% increase in GHG emissions from transport (1990-2004), and these figures do not include the growth in international aviation and maritime transport (EEA, 2007). These increases are directly related to the growth in travel that has exceeded the growth in GDP over this period. No effective action has been taken to address transport's contribution to GHG reduction targets.

There are substantial subsidies to transport, estimated by the EEA to be between €270-290 Billion for Europe over each year, and these cover budget subsidies, public funding of infrastructure, and exemptions from or reductions to fuel tax and VAT. In addition there are the costs of accidents, noise, air pollution, climate changes, health effects, nature and landscape, and other costs (e.g. policing). If there is to be an effective carbon market for transport, these subsidies for all forms of transport need to be reduced, and the external costs need to be fully paid for by the user of transport.

The New Transport Agenda

Ten key points need to be made here, so that a new transport agenda for the EU27 can be established:

1. Decoupling is essential, so that we can have economic growth (more widely interpreted), and clear environmental benefits, but with less transport. The debate must be set up so that all these three factors are working positively in the same direction, and not in opposition to each other as they do at present – this is the argument of the Stern (2007) report and of his more recent (2009) book on the Blueprint for a Safer Planet.

2. Diversification of energy sources for transport is also essential to move away from the dependence on oil and carbon based sources. The current situation is high risk and unsustainable. For example, city vehicles could use clean electricity from renewable sources, either through onboard storage or through a street based grid system. There are interesting possibilities here of using surplus electricity (overnight production from renewables) to power electric and hybrid vehicles from the existing electricity grid.

3. There are substantial sunk costs embedded in the existing infrastructure, built up over a considerable time to supply and maintain the transport system (road, rail and air). Any transition to a new technology is likely to be hugely expensive, and history suggests that alternative systems operate as complementary rather than replacement technologies. Perhaps the newer EU countries could switch to the new infrastructure (electric) before the same levels of investment in the existing carbon infrastructure have been made.

4. Pricing is clearly a key element in all futures, and substantial increases in fuel costs and the transfer of as many costs as possible to the price paid for fuel would be advantageous, so that the user gets clear and consistent messages (This includes the fuel costs, the annual taxation, insurance costs etc). New forms of car ownership may include novel forms of pricing, and the move towards leasing and shared car ownership may encourage greater transparency in understanding the total costs of driving. Included here is the possibility of personal carbon allowances or the use of cap and trade systems with companies to limit growth of emissions to acceptable levels.

5. Links between transport and technology need to be established, including technology in transport and in the transport infrastructure for all types of activity. In the short term, electric and hybrid vehicles offer the greatest potential for new technology in transport, together with more efficient ICE engines (King, 2007 and 2008). Alternative fuels are more problematic in the scale of production needed, their availability and energy density. For the more social issues related to technology, the advent of mobile communications means that notions of time and flexibility have been considerably enhanced, offering opportunities for new forms of activity participation. The focus here would be on the mobile technology and social networking (Larsen, Urry and Axhausen, 2006).

6. Transport is often the sector that has to accommodate the consequences of decisions taken in other sectors. Decisions on building new homes or offices or even hospitals, schools, shops and recreational facilities all have transport implications, yet there is little coordinated thinking here on how this problem can be addressed as most outcomes are

incremental. Long term implications and travel that is bedded into the system are overlooked, as most decisions are taken in a shorter term time horizon.

7. New institutional and organisational frameworks might help get around some of these key questions. This might mean that there is a traditional national (and EU) transport portfolio that deals with the issues of construction, maintenance and subsidy, but that other transport functions would be explicitly attached to other departments that would look at and test the longer term transport implications of decisions (positive and negative), and explore the means by which the overall environmental benefits can be enhanced and the costs reduced.

8. Information on the nature and scales of change required and how this relates to all stakeholders. They need to be engaged in the debate and informed about what they can do and how this contributes to the overall picture. There needs to be far greater involvement and empowerment of the public so that they can vote for change.

9. Political leadership is crucial, as effective action is dependent on clear goals and ambitions at the highest level. This also extends to city leadership and real leadership in business and the community. There is a need for a vision of a carbon neutral transport system for Europe, and this means redistributing travel between modes through the complete journey concept, from less efficient forms of transport to more efficient, with the accounting carried out on the basis of carbon, not cost. The overall amount of travel will have to be decreased.

10. The EU should consider setting up a new DG CLIMATE to address the issues of climate change across all areas of its activity. This new DG should have sufficient powers and budget to reflect it importance and have strong links with DG ENV and DG TREN. It should consider following the UK example of developing carbon budgets over five year periods to help focus action on immediate change rather than leaving action to the longer term, nearer to 2050 (Figure 1). Initially the role of this new agency might be to establish a strong mandatory framework within which a low carbon transport system might operate (Table 7). This would include stringent new emissions standards, regulations on the use of polluting vehicles, a carbon trading scheme that includes all transport, and the implementation of the proposals made in Table 4 on pollution free areas around the EU27.

John Urry's bleak view on the future of mobility (Urry, 2007, p276) describes the post car society. The legacy of the last 50 years has been mass mobility and digitisation leading to complex adaptive systems, with multiple and flexible mobilities, which in turn lead to individualised and self organised networks and travel. The question he raises is whether these well established systems can be changed to a "nexus system" based on GPS technology, and he contrasts two different visions of the future.

a) Dystopic Barbarism of unregulated climate change (Hobbesian) – where there is a brutal reversal of much of the recent network and mobility growth.

b) Dystopic Digitalism of self and society (Orwellian) – where power resides in huge databases with the individual losing freedom and identity in return for the network operating efficiently through digital tracking.

Any move away from the car based system is difficult to imagine, as so much capital is tied up in the global business around mass car mobility. A tipping point could be triggered by a catastrophic global warming event or through the nexus system. The new mobility could be based on slow transport with high levels of virtual connectivity, combined with local access and proximity. There is a clear need to reduce journey lengths and to redistribute travel to the most efficient modes (these should be full), with capacity to suit needs. There also needs to be a much greater user orientation in terms of different forms of transport for particular uses. The current idea of a car that suits all purposes must be replaced by vehicles most suited to the task at hand. Thinking needs to be innovative about how the total amount of travel can be maintain or reduced and not increased. It is the growth in travel that causes the greatest problems for a carbon free transport system.

Recommendations:

- Set out the EU vision for a low carbon transport system in Europe that can address the issues of vulnerability, security and resilience, as well as the risks and uncertainties anticipated in the next 40 years;
- Promote clear and consistent leadership at the EU and national levels, with the establishment of a new DG CLIMATE. One major task here would be to set up 5 year budgets for CO_2 emissions for each country by sector, and another would be to set up carbon markets for all transport modes (including international aviation and maritime), where the objective would be to tighten targets over time and to allocate rights through auction and not allocation;
- Invest in a range of renewable technologies, so that there is an opportunity for the land based transport system to make substantial use of electric vehicles;
- Move taxation from production (labour) to consumption, and invest in the "green economy". All efficiency should be measured in terms of the carbon used, and evaluation methods should be broadened to include carbon accounts and wider economic impacts;
- Develop a better understanding of system resilience and risk so that benefits can be "locked in" and rebound effects minimised;
- Move towards slower travel and an acceptance travel time reliability to reduce uncertainty;
- Assess transport as part of a much wider picture of change, as there is no single strategy that will produce a low carbon transport system. There is a need for combinations of powerful and mutually supportive strategies;
- Engagement of the population and other stakeholders, perhaps leading to institutional and organisational change, with a new allocation of power, resources and responsibilities;

In 1909, Henri Antoine Jules Bois wrote that "motor cars will in a hundred years be things of the past and that a kind of flying bicycle will have been invented which will enable everybody to traverse the air at will, far above the earth". It is dangerous to speculate, particularly about the future, but there is a clear requirement for major action in the transport sector now, as we have talked the talk. Now is the time to walk the walk.

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Annex 1

It is extremely difficult to forecast the baseline to 2050, particularly in the light of the current zero growth rates. The meta view taken here is to take the outputs from the ETAG (2008) and Tremove (to 2030) projects, as the TransVisions project is still to report its "definitive" figures. The figures given here (and elsewhere in the text) are indicative and based on a wide range of secondary sources – there has been no original modelling work, and indeed forecasting over this length of time with so many uncertainties is unlikely to be a precise science. In the ETAG (2008) study, the focus was on long distance travel within the EU27, defined as distances over 150 kms.

EU27		**1990**	**2000**	**2005**	**2025**	**2035**	**2050**
City – Gpkm	Car and M/C	3381	3756	3973	5350	5800	7100
	Bus	501	514	523	555	572	598
	Rail	356	379	391	440	460	500
	Total	**4238**	**4649**	**4887**	**6345**	**6832**	**8198**
Long Distance – Gpkm	Car	597	663	700	944	1039	1210
	Rail	63	66	65	77	81	89
	Water	44	42	37	48	52	59
	Total	**704**	**771**	**802**	**1069**	**1172**	**1358**
Air (Domestic + Internal to EU)		**234**	**322**	**372**	**699**	**851**	**1159**
Total Passenger - Gpkm		**5176**	**5742**	**6061**	**8113**	**8855**	**10715**
Freight – Gtkm	Truck	1289	1519	1705	2639	3048	3830
	Rail	386	401	410	457	476	508
	Water	136	259	286	344	368	411
	Total	**1811**	**2179**	**2401**	**3440**	**3892**	**4749**
Sea (Domestic + Intra EU27)		**1150**	**1348**	**1530**	**2060**	**2391**	**2890**
Population (m)		470	480	490	510	525	550

Notes: These figures are indicative of the scale of the growth expected in all transport modes – international maritime and aviation needs to be added. The growth rates assumed here are lower than those in the Tremove project for the period 2000-2020 – the growth rates from 2000-2050 are: Truck 1.8% p.a.; Rail 0.6% p.a.; Inland navigation 0.9% p.a. and Sea 1.5% p.a.

CO_2 Mt		1990	2000	2005	2025	2035	2050
Passenger City	km	4238	4649	4887	6345	6832	8198
	CO_2	491	576	616	735	802	1006
Passenger >150km	km	704	771	812	1069	1172	1358
	CO_2	82	95	109	130	141	178
Aviation	km	234	322	372	699	851	1159
	CO_2	85	136	151	181	207	282
Freight	km	1811	2179	2401	3440	3892	4749
	CO_2	302	364	401	545	597	746
Total	**CO_2**	**959**	**1171**	**1277**	**1591**	**1747**	**2212**
Population EU27 (m)		470	480	490	510	525	550
CO_2 emissions per person (t)		2.04	2.44	2.60	3.12	3.32	4.02

Notes: Assumed that freight emissions are about twice the level for passenger kms – international maritime and aviation need to be added. Again these figures are indicative. There are some assumed efficiency increases (see next table), with huge increases for aviation.
Assumed energy increases – CO_2 per km

	2005-2050
City Travel	0.126 to 0.122 = +2.7%
>150kms	0.134 to 0.131 = +2.2%
Aviation	0.407 to 0.243 = +40%
Freight	0.167 to 0.157 = +6%
Total	0.150 to 0.143 = +4.7%

Annex 2 Climate change explained - the impact of temperature rises

Mark Lynas – Guardian Tuesday 14 April 2009

Less than 2C: Arctic sea icecap disappears, leaving polar bears homeless and changing the Earth's energy balance dramatically as reflective ice is replaced during summer months by darker sea surface. Now expected by 2030 or even earlier. Tropical coral reefs suffer severe and repeated bleaching episodes due to hotter ocean waters, killing off most coral and delivering a hammer blow to marine biodiversity. Droughts spread through the sub-tropics, accompanied by heatwaves and intense wildfires. Worst-hit are the Mediterranean, the south-west United States, southern Africa and Australia.

2C-3C: Summer heatwaves such as that in Europe in 2003, which killed 30,000 people, become annual events. Extreme heat sees temperatures reaching the low 40s Celsius in southern England. Amazon rainforest crosses a "tipping point" where extreme heat and lower rainfall makes the forest unviable - much of it burns and is replaced by desert and savannah. Dissolved CO2 turns the oceans increasingly acidic, destroying remaining coral reefs and wiping out many species of plankton which are the basis of the marine food chain. Several metres of sea level rise is now inevitable as the Greenland ice sheet disappears.

3C-4C: Glacier and snow-melt in the world's mountain chains depletes freshwater flows to downstream cities and agricultural land. Most affected are California, Peru, Pakistan and China. Global food production is under threat as key breadbaskets in Europe, Asia and the United States suffer drought, and heatwaves outstrip the tolerance of crops. The Gulf Stream current declines significantly. Cooling in Europe is unlikely due to global warming, but oceanic changes alter weather patterns and lead to higher than average sea level rise in the eastern US and UK.

4C-5C: Another tipping point sees massive amounts of methane - a potent greenhouse gas - released by melting Siberian permafrost, further boosting global warming. Much human habitation in southern Europe, north Africa, the Middle East and other sub-tropical areas is rendered unviable due to excessive heat and drought. The focus of civilisation moves towards the poles, where temperatures remain cool enough for crops, and rainfall - albeit with severe floods - persists. All sea ice is gone from both poles; mountain glaciers are gone from the Andes, Alps and Rockies.

5C-6C: Global average temperatures are now hotter than for 50m years. The Arctic region sees temperatures rise much higher than average - up to 20C - meaning the entire Arctic is now ice-free all year round. Most of the topics, sub-tropics and even lower mid-latitudes are too hot to be inhabitable. Sea level rise is now sufficiently rapid that coastal cities across the world are largely abandoned.

6C and above: Danger of "runaway warming", perhaps spurred by release of oceanic methane hydrates. Could the surface of the Earth become like Venus, entirely uninhabitable? Most sea life is dead. Human refuges now confined entirely to highland areas and the polar regions. Human population is drastically reduced. Perhaps 90% of species become extinct, rivalling the worst mass extinctions in the Earth's 4.5 billion-year history.