PLUREL

Driving Forces and Global Trends

Module 1

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PERI-URBAN LAND USE RELATIONSHIPS – STRATEGIES AND SUSTAINABILITY ASSESSMENT TOOLS FOR URBAN-RURAL LINKAGES, INTEGRATED PROJECT, CONTRACT NO. 036921

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Environmental Drivers of Change

Impact of Environmental Drivers on Peri-Urban Land Use Relationships

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SIXTH FRAMEWORK PROGRAMME

Contents

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Abstract

The natural environment has long been the provider of urban resources such as water or minerals, and the 'receptor' of urban development. Now the balance is being turned around. As more of the EU is urbanized, the environment becomes a precious resource to be safeguarded, and a limit on urban development. Meanwhile the environmental agenda is shifting from the local to global scales, and issues such as climate change, food security & resource depletion now dominate. Peri-urban areas are impacted on by a wide range of environmental, economic and social drivers of change, which together act to shape landscapes and environments in these locations.

Objectives/aims

This report aims:

- To report on four of the most significant environmental drivers of change, namely agriculture, climate change, energy and transport. (following on the previous D1-3-1 which focused on the environmental receptors).
- To look at current trends and projections to inform the scenario framework
- To explore the challenge of multiple 'cumulative causation' in environment / peri-urban interactions.

Structure of report

Each of the key environmental drivers is considered in turn, looking particularly at:

- The impacts that each driver has on environmental resources (air, biodiversity, soil and water).
- The key trends that currently characterise each environmental driver.
- The peri-urban land use impacts associated with each driver and the impacts on environmental quality that they generate.
- Possible future changes to each environmental driver through the use of a scenarios approach.

This analysis of environmental drivers provides a comprehensive overview of how changes in environmental quality, driven by key EU sectors including agriculture and transport, can impact on Europe's peri-urban areas.

Environmental drivers are relevant across the whole PLUREL:
- M1 – reference point for economic, demographic and land use modelling.
- M2 – spatial & governance analysis on the effects on different urban types.
- M3 – background for case study and policy analysis.
- M4 – reference point for impact assessments and systems analysis.

Results and findings

There are major impacts from current trends in peri-urbanization, on the environmental media of soil, air, water and bio-diversity. These are both direct cause-effect relationships, and indirect impacts from systemic effects.

Agriculture and rural development:

- - Competition for scarce water resources will increase, with difficult choices between farming vs urbanisation;
- - As water bodies become drier, settlements may be abandoned. Lack of water may constrain new development in some regions.
- - Organic & niche farming may reinvigorate declining peri-urban communities.
- - With higher income and employment, local economies may grow with services improving accordingly.

Climate change: impacts, adaptation, and effects of mitigation policy (fig 2):

- - while there are large uncertainties on impacts, the variability and extreme events in local climates are very likely to increase;
- - the peri-urban area is one of the main resources for urban adaptation, via green infrastructure, flood protection, micro-climate design
- - Changes in urban form, for example drives towards compact settlements and the protection and enhancement of greenspace areas.
- - Increased use of peri-urban land to produce renewable energy, e.g. biomass production, energy from waste, and wind turbines and solar panels.

Energy & transport:

- - both fossil & renewable energy sources put pressure on peri-urban spaces and infrastructure;
- - transport is the major cause of urban and peri-urban air pollution: and also the most direct influence on peri-urban development.
- - climate emissions policy favours public transport, with effects on commuting patterns and settlement structure.

Also there are underlying challenges in environmental policy:

- - Synergistic / cumulative effects can magnify the problems: e.g. the EU heat wave of 2005 showed that mortality was increased by social exclusion, particularly for the older.
- - Resilience – this is both a physical concept: and an economic and socio-cultural-political agenda.
- - Investment – as climate risks and impacts cross boundaries of territories and sectors, it is more difficult to allocate costs, benefits and investment needs. And the climate change ‘policy horizon’ fixes at a convenient date of 2050 or 2100, while the need for investment has to look beyond.
- - Policy integration – many of these pressures and responses are in conflict, with few clear answers on how policy integration works, who should be involved, where are the boundaries, and how the resources can be found.

Popular science summary of main results

Environment is a growing factor in peri-urban development policy. In many parts of the EU the local environment is improving, but at the same time standards and expectations from the public and stakeholders are also rising. High quality environments with green infrastructure are now realized to be essential for economic development, public health and community well-being, as well as providing resources and functions such as water, flood protection, and climate adaptation.

In practice there are conflicts with the economic development agenda and its by-product of urban sprawl. There is a realization that environmental policy is not often simple or direct, rather we need to look at a whole city-region system and the role of the peri-urban in it.

Key words

Research methods, European environment, air quality, biodiversity, soil, water, agriculture, climate change, energy, transport, scenarios, peri-urban land use.

Classification of results/outputs:

Spatial scale for results: **Regional, national, European**	**European**
DPSIR framework: **Driver, Pressure, State, Impact, Response**	**The full DPSIR range is involved**
Land use issues covered: **Housing, Traffic, Agriculture, Natural area, Water, Tourism/recreation**	**All landuses and activities with environmental impacts**
Scenario sensitivity: **Are the products/outputs sensitive to Module 1 scenarios?**	**The results will be sensitive to scenarios (not covered in this report)**
Output indicators: **Socio-economic & environmental external constraints; Land Use structure; RUR Metabolism; ECO-system integrity; Ecosystem Services; Socio-economic assessment Criteria; Decisions**	**Mainly focused on environmental and ecosystem output indicators.**
Knowledge type: **Narrative storylines; Response functions; GIS-based maps; Tables or charts; Handbooks**	**Methodology and baseline report**

How many fact sheets will be derived from this deliverable:	1

1. Introduction

The natural environment has long been the provider of urban resources such as water or minerals, and the 'receptor' of urban development. Now the balance is being turned around. As more of the EU is urbanized, the environment becomes a precious resource to be safeguarded, and a limit on urban development. Meanwhile the environmental agenda is shifting from the local to global scales, and issues such as climate change, food security & resource depletion now dominate. Peri-urban areas are impacted on by a wide range of environmental, economic and social drivers of change, which together act to shape landscapes and environments in these locations.

Role in PLUREL work programme

Environmental drivers are relevant across the whole PLUREL:

- M1 – reference point for economic, demographic and land use modelling.
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Methodology

This study took a qualitative approach to the wider scope of environmental impacts & responses for the peri-urban. It looked at 4 key drivers: climate change, agriculture, energy & transport, with 4 research questions:

- current trends in each environmental driver;
- impacts of each on environmental quality (air, biodiversity, soil and water).
- future projections with a scenarios approach.
- implications for peri-urban landuse & development;

Structure of the deliverable

- Firstly there is an introduction and context
- The second part is an outline of the methodology for analysis (summary of D1-3-1)
- Parts 3-6 is a There follows an analysis of four key environmental drivers (agriculture, climate change, energy, transport) impacting on European environments and peri-urban landscapes. These drivers are addressed in turn, with a standardised set of issues considered in each case. These are:
    - Summary of the impacts of each driver on environmental quality.
    - Assessment of trends and projections relating to the driver, and an analysis of how these changes are impacting on environmental quality.
    - Investigation of the relationship between trends and projections concerning each driver, environmental quality and peri-urban land use.
    - Application of the PLUREL scenario framework to each driver to provide an analysis of how they may evolve in the future.
- Annex A summarizes the scenario environmental variables:

- Annex B shows research in progress to explores the challenge of working with a systems approach to cumulative causation.

Context: Environmental Drivers

The form and function of peri-urban areas is ultimately an expression of a range of environmental, economic and social drivers of change impacting on these landscapes. For example, economic growth rates will affect the extent of capital investment and resulting built environment development or expansion of commercial and industrial infrastructure. Similarly, social issues such as population growth and migration rates will influence issues such as housing numbers or the extent of public service provision (e.g. schools, hospitals). However, it is environmental drivers of change that form the focus of this report. Four key drivers are consider; agriculture, climate change, energy and transport. There are clearly a range of other environmental drivers that exert an impact on peri-urban areas, such as forestry or tourism for example. However, the following analysis of the four drivers selected for this report provides a comprehensive overview of how environmental drivers of change impact in peri-urban areas.

Linkages and synergies

It is important to emphasise that environmental, economic and social drivers are interlinked through a series of complex two-way causal chains. Changes in one of the drivers, for example the impact of climate change on water resources, will have economic and social repercussions. As the availability of water declines, industries such as agriculture or tourism may be threatened in certain regions, with negative impacts on local economies and communities. Further, limited water supplies may limit the potential sustainability of peri-urban growth if there is not enough of this vital resource to support the development of new communities. In some cases, these socio-economic effects may act to intensify the impact of the original environmental driver. Using the example of water shortages again, countries experiencing the worst of this climate change impact may be encouraged to develop energy-hungry desalination plants leading to significant greenhouse gas emissions and the acceleration of climate change. This report adopts a systems approach to the analysis of environmental drivers and their effect on peri-urban areas. Linkages between the range of different drivers are explored within this report, particularly in the context of peri-urban land use impacts.

Looking to the future

Future directions of change in environmental drivers will significantly impact on peri-urban areas. The possible evolution of agriculture or energy can be explored through the examination of trends related to these sectors. Indeed, European agriculture is characterised by trends such as growing irrigation demand, a reduction of use of pesticides and fertilisers, and accelerating loss of high nature value farmland. Trends such as these exert significant impacts on environmental quality and peri-urban land use, the likes of which are explored within this report. However, the forward projection of trends can not always provide an accurate picture of the future evolution of a sector such as agriculture. Issues such as the pace of technological development, the direction of policy and legislation, or consumer behaviour can profoundly affect agricultural markets and farming practices. Yet, it is not possible to precisely predict how issues such as these will develop. Scenarios provide a means of exploring the development of a topic (be that climate change, agriculture etc) under a range of different possible futures aid can aid decision making where levels of uncertainty are high. The PLUREL scenarios are utilised within this report to perform the function of providing an overview of the possible future development of the environmental drivers studied during the project.

In summary, this deliverable provides a comprehensive insight into four important environmental drivers impacting on peri-urban land use relationships in Europe. The 'futures' dimension of the work helps to demonstrate how the environmental drivers may evolve in the future, which is an important factor in developing strategies for sustainable peri-urban areas.

2. Agriculture: trends, projections and impacts

Introduction and context

In Europe, agriculture is the dominant land cover type accounting for 55% of land, in comparison to 37% for forestry and 5% for urban areas (EEA2006a). Globally, pasture and crops cover 37% of the Earth's surface (1999 figures) (FAO 2002). In Europe, farming practices are diverse ranging from industrial scale monoculture to subsistence farming in mountain landscapes. Across Europe, the amount of land devoted to agricultural production is gradually declining, principally to increases in urban land, semi-natural land and forest cover (EEA 2006). Two important forces characterise European agriculture. These are the intensification of farming where input levels (of fertilisers, pesticides, energy etc) are high, and in contrast, the marginalisation and abandonment of agricultural land in less productive locations and those areas at threat from other land uses.

Agriculture is part of Europe's landscapes and ecosystems. Indeed, farming is sustained by natural resources such as biodiversity, soil and water. However agriculture, principally as a result of the twin forces of intensification and abandonment, exerts considerable pressure on environmental quality both at the local and global scale. Arguably, due to its close connection to the landscape, agriculture exerts the biggest environmental impact of any human activity in Europe. Livestock production can be particularly harmful to the environment (FAO 2006). It is also important to acknowledge that although agriculture generates significant negative environmental impacts, it is also impacted by environmental change. For example, air pollution (particularly ozone) can affect plant growth and crop yields, soil degradation can severely limit agricultural production, and climate change has the potential to profoundly affect agriculture (both positively and negatively depending on location). It is often the case that farming suffers from the environmental problems it helps to create, for example soil degradation.

There are a wide range of drivers that exert pressure on the agricultural sector. They result in the creation of trends which in turn generate environmental impacts. It is important to understand the factors that drive underlying trends (and associated environmental change) within agricultural. Broadly speaking, drivers of change can be classified as being either external or internal to the agricultural sector (EEA 2006). External drivers act at the 'global' scale, whilst internal drivers operate at the individual farm level. The most significant of these drivers include international trade, population growth, consumer preferences and markets trends, technology, farm management practices and social/cultural issues within the farming community (EEA 2006, EEA 2007). For example, regarding international trade, Europe is a major importer and exporter of agricultural produce. Its agricultural sector is affected by changes in international trade patterns and associated policy changes (e.g. from WTO and World Bank). These changes impact extensively on farm management practices for example. Further, in reference to social/cultural issues within farming, levels of education and awareness amongst farmers of the relationship between farming and the environment can also drive change in farm management practices.

Agriculture is a complex sector with a wide range of drivers affecting its evolution. The future direction of these changes is uncertain. Nevertheless, it is clear that agriculture will continue to have a major impact on the quality of Europe's environments, and will also remain one of the most important drivers of change on the continent's peri-urban landscapes. The following discussion explores these issues in greater detail, focusing in several key issues. These include:

* Summary of the impacts of agriculture on environmental quality.
* Assessment of trends and projections relating to the agricultural sector, and an analysis of how these changes are impacting on the environment.
* Investigation of the relationship between agricultural trends and projections, environmental quality and peri-urban land use.
* Application of the PLUREL scenario framework to the analysis of transport impacts in Europe.

Agriculture: summary of impacts

Broadly, agriculture results in the pollution of the environment and the depletion of natural resources. But, it also contributes to environmental preservation and enhancement (particularly in relation to biodiversity) (EEA 2006). Agriculture impacts on each of the key environmental resources being considered within PLUREL, namely air, biodiversity, soil and water. The PLUREL environmental resource baseline profile (cross reference) provides greater detail of the nature and extent of these impacts, the most significant of which are highlighted below. These are considered in greater detail within Table 1.

Air quality
Despite recent falls in the emissions of acidifying and eutrophying substances and ozone precursors from agriculture, farming remains an important contributor to air pollution and is the dominant anthropogenic source of ammonia. Further, agriculture is also responsible for the release of significant amounts of greenhouse gases including methane and oxides of nitrogen. Moreover, carbon dioxide is released from farming vehicles (machinery and transportation) and as a result of the loss of carbon rich habitats including forests and grasslands to farming. In 2002, agriculture was responsible for 10% of greenhouse gas emissions from the EU 15 (EEA 2006), although total emissions from agriculture have nevertheless declined by 9% since 1990 (EEA 2006).

Biodiversity
In Europe, agriculture has both positive and negative impacts on biodiversity. In fact, in many areas it is extensive low impact agricultural landscapes that provide habitats (known as high nature value farmland) for some of Europe's most endangered species of flora and fauna. However, intensification and abandonment (and associated impacts on environmental quality) have considerable negative impacts on biodiversity and the habitats that support it.

Soil
Soil degradation encompasses a range of different processes including compaction, contamination, salination, sealing and erosion. Aside from surface sealing which is largely a consequence of urbanisation, agriculture is a key contributor to soil degradation processes. Where agriculture is intensive, farm machinery leads to soil compaction, agricultural inputs and air pollutants contribute to soil contamination, unmanaged irrigation leads to salination of soils (IEEP 2000), and unsustainable farming practices (e.g. overgrazing and excessive tillage) contribute significantly to soil erosion and loss of topsoil.

Water
Agriculture negatively impacts on water quality and quantity. Abstraction from water bodies and aquifers, often at unsustainable rates in southern Europe, can reduce water availability (for humans and flora and fauna) and can lead to saline intrusion in coastal aquifers. In terms of water quality, the runoff of agricultural inputs containing pollutants including nitrogen and phosphorous (principally from pesticides and fertilisers) and the

loss of topsoil into water bodies (via water and wind) are key causes of pollution of ground and surface water bodies.

Agriculture trends and projections

There now follows (Table 1) an overview of some of the most significant issues impacting on European agriculture. Trends and projections relating to these issues are discussed, with environmental impacts associated with a continuation of these trends highlighted. Key emerging issues can be summarised as:

- ***Organic farming*** is increasing, although still represents a relatively small share of agricultural area in Europe. Further growth is projected, with associated positive impacts on environmental quality.
- ***Irrigation demand*** is growing strongly in southern Europe, and may increase further with climate change. Significant negative environmental impacts are associated with much irrigation practice.
- ***Emissions of air pollutants*** from agriculture are considerable, although are gradually declining. Continuation of this trend will have environmental benefits, reducing pollution of soil and water in particular.
- ***Pesticide and fertiliser use*** per hectare of land is falling, although remains high in global terms. On balance, negative impacts to air, biodiversity, soil and water will continue to be significant.
- ***High nature value farmland,*** a key habitat for much of Europe's most valued biodiversity is at threat from intensification and land abandonment.
- ***Agri-environment schemes***, which are in principle beneficial for environmental quality, are expanding with public expenditure also increasing.
- ***Agricultural intensification*** is increasing, as demonstrated by increasing milk production and cereal yields in recent years. Intensification is linked to many of the environmental problems stemming from farming.
- ***Agricultural extensification*** is increasing slightly, with numbers of low input farms growing at the expense of high input farms. Less use of pesticides, fertilisers etc has significant environmental benefits.
- ***Marginalisation and land abandonment*** is increasing in some parts of Europe. Associated loss of high nature value farmland harms biodiversity, but reduced use of farming inputs can have environmental benefits.
- ***Soil erosion*** is increasing, particularly over southern Europe. Negative impacts to environmental quality, including water pollution and loss of biodiversity, can be expected to increase.
- ***Animal husbandry*** has declined, particularly in Eastern Europe and the new member states. Consequently, associated environmental pollution and demand on resources (particularly water) has decreased.
- ***Per capita food consumption*** is projected to grow slowly in Europe. More rapid growth in developing countries (particularly meat and dairy products) may increase demand for European agricultural exports.
- ***Global agricultural demand*** is slowing as more regions reach high calorie diets. Farming of non-food products (e.g. biofuels) may increase.

AGRICULTURE		
Issue	***Trends and projections***	***Impacts on environmental quality (air, biodiversity, soil, water)***
Organic farming	Area under organic farming grew by 112% (from 1.8-3.7% of utilised agricultural area - UAA) between 1998-2002 (EU 15) (EEA 2006). Annual growth in consumption rates of organic produce in member states range from 5-10% depending on previous market penetration and consumer demand.	Lower inputs of fertilisers and pesticides reduce pollution to air, soil and water benefiting human health and biodiversity. Agricultural genetic diversity is protected as more varied cropping and animal husbandry is used. Further, climate change mitigation and adaptation is promoted for example via reduced energy inputs, provision of carbon storage by increasing plant biomass, and the maintenance of more resilient soils.
Irrigation demand	Between 1990 and 2000, irrigable area increased by 12% (EU 12). Much of this area is in southern Europe. In France, Greece and Spain irrigable area increased by 29% during this period (EEA 2006). The impact of climate change, which could see 20-30% less precipitation in southern Europe by the 2080s (IPCC 2007), will increase demand further.	Irrigation impacts negatively on surface and groundwater quality and quantity, soil quality and quantity, and biodiversity and habitats (IEEP 2000). Through permitting more intensive agricultural production and associated increases in inputs, irrigation has secondary impacts which intensify those which it contributes to directly.
Emissions of air pollutants	Between 1990-2002, emissions of methane fell by 8.7% (fall in livestock numbers) and nitrous oxides by 8.2% (changes in farm management practices) (EU 15) (EEA 2006). Agriculture remains the key source of anthropocentric ammonia emissions, and is a significant (yet gradually declining in relative terms) source of greenhouse gas emissions.	Despite falls in the emission of pollutants, agricultural air pollution leads to acidification (of soils and water) and eutrophication of water bodies with negative impacts on biodiversity. Agriculture is responsible for around 10% of European greenhouse gas emissions and therefore is accelerating the occurrence of impacts associated with climate change.
Pesticides and fertilisers	Between 1990-2000, pesticide consumption fell from around 3kg/ha-2kg/ha (EU 15). Reductions in fertilizer inputs also dropped during this period from around 130kg/ha-100 kg/ha (EU 15) (EEA 2007). As a result, the gross nitrogen balance (the potential surplus of nitrogen on farmland) fell by 16% between 1990-2000 (EU 15) (EEA 2006). West and central Europe has the highest fertilizer inputs of any region globally (13% of global usage in 2002) with usage predicted to grow by almost 20% by 2030 (EEA 2007).	Falls in pesticide and fertiliser use benefits the environment as pollution to air, soil and water is lessened. Nevertheless in certain industrial and high input farming systems local hotspots of environmental problems (e.g eutrophication of lakes, nitrates in groundwater) remain significant challenges. Moreover, although reductions in farming inputs have been seen over recent decades, usage remains high (and is predicted to remain so in the future) with corresponding negative environmental impacts.
High nature value (HNV) farmland	15-25% of the European countryside is classified as HNV farmland (EEA 2006). Much of Europe's most valued biodiversity resides in HNV farmland. Increasing agricultural abandonment, particularly in mountain regions and in southern and eastern Europe (where a significant proportion of HNV farmland is found) is reducing the extent of this important habitat. Further, less land is now allocated to mixed livestock farms (down from 16% to 12% between 1990-2000) which are often of high nature value (EEA 2006). Intensification in some regions is also contributing to a loss of HNV farmland.	Negative impacts are particularly associated with biodiversity and habitats. For example 92% of European butterfly species depend on agricultural habitats, principally extensive farmland (EEA 2006). Also, significant numbers of Europe's rare and endangered bird species depend on HNV farmland. Farmland bird populations have declined by around 30% since 1980, particularly in Belgium, France, the Netherlands, Sweden and the UK (EEA 2006). If HNV farmland is subsequently modified for intensive agriculture, negative impacts on environmental quality will generally increase.
Agri-environment schemes	Between 1998-2002, UAA allocated to agri-environmental schemes increased from 20%-24% (EU 15). Schemes include reduction of inputs, support for extensification and organics, and biodiversity conservation. From 1993-2003, expenditure on schemes increased by 40 fold to 2 billion Euros annually (EEA 2006).	In principle, agri-environment schemes improve environmental quality by lessening negative impacts of agriculture as they work in closer harmony with the habitats and landscapes in which they reside. However, they must be designed, targeted (spatially), and monitored appropriately to be effective

		(EEA 2006).
Intensification	Intensification has been the predominant force in EU agriculture over the past 40 years. Associated trends include increases in livestock density (particularly pig and dairy). Also, between 1990-2000 average milk yields increased by 14% and cereal yields by 16% (EU 12). (EEA 2006). Further agricultural specialization is likely to take place as European farms aim to maintain income levels in the face of increasing competition globally (EEA 2007).	Intensification generally worsens many of the environmental impacts associated with farming. This is due to factors including increased inputs to raise crop yields, mono-cropping, and the use of unsustainable farm management approaches (e.g. manipulation of sewing times, aggressive ploughing techniques). Whilst specialization is sometimes associated with moves to low input farming, increases in monoculture and high input approaches also occur, making environmental management more challenging.
Extensification	There are signs that long term agricultural intensification patterns may be weakening a little. Between 1990-2000 the share of high input farms in the EU12 declined from 44% to 37%, whilst the share of low input farms increased from 26% to 28% (EEA 2006).	Extensification leads to lower use of agricultural inputs and the spread of low input farming to less productive lands. Declining input levels can reduce pollution and exploitation of natural resources, although spread to less productive lands many negatively impact biodiversity.
Marginalisation	During the 1990's, marginalization increased in Northern Ireland and Southern Portugal (EEA 2006). It is also a problem in Eastern Europe. For example in Estonia, between 1990-2000 total abandoned arable land rose from around 1% to around 25% (EEA 2004) principally due to economic and political change in the former Soviet Union.	Marginalisation is often linked to the loss of HNV farmland and corresponding negative biodiversity impacts. However, if associated with high input farming, abandonment can reduce environmental pollution. Abandonment can lead to aforestation and positive impacts including CO2 storage and habitat formation, although in some cases aforestation can reduce habitats and biodiversity.
Land cover change	In the EU 12, total UAA declined by 2.5% during the 1990s (EEA 2006). Urbanisation contributed to this loss. Further, there was a net loss of agricultural land to forest and semi-natural land of almost 500km² (particularly Italy and Hungary) indicating of agricultural abandonment. Several countries ran counter to this trend - in Spain, France and Greece, forest and semi-natural land was lost to farmland signifying intensification. Land cover change within the agricultural sector is taking place. This includes transfer from pasture to arable and permanent crops (e.g. in Estonia, Lithuania, Ireland and the Netherlands), and conversely the growth of pasture, set side and fallow land at the expense of arable and permanent crop land (particularly in Germany and the Czech Republic). Regional variations in trends are evident (EEA 2006a).	Environmental impacts of agricultural land cover change and loss depends on the nature of that change and the type of land cover replacing the farmland. Regional variations in impacts are therefore evident. The loss of extensive pasture to arable and permanent crops in the Baltic States will involve impacts associated with intensification. However, increases in low input farming in Germany will benefit environmental resources. Regarding the environmental impacts of the loss of farmland to other land uses (e.g. urban, forest), considering that intensive agriculture is one of the most harmful of human activities, this may often be advantageous. However, the loss of HNV farmland will generally be detrimental to biodiversity. Loss of forest and semi-natural land to agriculture will generally signify intensification and the increase of commensurate environmental impacts.
Soil erosion	Soil erosion, particularly by water, is increasing in certain regions. Soil loss by water of over 10 tonnes/ha/year is occurring in parts of southern Spain and western Greece. Italy and southern France are also experiencing significant soil loss. In parts of southern Europe, organic carbon content is soil is low and declining (EEA 2006).	Soil erosion (+ transport of pesticides/fertilizers) contributes to water pollution and biodiversity loss. Good soil structure is important for climate change mitigation as soils with organic content store carbon, and also aid adaptation by providing resistance to floods and droughts. In extreme cases, desertification can occur.
Animal husbandry	There has been a general decline in cattle, sheep, pig and goat numbers. During the 1990s, the biggest falls (of 40-50%) occurred in the new member states, Eastern Europe and Central Asia. Falls of 10-20% took place in the EU 15 (EEA 2007). Nevertheless, meat and dairy	Livestock production is one of the key causes of land based environmental pollution, and places huge demands on environmental resources (soil, water). Farm animals and their feedstock consume vast amounts of land, and contribute significantly to climate change and

	consumption in Europe remains high in global terms, and livestock production has simply been transferred overseas.	poor air quality (FAO 2006a). Declines in livestock numbers is therefore generally beneficial for the environment.
Per capita food consumption	In industrial countries per capita food consumption is projected to grow slowly, from 3446 to 3540 kcal/person/day for the period 2000 to 2050. More significant increases are expected for other regions e.g. in East Asia, growth is projected from 2872 to 3230 kcal/person/day over this period. Further, undernourishment in developing countries is projected to decrease from 17.2% (2000 figures) to 3.9% by 2050 (FAO 2006a).	Much of the increases in calorie consumption in developing countries will come from meat and dairy products, which will put additional stress on environmental resources and quality. However, much additional livestock production will take place outside the EU. Nevertheless, considering the importance of the export market, EU growth in agricultural production may take place in some sectors (with associated environmental impacts) to satisfy external rather than internal demand.
Agricultural commodity consumption	Projections for future consumption of different food groups shows that for industrial countries, increases in consumption of meat and dairy (by 11.5% and 6% respectively) are expected between 2000-2050, whereas small reductions in cereals and roots/tubers are anticipated. In developing countries, growth in all commodities is expected between 2000-2050, particularly meat (101%) and dairy (72.6%) (FAO 2006a).	Without a shift to more sustainable methods, growth in consumption of meat and dairy products will have severe environmental impacts. In particular, greenhouse gas emissions, environmental pollution and loss of habitats and biodiversity will increase. However, as much of the growth in production is likely to be absorbed by regions including north and south America, Europe may escape the worst of these impacts (with the exception of climate change).
Global agricultural demand	Due to slowing growth in global population and steady increases in the number of people with relatively high daily calorie consumption, rates of growth in demand for agricultural products has declined in recent decades (FAO 2002). These drivers are not expected to change, and growth in demand is projected to decline further. Globally, annual growth in demand is predicted to fall from 2% (1989-1999 figures) to 1.4% from 2015-2030 (FAO 2002). Declines in growth rates for agricultural production can also be expected.	Declining levels in growth of demand for and production of edible agricultural products will change the relationship between agriculture and the environment in the future. However, although there will be a relative decline in foodstuffs production (and related environmental impacts), emphasis could shift to crops such as biofuels or cotton for example. On balance, the environmental impacts of agriculture may therefore weaken little.

Table 1: Agricultural trends and related environmental impacts

Agriculture & peri-urban linkages

The agricultural sector and the environmental impacts that it generates significantly affect the core PLUREL agenda, peri-urban land use relationships. Table 2 offers some insights into how agricultural trends link to peri-urban areas. The list is by no means exhaustive. Nevertheless, the information contained within Table 2 does demonstrate how land use in peri-urban areas may evolve in the future as trends in the agricultural sector are played out. Where possible, environmental hotspots that are more likely to experience these impacts are identified. A number of cross cutting issues can be identified which help to characterize agriculture's linkages with peri-urban landscapes. These include:

- ***Legislation and policy:*** In Europe, the Common Agricultural Policy (CAP), which accounts for almost half of the EU's annual budget, uses economic instruments including tariffs, quotas and subsidies to influence agricultural practice and production. CAP policy developments exert major change on farming activities.

Changes in other policy fields, for example the promotion of biofuels, can have corresponding impacts on agricultural production patterns. In eastern Europe, political and economic change have had dramatic impacts on the agricultural sector with policies promoting privatisation and commensurate reductions in state support for farming. Where legislation and policy encourages intensification, impacts such as the over abstraction of water from underground aquifers can occur. This could in extreme cases limit urban development opportunities in peri-urban areas due to a reduction in available water supplies. Further, high nature value farmland may be protected by legislation (such as the Habitats Directive) which improves prospects for biodiversity in peri-urban areas.

- ***Farm management:*** Changes in farm management practices, for example moves towards specialisation or intensification, can have significant impacts on landscapes and environmental quality. These impacts result from, for example, land use changes (e.g. increased field sizes), tillage practices, changes to livestock and cropping patterns, and variations in the use of inputs such as fertilizers and pesticides. The nature and extent of environmental impacts in peri-urban areas, such as soil erosion or the eutrophication of water bodies, is heavily dependant on farm management practices which can either intensify or limit these problems.
- ***Consumer preferences and market trends:*** Consumers, as the end users of much agricultural produce, drive some changes in farming practices and management. For example, the growth in demand for organic produce is stimulating agricultural change (albeit minor in relative terms). Similarly, public concerns over pesticide levels have led to national reduction strategies in the Netherlands, Denmark and Sweden (EEA 2006). Increasing public concern over food issues such as animal welfare and health impacts are likely to remain significant. In the marketplace, the dominance of supermarkets over recent decades has stimulated evolution in farming practices. Peri-urban areas may benefit from developments such as the reinvigoration of organic farming or increased demand for locally produced food products as agricultural landscapes could be used less intensively. Also rural economies could be stimulated. However, where public concern is lower, damaging industrial scale farming practices could dominate with negative environmental and landscape impacts.
- ***The economics of farming:*** Economic considerations are a significant driver of farming practices. For example, land abandonment can result from decisions by farmers to look for more secure and highly paid work. Likewise, intensification may be due to attempts to raise productivity and profitability. Associated impacts on peri-urban environments could include the loss of rural employment where land is abandoned, with commensurate raising of pressure on urban services. The over-abstraction of water resources could take place, for example, where agriculture becomes more intensive.

Table 2 highlights examples of peri-urban land use impacts associated with the continuation of trends currently shaping the agricultural sector. Although there are common drivers of change affecting the relationship between farming and peri-urban landscapes such as those discussed above, some spatial variation relating to the nature and extent of these impacts can be expected as these trends play out differently in countries across Europe according to factors including political priorities, climate, topography and traditions in agricultural practice.

AGRICULTURE		
Trend	***Environmental 'hotspots'***	***Peri-urban land use impacts associated with continuation of trend***
Organic farming increasing	Scotland, Austria, Italy, Finland, Sweden, Denmark and Germany have higher than average cover. Eastern Europe and Central Asia lag significantly behind.	- Organic farming may reinvigorate declining rural communities. - With higher income and employment, local economies may grow with services improving accordingly. - Sustainable use of environmental resources generally benefits humans and biodiversity (unlike intensive agriculture).
Irrigation demand increasing	Southern France, Spain and Greece have seen large recent increase. Many areas of southern Europe are heavily reliant on irrigation.	- Competition between users for scarce water resources will increase, creating difficult choices e.g. farming vs urbanisation? - As water bodies become drier, settlements may be abandoned. - Lack of water may constrain new development in some regions. - Decline of agriculture may pressure services in surrounding urban areas.
Emissions of pollutants falling	Higher farming intensity in north and west Europe, which is where benefits will be most noticeable. Local hotspots remain in many areas where intensive farming is practiced.	- Lower pollutant emissions improves environmental quality in rural and urban areas to the benefit of humans and biodiversity. - Improvements in environmental quality may attract people to rural areas, particularly if urban environments worsen. - Where environmental quality improves, new land uses may be encouraged, e.g. recreation, nature protection. - Agricultural 'ghettos' may occur where pollution remains high.
Pesticides and fertilisers use reducing	Exceptions (to reductions in nitrogen) include Ireland and Spain. Netherlands has a very high nitrogen balance. Local hotspots exist in many countries. Inputs are considerably higher in the EU15 other member states.	- Lower input farming methods can generate improvements in environmental quality to the benefit of humans and biodiversity. - Water bodies become more attractive increasing opportunities for recreation. - Acidification of soils decreases, encouraging forestry.
HNV farmland reducing	UK, Sweden, Spain, Portugal, Italy, France and Greece have large areas of HNV farmland. Significant losses in south and east Europe and mountain regions.	- Loss of HNV farmland is often associated with a decline in traditional agricultural practices. - Agricultural communities may fracture, with a loss of social, cultural and economic structures and relationships. - Increased pressure may be placed on services in urban areas. - Depending on the type of land use that replaces HNV farmland, environmental quality may decline, particularly biodiversity.
Agri-environmental schemes expanding	Luxembourg, Sweden, Finland and Austria have over 80% of UAA covered by these schemes. Most EU 15 countries have less that 30% of UAA covered.	- In areas where there is scope for expansion, these schemes offer significant benefits to environmental quality. - Agricultural landscapes change to less intensive patterns. - Activities such as recreation, tourism and nature conservation can co-exist more comfortably with farming under these schemes.
Intensification reducing	Agricultural areas of north west Europe. Livestock density remains high in the Netherlands, Belgium, west Germany, west of the UK, northern Spain, Brittany and the Po valley.	- Traditional farming practices and communities may recover. - Reduction in intensive farming will change agricultural landscapes e.g. reducing field sizes, increasing HNV farmland. - Lower agricultural inputs improves environmental quality. - Farming remains intensive in many areas bringing with it many of the negative environmental impacts of agriculture particularly on high quality farmland, although economic benefits may remain.
Extensification increasing	Traditionally intensively farmed regions e.g. Germany.	- Extensive farming (if replacing intensively farmed land) can allow a wider range of land uses to coexist e.g. recreation, conservation. - If associated with marginalisation, extensive farming may signal a loss of farming employment and negative socio-economic impacts.
Marginalisation increasing	Marginalisation is projected to increase in Ireland, Portugal, Northern	- Land abandonment and associated environmental problems. - Dislocation of rural communities and employment bases which may face a spiral of economic decline.

	Ireland and large parts of Italy (EEA 2006).	- Potential for new industries to develop in rural areas. - Increased pressure on urban services due to rural emigration.
Land cover change evolving	Land cover change is diverse and regionally dependant. See Table 1 for further spatial detail.	- Agricultural abandonment has negative economic and social impacts, e.g. loss of employment and community cohesion. - If land was intensively farmed environmental quality will improve. If it was HNV farmland biodiversity will generally suffer. - Loss of forest and semi natural land to agriculture signifies intensification and impact associated with this process. - Loss of marginal land which may have environmental functions. - The impacts of intra-agricultural land use change depend on the nature of the change and can be positive and negative.
Soil erosion increasing	Southern Spain and western Greece, and to a lesser by still significant extent southern France and Italy.	- Soil erosion reduces agricultural potential leading to marginalisation, land abandonment and rural emigration. - Loss of farming jobs and support for local economies. - Farmers may diversify into other industries such as tourism. - The threat of flooding locally and downstream is increased.
Animal husbandry declining	Largest falls in Eastern Europe and Central Asia. Significant declines in the EU 15.	- Environmental impacts associated with livestock production decrease improving local environmental quality. - Pastures may be transferred to other uses such as cropping, forestry or recreation. - Pastures may revert back to natural grasslands or forests.
Per capita food consumption increasing	This is not a spatially dependant trend.	- Increase in meat and dairy consumption (see below). - Increased demand for agricultural foodstuffs pressures marginal agricultural lands and intensifies production in existing areas. - New agricultural areas may open to meet consumption increases.
Meat and dairy consumption increasing	This is not a spatially dependant trend.	- Increase in meat and dairy consumption globally will increase demand for pastures and farmland producing stock feed. - Pastures may become more common as recent declines in livestock numbers reverse to meet increasing demand.
Global agricultural demand decreasing	This is not a spatially dependant trend.	- As agricultural foodstuffs no longer drive increases in demand and production, non-food commodities (biofuels, cotton etc) will become more common. - Marginal lands may be farmed for non-food commodities if economically viable, particularly in eastern Europe and Central Asia.

Table 2: Agricultural trends and associated peri-urban land use relationships

There is an inherent subjectivity associated with predicting the continuation and impact of trends affecting the agricultural sector. Nevertheless, the direction of change in factors such as irrigation demand, the use of pesticides and fertilizers and soil erosion will have a marked impact on peri-urban areas. Aside from landscape and environmental impacts, knock-on effects on rural development, patterns of peri-urban development and marginalization of agricultural land could also be expected. The PLUREL scenarios provide a route into exploring different possible futures and the extent to which these may affect the agricultural sector. There follows a discussion of related issues, from which impacts on peri-urban land use can be inferred.

Agricultural futures

It is not possible to accurately predict how the agricultural sector may evolve in the future. However, through the use of 'scenario thinking,' it is possible to explore how the sector may evolve in response to different drivers of change acting upon it. The PLUREL scenario set provide the framework for this exercise, the key findings of which are summarised in Table 3. Current agricultural trends are considered in the context of each of the four PLUREL scenarios to provide a visualisation of the nature of possible changes in the agricultural sector under different possible futures. Tables 1 and 2 above provide details of environmental and peri-urban land use impacts related to current trends in the agricultural sector, and provide a useful point of reference when considering the possible impacts of the scenarios on European agriculture. Key issues arising from each of the PLUREL scenarios include:

A1b Hypertech
The A1b hypertech scenario is characterised by drivers including globalisation, rapid technological change, peri-urbanisation and rural population growth and weak spatial planning policies. This scenario is likely to be accompanied by significant change to the agricultural sector. Increases in population and per-capita GDP increases demand for agricultural products, with associated impacts including increased soil erosion and agricultural pollution. Government policy and regulation is not strong enough to restrain profit motivated agri-business practices. The impact of technological change could have positive and negative environmental implications in this respect, for example relating to biotech, irrigation management and generic engineering. Land use patterns also change, with productive farmland lost to development and land abandonment due to climate change impacts.

A2 Extreme Water
Key themes of this scenario include high population growth, limited environmental awareness, rapid urbanisation and a general shift to regional and local patterns of working and living. Climate change impacts are severe, particularly in the context of water resources (flooding, drought and sea level rise), leading to widespread farmland abandonment. Negative aspects of agricultural practice (water exploitation, soil erosion, pollution, biodiversity loss) intensify due to a lack of environmental ethics and harmful agricultural practices. The urban emphasis of this scenario leads to further neglect of countryside resources, which are already suffering from severe climate change. Resulting impacts including desertification, coastal algal blooms and severe land contamination become more common. Pockets of resistance do exist where traditional low impact farming methods are practiced on a local scale.

B1 Peak Oil
Environmental concerns permeate government policy, business practice and public consciousness. This is brought on by peaking of oil supplies and society's subsequent realisation of their 'addiction' to fossil fuels and a firm consensus over the need to respond to climate change. These shifts occur under a banner of global cooperation and an increased zeal to collectively address cross-boundary challenges. The agricultural sector receives particular attention due to the scale of its environmental impacts. Accordingly, responses are developed to problems such as soil erosion, over abstraction of water resources, energy inefficiency and agricultural pollution. Sectoral changes include an increase in organic farming, reduction in intensive meat production and greater use of farmland for renewable energy generation and carbon sequestration reasons. Environmental quality improves markedly as a result.

B2: Fragmentation
Environmental awareness is also high as in B1 Peak Oil, although under this scenario societies, governments and economies operate largely on a regional and local scale. This creates winners and losers, both economically and environmentally. Agriculture responds to these changes and related impacts. For example, many areas become increasingly self sufficient with agricultural land producing food and energy crops to serve surrounding regions. Generally, low input farming methods are employed to the benefit of the environment. However, there are less prosperous and more growth oriented regions where intensive high input farming dominates and associated environmental problems remain. Further, some regions loose population leading to land abandonment. Effectively, Europe's agricultural landscape becomes much more diverse with farming methods influenced by local climate, customs etc rather than the agendas of global agri-business.

Issue and current trend	PLUREL scenarios A1b hyper-tech	A2 extreme water	B1 peak oil	B2 fragmentation
Organic farming increasing	Some growth with increased spending power but remains a niche market as awareness of potential benefits remains low.	Intensive high-input farming squeezes out organics. Demand and support for organic produce is low.	Stimulated by subsidies, consumer demand, supportive legislation and appreciation of environmental benefits.	Shift away from high intensity globalised agricultural markets to local environmentally benign farming practices.
Irrigation demand increasing	Climate change, increasing population, demand for 'exotic' foods all year round, high-tech approach to agriculture.	Low investment in water efficient practices, climate change and reactive policy drives demand upwards.	External costs of irrigation driven water shortages are recognised. Technology and policy reduce water use	Environmentally conscious policy and practice lowers water use. Some small farms cannot adapt and disappear.
Emissions of pollutants falling	Increased use of pesticides and fertilisers on high input farms, lax environmental legislation and monitoring	High input of energy and chemicals. Policy targeted at increasing yields, not environmental performance	Policy and consumer choice supports low input and impact farming. Agriculture works more closely with ecosystems.	Societies respect their local environments. Sustainable farming practices are central to community wellbeing.
Pesticides and fertilisers use reducing	Increase in high input farming methods, reduced incentives for environmental stewardship and enhancement	Increased use linked to expansion of yields at all costs to tap into markets to feed the growing global population.	Agriculture identified as a key cause of ecosystem degradation. Policy and practice is altered accordingly.	Policy to enhance local environment quality targets agriculture. Consumers demand low-input produce.
HNV farmland reducing	Traditional farming methods decline, smaller number of larger farms, climate change impacts on sensitive areas	Less productive areas are abandoned and adopted by subsistence farmers using traditional methods.	Biodiversity legislation protects existing areas. Compact urban growth opens up space for new HNV farms.	Policy preserves local identity and environments enhancing HNV farmland. Farms paid to protect biodiversity.
Agri-environment schemes expanding	Fewer incentives to manage land sustainably, greater emphasis on expanding agricultural output	Public resources are turned towards enhancing yields. The environment is low on the agenda of agricultural policy.	Public resources fund further expansion. Markets demand 'cleaner' agricultural produce. Biodiversity protection grows.	Schemes support policy direction. Some regions benefit more than others in line with resource availability.
Intensification reducing	Bio-tech fuels intensification, more high input and commercial farming methods, globalisation of agriculture	Nodes of intensification and abandonment. Floodplain and drought-striken farmland lost pressuring other areas.	High energy prices, resource saving policy and practice and consumer preferences place emphasis on low input farming	Generally local communities shun high input farm products. Some regions become intensive farming hotspots.
Extensification increasing	Peri-urban expansion, trends to intensification and higher demand for food run counter to extensification patterns	Increases in S Europe as climate change reduces land productivity. Marginal lands are increasingly utilised.	Energy intensive farming is not viable. Extensive methods are favoured. Supported by ecologically sensitive policy.	Traditional low impact farming methods on HNV farmland. Little land is abandoned. The most productive use is sought
Marginalisation increasing	Climate change forces further land abandonment, industrialisation of farming reduces employment base	Soil erosion and flooding force some farmers off the land. Rural out-migration lead to widespread abandonment.	Biotech biomass crops resilient to marginal soils. Rural spaces are maintained for recreation, biodiversity	Land is valued for food and non-food agricultural use. Land is used for biomass, biodiversity, organics etc
Land cover change evolving	Loss of farmland via peri-urbanisation and 'metropolitanisation' of rural areas. Weak spatial planning.	Rural areas become less favoured in politically and economically. Farms are lost, reverting to natural habitat.	Compact urban growth offers space for farm expansion. Some farmland is set aside for biodiversity, carbon storage.	Regionally diverse patterns emerge according to policy, resources etc. HNV and productive farmland protected.
Soil erosion increasing	Flooding + drought both increase soil erosion, little regard to environmental impacts of farming	Climate change accelerates. Agricultural policy and farming methods feed further erosion.	Policies to halt soil erosion are developed. Soil is protected as a valuable resource. Climate change is less intense	Continues in some areas where policy does not meet the challenge. Generally, reductions are experienced.
Animal husbandry declining	Meat production is dominated by non-EU countries, specialist meat producers (e.g. organic) expand	Imports from outside the EU decline. Regional production increases to meet domestic demand.	Carbon intensive nature of meat is recognised. Taxes increase, prices rise, and demand falls.	Growth in local production and consumption as less meat is imported. Environmentally sensitive methods are used.
Per capita food consumption increasing	Rapid economic growth, regional convergence of income and cultures, higher demand for food products	Population growth and some increase in per-capita incomes leads to slight advance in consumption levels.	Consumption continues to rise. Markets shift to local, low input, and seasonal produce.	Further growth is seen, particularly in resource rich regions. Citizens engage more closely with the food sector.
Meat and dairy consumption increasing	Rapid economic growth, high calorie diets, regional income and cultures converge, biotech enhances supply.	Most EU regions converge, increasing overall demand. Some wealthy areas see greater consumption.	High energy prices and carbon tax impact on price of animal products. Impacts on the environment are accepted	Full cost of meat/dairy is reflected in prices, reducing demand. Meat is increasingly seen as a 'luxury' product.
Global agricultural demand falling	Greater emphasis on non-food agriculture (e.g. biofuels) in EU balanced by increased demand for food products	Population growth stimulates demand. Little penetration of non-food products. Rising costs dent demand slightly.	Environmentally sensitive biofuel production increases. High oil price drives high food price impacting global markets	Biofuels and set-aside (carbon sinks, biodiversity) financially supported. Local production meets market demand.

Key		
	Acceleration of current trend	(green)
	Continuation of current trend	(light blue)
	Reversal of current trend	(red)

Table 3: 'Wind tunnelling' agriculture trends through the PLUREL scenarios

Agriculture: Conclusions

External and internal drivers of change impacting on the agricultural sector, such as international trade, farm management practices, consumer preferences and technology contribute to the creation of related trends (such as soil erosion, increasing irrigation demand etc) which in turn generate environmental impacts. For example, changing consumer preferences have increased demand for organic food products and a correspondingly agricultural land dedicated to organic production. This trend improves environmental quality due to, for example, the reduction in inputs of fertilisers and pesticides. Complex chains of cause and effect such as this are common due to the scale of the impact of the agricultural sector on Europe's landscapes. A range of future challenges will fundamentally affect this relationship.

For example, as is the case in many sectors, technological change has, and will continue to have, a profound impact on agriculture. In terms of environmental impacts, these changes can be both harmful and beneficial as they lead to intensification and/or more efficient use of inputs. Prospective future changes in, for example, irrigation, biotechnology or pesticides could have a major effect on the impact of farming on the environment. Due to the strength of the linkages between agriculture and peri-urban areas, associated impacts on this element of Europe's landscape would be inevitable. Similarly, shifts in the costs and availability of factors of production on which farming depends, including both human and natural resources, drive change in the agricultural sector. For example, the rising cost of oil in recent years has impacted on farming due to its prevalence as both a fuel and as the basis of inputs including fertilisers and pesticides. Further, ongoing rural emigration in many parts of Europe reduces the agricultural labour force impacting on the ability of farmers to maintain production levels. In both these cases, it can be seen that changes in the cost of factors of production will impact on both environmental quality and peri-urban land use relationships.

This discussion has explored the linkages between agriculture, environment and peri-urban land use. It has been established that policy makers must be fully aware of the impacts that this crucial sector has on peri-urban development patterns. The creation of strategies for the sustainable development of these areas must acknowledge the scope and depth of agriculture's relationship with peri-urban landscapes, and target resources to exploit opportunities and address challenges.

PLUREL

Agriculture: References

European Environment Agency (2004) High Nature value farmland – characteristics, trends and policy challenges, European Environment Agency, Copenhagen.

European Environment Agency (2006) Integration of environment into EU agriculture policy, European Environment Agency, Copenhagen.

European Environment Agency (2006a) Land accounts for Europe 1990-2000, European Environment Agency, Copenhagen.

European Environment Agency (2007) Europe's environment: the fourth assessment, European Environment Agency, Copenhagen.

Food and Agriculture Organisation (2002) World agriculture: towards 2015/2030 summary report, Food and Agriculture Organisation, Rome.

Food and Agriculture Organisation (2006) Livestock's long shadow: environmental issues and options, Food and Agriculture Organisation, Rome.

Food and Agriculture Organisation (2006a) World agriculture: towards 2030/2050 interim report, Food and Agriculture Organisation, Rome.

Institute for European Environmental Policy (IEEP) (2000) The Environmental Impacts of Irrigation in the European Union, IEEP, London.

Intergovernmental Panel on Climate Change (IPPC) (2007) Climate Change 2007: Synthesis Report, IPCC, Geneva.

3. Climate change – trends, projections and impacts

Introduction and context

The evidence for global climate change and the central role that humans play in driving this process is now overwhelming. Recent trends, for example concerning the reduction in the extent of the polar ice sheets, retreating glaciers, increasing temperatures, and rising sea levels, provide visible evidence of the impacts of a changing climate. Scenarios such as those developed by the Intergovernmental Panel on Climate Change (IPCC) provide a means of visualising what the future might look like as climate change takes a firmer hold. Table 5 provides a detailed review of the key change to Europe's climate that are projected to occur over the 21st Century. In Europe, figures for annual precipitation change show a stark north/south divide. Southern Europe could potentially receive 20-30% less rainfall by the 2080s, whilst Northern Europe could receive 20-40% more. Concerning temperature change, the picture is more consistent with all of Europe projected to become warmer. Some regional variation can nevertheless be expected with annual temperatures projected to rise by up to 5 ºC in Northern Europe by the 2080s, and up to 3.5 ºC in parts of Southern Europe.

There is a huge challenge to be faced to keep climate change from reaching the point where catastrophic chains of positive feedback lead to impacts that would very difficult to manage. The EU (as stated in the 6th Environmental Action Programme) aims to keep temperature rise to 2ºC above pre-industrial levels, which is the point where it is thought that 'runaway' climate change will be difficult to prevent. This in itself will take an incredible effort from all sectors of society as current atmospheric concentrations of CO_2 are already at or close to the level that will commit the globe to a 2ºC rise. In Europe, where over 80% of the population is predicted to be living in urban areas by 2020, exploring the contribution of rural-urban regions to climate change mitigation and adaptation has never seemed more relevant and urgent.

There follows a detailed investigation of the impacts of climate change in Europe. This is based around the identification of key trends and projections relating to climate change. Climate change is an all encompassing process and will create a multitude of social, economic and environmental impacts. In analyzing the impacts of trends and projections for Europe, particular focus is paid to the relationship between climate change, environmental quality and peri-urban land use. The refinement of the focus of the study in this way (avoiding a broad scale investigation of the impact of climate change) forms a necessary boundary for the investigation. The following issues are considered:

- Identification of key trends and projections concerning the release of greenhouse gases in Europe.
- Summary of the impacts of climate change on environmental resources.
- Assessment of trends and projections concerning climate change impacts, and an analysis of how these affect environmental quality.
- Investigation of the relationship between climate change impacts, environmental quality and peri-urban land use.
- Application of the PLUREL scenario framework to the analysis of climate change impacts in Europe.

Greenhouse gas emissions in Europe: issues, trends and projections

Much of the warming recorded over the globe in recent years can be attributed to the release of greenhouse gases (GHGs) by humans (EEA 2007, IPCC 2007). Carbon Dioxide (CO_2) is the most significant GHG, accounting for around 80% of emissions, with methane and nitrous oxides also being important. Although climate change operates on a global scale, Europe contributes disproportionately to the problem as per capita emissions are higher that the global average. Table 4 provides more detail on issues relating to Europe's greenhouse gas emissions, including projections for changes in emissions from different sectors. Key issues can be summarised as:

- Emissions of GHGs have fallen slightly in recent years when compared against 1990 levels. Reductions have been experiences in the energy, waste, agricultural and industrial sectors, although transport has seen significant emissions increases.
- It is anticipated that emissions of GHGs will increase in coming decades, and are projected to be 8.4% above 1990 levels by 2030.
- The energy sector accounts for the highest proportion of EU GHG emissions, with transport making the second largest contribution.

Emissions of GHGs do have direct impacts on environmental quality. For example, increases in CO_2 can stimulate plant growth and nitrous oxide can contribute to pollution of land, air and water. It is, however, the effect that GHGs have on the climate system that has the greatest potential and actual impact on environmental quality. Related issues are discussed in Table 5.

The specters of climate change, energy security and rising energy prices are firmly on political agendas across the continent. It is likely that in the future, reducing emissions will become a greater priority to be achieved as a result of either climate change mitigation policies or indirectly via policies to reduce energy use (either through efficiency measures or demand reduction). The outcome of negotiations regarding a successor to the Kyoto Protocol will have important repercussions in this respect. If the EU's target to keep emissions to no more than 2°C above pre-industrial levels is to be achieved, much change is on the horizon. Indeed, the European Environment Agency (EEA 2007) deems it necessary for developed economies to achieve 15-30% reductions by 2020 and 60-80% reductions by 2050. Peri-urban landscapes will doubtless be affected greatly by efforts to achieve these targets. The likelihood of significant structural changes such as those relating to urban form, transport and energy generation will depend on a range of factors including political motivation, availability of resources for capital investment, public support for climate change mitigation policies, and future energy prices. However, in the event that insufficient action is taken to address climate change via emissions reduction strategies, peri-urban landscapes will still be affected by climate change impacts, and to a greater degree than if mitigation measures are successful over coming decades. The discussion now turns to the effects of climate change, and particularly associated environmental and peri-urban impacts.

CLIMATE CHANGE: EMISSIONS	
Issue	***Trends and projections***
Falling GHG emissions between	Between 1990-2005, GHG emissions in the EU 27 fell by 7.9% (EEA 2007a). Much of the overall decrease can be attributed to the new member states, which experienced

1990-2004	economic restructuring and falling emissions during this period (EEA 2007). Despite overall declines, between 2000-2004 all EU regions increased their emissions.
Further reductions on emissions projected, but with increases over the longer term	Between 2005-2010, emissions in the EU 27 are projected to fall further, to 11% below 1990 levels. However, emissions are then expected to rise again and by 2020 are projected to be 6% below 1990 levels. Projected rises in emissions post-2010 suggest that planning has been focused principally on meeting Kyoto targets. With the implementation of existing and proposed domestic and international (Kyoto mechanisms) measures, emissions in the EU 15 could feasibly reach 11.4% below 1990 levels by 2012, surpassing its Kyoto target of an 8% reduction (EEA 2007a). Faster growth in emissions is expected in the EU 10, EECCA and SEE than in the EU 15 (EEA 2007). Projecting forward the impact of current policies, emissions in the EU 25 will be 6% above 1990 levels by 2020, and 8.4% above this level by 2030. Significant reductions in these figures could be achieved although this would depend on major changes in the energy sector and the uptake of new technologies such as carbon capture and storage (EEA 2005).
Emissions from energy use and supply (excluding transport)	The energy sector (supply, manufacturing, households etc) accounted for 59% of EU 15 emissions in 2005. Across the EU 27, emissions fell by 11% between 1990-2005, with a further 2% fall expected with existing measures by 2010. Emission levels have decoupled from increasing energy demand due to efficiency improvements and switching to less carbon intensive fuels (coal to natural gas) (EEA 2007a).
Emissions from industrial processes	In 2005, industrial processes (particularly cement and steel manufacture) accounted for 8% of total of EU 15 emissions. In the EU 27, a 20% reduction was experienced between 1990-2005. However, without additional investment in abatement measures emissions are expected to rise by 6% by 2010 (EEA 2007a).
Emissions from agriculture	Agriculture accounted for 9% of EU 15 emissions in 2005. In the EU 27 between 1990-2005, emissions fell by 20%, and are projected to fall by a further 3% by 2010 with existing measures. Decreases are largely due to efficiency improvements, less use of nitrogen fertilizer and falling numbers of cattle (EEA 2007a).
Emissions from waste management	In 2005, waste accounted for 2% of EU 15 emissions. Across the EU 27, emissions from the waste management sector fell by 31% between 1990-2005, with a further decrease of 9% to 2010 expected with existing measures (EEA 2007a). Falls can be attributed to declining methane emissions from landfill sites.
Emissions from transport	In 2005, transport was responsible for 21% of EU 15 GHG emissions. In the EU 27, transport emissions increased by 26% between 1990-2005. Emissions are expected to stabilize to 2010, largely as a result of increased use of biofuels in countries such as Germany (EEA 2007a).

Table 4: Climate change emissions trends and related environmental impacts

Climate change: summary of environmental impacts

The impacts of climate change on environmental resources are numerous, complex and interconnected. Table 5 looks at how climate change trends and projections are set to impact on Europe's environmental resources, focusing on air, biodiversity, soil and water. Although these different elements of environmental quality are considered individually, it is important to emphasise that complex synergies (many of which are not fully understood) operate between them. For example, temperature increases can reduce soil moisture content leading to soil instability and greater propensity to leach nutrients into water courses, which can in turn result in aquatic pollution. The following points summarise the nature of the relationship between climate change and environmental quality in the context of four key environmental resources. These issues are considered in greater detail within Table 5

Air quality
Air quality and climate change are closely linked. The burning of fossil fuels is one of the key drivers behind poor air quality (through the release of pollutants such as sulphur and nitrogen oxides and particulates) and also climate change (through the release of carbon dioxide and other GHGs). Consequently, EEA (2004aq, 2006aq) indicate that policies to address climate change through reducing fossil fuel use will also benefit air quality, particularly in new member states where air quality is generally poorer. Climate change mitigation policies could reduce the cost of managing air pollution by up to 10 billion Euros annually, reduce the number of premature deaths related to air pollution by at least 20000 per year in the EU 25, and also benefit ecosystem health through reducing acidification, eutrophication and ozone creation (EEA 2006).

The release of air pollutants can also have a direct impact on climate change processes and climatic variables. For example, increases in oxides of nitrogen raise ozone levels, which in turn enhances radiative forcing and temperature increases. Further, the release of pollutants may influence precipitation patterns as particles of soot act as a 'seeds' around which raindrops form, whilst the same particulates can also reflect heat back into the atmosphere delaying temperature increases driven by climate change (EEA 2004).

Biodiversity
Even the most optimistic climate change scenarios pose considerable risk to biodiversity (Thuiller et al 2005). Indeed, climate change could become the most important factor driving biodiversity loss and ecosystem change in the future (MEA 2005). Most member states are expected to loose at least 50 plant species from 1995-2100, although Scandinavia and the Baltic states are likely to gain (invasive) species (EEA 2005). A further study (Schroter et al 2004) found that under high emissions scenarios, that up to 80% of Europe's species richness could be lost by 2080. Loss of species richness will generally lead to less stable ecosystems (EEA 2005a).

Impacts of climate change on biodiversity and ecosystems can be categorized as changes in phenology (i.e. biological phenomena such as flowering times, breeding cycles), behavioral patterns (e.g. migration routes, plants response to drought) ecosystem changes (e.g. productivity, species composition) and CO2 related impacts (e.g. carbon sequestration capacity of ecosystems) (EEA 2006a). These impacts arise from a range of interrelated changes to climatic variables (principally temperature and precipitation) and knock-on effects such as sea level rise. Ecosystems are particularly vulnerable to climate change impacts due to their low level of adaptive capacity and high level of sensitivity and susceptibility to changes in climatic conditions (EEA 2005a). Regions particularly at risk of biodiversity loss are the Arctic, coastal zones (especially the Baltic), the Mediterranean and mountain areas (EEA 2005a, Schroter at al 2005). There is evidence that climate change has already affected ecosystems in some European regions including the Alps and the Arctic (EEA 2004a, 2005a).

Soil
Climatic variables are central to the formation, sustenance and weathering of soil, and projected rapid changes to the climate will have a dramatic effect on soil cycles and processes. This will be to the detriment of numerous economic sectors, especially agriculture. It will also impact negatively on biodiversity as soil is central to the sustainability of many terrestrial and aquatic ecosystems (through the deposition of nutrients), and can even be regarded as a living ecosystem in its own right. Higher temperatures will speed soil mineralization processes, increase the risk of drought and subsequent salinisation, and hasten permafrost thawing (EEA 2004, EEA 2005a). Increased precipitation will lead to faster soil weathering, additional runoff of nutrients into water bodies, and changes in soil structure due to saturation. Conversely a drier climate, as is projected for much of southern Europe, will reduce soil moisture content with impacts on biodiversity. Less rain may also speed the breakdown of soil structure which in extreme cases can lead to desertification, a phenomenon that is increasing in

pace over southern Europe. Soil will also be impacted on indirectly by climate change. For example, reduced precipitation will increase demand for irrigation which may lead to soil salinisation if not managed properly.

Water
Observed changes in the climate over recent decades have impacted on the hydrological cycle and the availability of water resources in some regions. Projections for further climate change are set to accelerate and intensify these impacts (Bates et al (2008), Eisenreich (2005)). Europe exhibits a clear north-south gradient in respect to observed and projected climate change. Southern, central and eastern Europe are expected to be severely affected in the future, with higher temperatures and lower precipitation combining to reduce available water resources. Associated socio-economic changes, for example greater demand for water in the agricultural, industrial and domestic sectors, will exacerbate these shortages in supply as abstraction increases. Climate change is also anticipated to bring an excess of water to some regions, particularly in central, northern and western Europe in the winter months, with associated flooding becoming more common. Negative social, economic and environmental impacts can be expected to arise as a result of these changes to the hydrological cycle. These impacts are numerous and wide ranging and include, a significant reduction in Europe's hydropower potential, reduced water quality, reduction of crop yields in the Mediterranean region, impacts on human health, and disruption to ecosystems across the continent (Bates et al 2008). Changes in hydrological process can also feedback and link to climatic variables. For example, evapotranspiration from soil and surface water bodies helps to moderate air temperatures. A reduction in water supplies may therefore increase temperatures leading to human comfort issues in urban areas for example.

Climate change: trends, projections and impacts on environmental quality

The previous section summarised some of the most significant environmental impact associated with climate change. Table 5 below expands on this discussion providing a detailed look at trends and projections related to climate change impacts in Europe, providing a comprehensive insight into the nature and extent of the problem. In each case, related impacts on environmental quality are highlighted. In summary, key climate change related trends impacting on the European continent include:

- ***Temperature increases*** are expected across Europe at a pace higher than the global average. Associated impacts on environmental quality, particularly under the higher emissions scenarios, are negative.
- ***Precipitation patterns*** are projected to change considerably, with northern Europe becoming wetter and southern Europe drier. Associated environmental impacts are predominantly negative.
- ***Flooding*** frequency and magnitude is likely to increase over northern Europe with negative effects on environmental quality including habitat damage and water quality impacts.
- ***Droughts*** are expected to become more frequent and intense over southern Europe, with potentially severe negative environmental impacts including desertification and forest fires.
- ***Summer heat waves*** are now more frequent, and are projected to become even more common over much of Europe. Heat waves are associated with worsening air quality and changing ecosystem composition for example.

- ***Sea level*** is expected to continue to rise at an increasing rate. Depending on the magnitude and rate of change, impacts such as loss of coastal habitats and salination of coastal aquifers will become more common.
- ***Wind speed*** is projected to increase over parts of northern Europe, with decreases possible in southern Europe. Air pollution patterns may change as a result.
- ***Snow cover*** is likely to decrease over much of Europe, with potentially significant biodiversity impacts and changes in hydrology in some areas.

CLIMATE CHANGE IMPACTS		
Issue	***Trends and projections***	***Impacts on environmental quality (air, biodiversity, soil, water)***
Temperature	Europe's temperature has risen faster than the global average, and is now 1.4ºC higher than pre-industrial levels (IPCC 2007). Temperature increases continue, with the period 2000-2007 0.21ºC warmer than the 1990s, which is currently the warmest decade on record (IPCC 2007). Europe's temperature is likely to increase by more than the global average in the coming decades, with northern Europe warming slightly faster than the south. Projections vary with emissions scenario, with 2-6ºC increases expected by the 2080s. Seasonally, warming is expected to be greatest in northern Europe in winter, and the Mediterranean in summer. Temperature variability is expected to be highest in the summer (particularly in central Europe) and lower over most of Europe in winter (IPCC 2007). Very cold winters are expected to become a rarity (EEA 2005).	Increased forest fire risk in the Mediterranean, loss of species in mountain areas (more than 90% loss with a 3ºC rise), and reduced water quality (in coastal areas due to algal blooms and inland waters due to lower flows) will threaten biodiversity and change ecosystem composition (EEA 2005a). The growing season is likely to increase over 85% of Europe (EEA 2005), increasing productivity of some ecosystems, although also increasing exposure of vegetation to air pollutants (EEA 2004). In terms of water resources, higher temperatures will induce evapotranspiration, reduce water supply, and encourage salination and eutrophication of water bodies. Continued melting of glaciers in the Alps is predicted (75% of Swiss glaciers are expected to be lost by 2050 (EEA 2004a)) impacting on land stability and river flows (EEA 2007). Higher temperatures speed mineralization processes in soils, increasing availability of nitrogen that stimulates plant growth. However, where soils are nitrogen rich, eutrophication risk will increase (EEA 2004). Soils are also at risk of salinisation and permafrost thawing in Arctic Europe and Russia (by 12-22% by 2050) is predicted (EEA 2005a)).
Precipitation	From 1961-1990, northern, western and central Europe and the Arctic became wetter in winter, whilst drier winters were experienced in south and south eastern Europe. In summer, most areas have become drier (Giorgi 2004). Indeed, Eisenreich (2005) notes that northern Europe has become 10-40% wetter over the last century, whilst parts of southern Europe are now 20% drier. Averaged over Europe, a slight increase in rainfall is expected by 2100 (EEA 2005), with increases in precipitation extremes (IPCC 2007). However, a distinct north/south split is expected, and in some cases amplification of seasonal variations. In winter, most areas outside the Mediterranean are expected to receive more rain, particularly the north where increases of up to 16% are possible by the 2080s. In summer decrease are expected over most of Europe, particularly the south where up to 27% less rain may fall by the 2080s (Eisenreich 2005, Giorgi 2004a, IPCC 2007). Further variation is likely locally according to altitude, especially where topography is complex (IPCC 2007).	The hydrological cycle, and all associated elements of environmental quality, will be impacted by precipitation change. This will impact on habitats and the composition of ecosystems, soil quality and structure, and water resource issues. For example, in the Mediterranean and parts of southern Europe, soil moisture content is expected to fall during the summer months (IPCC 2007), with likely impacts on plant communities and linked fauna. In these regions, declining precipitation levels will also lower river discharge increasing pollutant concentration in water bodies and will slow groundwater recharge, both to the detriment of biodiversity. Impacts associated with higher precipitation levels and more intense rainfall events include increased weathering of soils by water, higher river flows and ground saturation raising flood risk and improved air quality through removal of pollutants (yet deposition of pollutants into soils and water bodies may increase). Changes in precipitation levels (increases and decreases) may act to reduce the growing season, particularly in parts of northern Europe (saturation of soils) and the Mediterranean (drought). This may in turn reduce exposure of vegetation to air pollutants (EEA 2004).

Flooding	Flood events have increased in frequency recent years (EEA 2005b). Discharges from many European rivers have increased over the winter months. By the 2070s, discharges in parts of Scandinavia could by 25-50% higher than at present. Also, there is more chance of extreme precipitation events (frequency and magnitude), both in summer and winter, but particularly in northern and western Europe in the winter (EEA 2007, IPCC 2007). As a result of these changes, flood magnitude and frequency is likely to rise in much of Europe Eisenreich (2005).	Flooding impacts on various elements of environmental quality. Floods can physically damage water courses and riparian zones, disrupting habitats and biodiversity. Flooding and associated heavy rainfall increases surface water runoff and the transport of pollutants (from urban hard surfaces and farms) into water bodies, with water quality worsening. Water-logging of soils may also result. Flooding can lead directly to soil erosion and negative impacts on soil quality. In downstream areas, transported soil can increase sedimentation with negative impacts on aquatic ecosystems.
Drought	Discharges from many European rivers (particularly in the south and east) have been decreasing over the summer months, and summers are drier in many parts of Europe (EEA 2007, Giorgi 2004). Globally, climate change is likely to account for around 20% of increases in water scarcity (UNESCO 2003). Climate change is predicted to bring reduced rainfall and longer periods of drought in the Mediterranean and central Europe. River flows could be up to 50% lower by the 2070s in regions of Spain, Italy, Greece and Turkey. Even by 2030 it is possible that these regions (which are already water stressed) will have between 10-25% less water available for consumption. (EEA 2007, IPCC 2007). The threat of severe drought is generally confined to the south, and longer dry spells are not expected over northern Europe (IPCC 2007).	Some Mediterranean ecosystems are close to the limits of their ability to cope with water stress (EEA 2005a). Greater abstraction during drought periods will pressure biodiversity further, and could also speed salination of coastal aquifers. Droughts raise soil weathering rates, stressing biodiversity (EEA 2004), with high temperatures affecting pace of soil decomposition increasing potential supplies of nutrients. Soil moisture content is also affected leading to a loss of soil quality (e.g. through salination), and stress of vegetation. However, water stress reduces plants exposure to pollutants as their stomata close to conserve water (EEA 2004). Further, 'baked' soils are less absorbent and receptive to short bursts of extreme rainfall, increasing risk of flash flooding. Other impacts include increased risk of forest fires. During the 2003 drought, 25000 forest and heath fires were report in Europe (Eisenreich 2005). Droughts also reduced species richness, lower carbon sequestration capacity, and lower productivity (EEA 2005a).
Heat waves	Summer heat waves are more frequent. The 2003 heat wave was the most extreme on record (EEA 2007), and may be the hottest summer since 1500 (Eisenreich 2005). Heat waves are expected to become more common and intense. The number of areas with events lasting 7 days or more is projected to grow, particularly over France, Germany and Eastern Europe. By the 2050's, the Mediterranean could have an extra month per year with days over 25ºC (EEA 2007). Temperature variability during the summer months is expected to be most pronounced in central Europe (IPCC 2007).	Temperature increases impact on chemical reactions between air pollutants, encouraging greater ozone formation, for example, which can harm plant growth. Increases in stagnant high pressure systems (often associated with heat waves) may also lead to a greater incidence of pollution events, particularly in urban areas (EEA 2004). Higher temperature increase exposure of plants to air pollutants such as sulphur dioxide and ozone (EEA 2004). Heat waves increase risk of forest fires in southern regions, changing ecosystem composition to the benefit of fast growing species but to the detriment of others (EEA 2007).
Extreme weather events	The number of extreme climate related events has doubled over the 1990's (EEA 2004a). There are now fewer extreme cold weather events across Europe (EEA 2007). Although, the role of climate change is unclear (EEA 2005), in the future, it will be climate extremes not gradual changes that generate the most significant negative impacts (EEA 2007).	Through processes including floods, droughts, storms and heat waves, all aspects of environmental quality are negatively affected. These impacts are discussed within this table.
Sea level	Over the 20th century, global sea levels have risen on average by 1.7mm/year. Regionally, observed sea level rise varies. In Europe, coastal regions have seen rises of 80-300mm over the 20th Century. Globally, sea level rise of 18-59cm is projected by the end of this century. More significant increases	Key impacts will include loss of coastal wetlands, coastal erosion, and saline intrusion into coastal aquifers. Coastal ecosystems (and their habitats and biodiversity) are particularly vulnerable as many are below sea level, frequently flooded, and close to their temperature tolerance limits (EEA 2005a). In particular, coastal ecosystems may be lost around the

	are possible under certain scenarios (e.g. melting of polar ice sheets which could add a further 10-20cm by the end of the century) although uncertainties prevent accurate predictions (IPCC 2007).	Mediterranean, Baltic and Black seas where tidal ranges are low (EEA 2005a, EEA 2007). Mediterranean and Baltic coastal wetland habitats could shrink by over 50% if temperatures warm by 2-3ºC (EEA 2006a).
Wind speed	By the 2080s, increase in average and extreme wind speeds (in some cases by 10-15%) is more than likely over northern Europe. In southern Europe, a drop in average wind speed is expected, by 10-15% in some areas. Changes in the North Atlantic Oscillation could prompt an increase in storminess over western Europe, particularly during winter. There is some uncertainty in predicting future changes in wind speed and storminess (IPCC 2007).	Increased wind speed in northern Europe could aid the dispersal of pollutants improving air quality in some areas. But, down-wind rural areas could receive more airborne pollutants with associated problems for ecosystems e.g. acidification of soils and water bodies. Potential increases in the prevalence of Atlantic storm systems could worsen coastal erosion and storm damage in western Europe, with negative impacts on ecosystems and biodiversity.
Snow cover	The duration of the snow season is likely to decrease by one to three months over northern Europe. A 50-100% decrease in snow depth is expected over much of the continent. However, little change in cover is expected in the coldest areas of northern Europe and over the high Alps (IPCC 2007)	The number of plant species on alpine summits and in Arctic lakes is increasing as their time under snow cover decreases (EEA 2006a), although species adapted to seasonal snow cover may suffer. Surface and groundwater bodies replenished by melt waters (and associated ecosystems) will come under increasing stress. Soil erosion may increase where protective snow cover declines.

Table 5: Climate change impact trends and related environmental impacts

Climate change / peri-urban land use linkages

Rural-urban regions are drivers of climate change through the release of greenhouse gas emissions, yet are also impacted by its effects. This reveals the two core elements of the climate change agenda; mitigation and adaptation. Rural-urban regions have a crucial role to play in addressing both issues. Mitigation concerns reducing greenhouse gas emissions. Core issues affecting peri-urban landscapes, such as urban form, transport demand and modal split, energy generation, and housing provision are central to mitigation strategies, and are crucial in the context of the development and future evolution of rural-urban regions. It is evident that policies aimed at reducing GHG emissions will have visible impacts on peri-urban landscapes. Examples of possible changes include:

- Greater investment in public transport with potential impacts on commuting patterns and settlement structure.
- Changes in urban form, for example drives towards compact settlements and the protection and enhancement of greenspace areas.
- Changes in business locations, logistics management, and product manufacturing processes.
- Increased use of peri-urban land to produce renewable energy, for example via biomass production, energy from waste schemes, and wind turbines and solar panels.

Climate change adaptation concerns reducing vulnerability and increasing resilience to the impacts that are projected to become more common in coming decades. In practice, the severity of some climate change impacts will be influenced by the extent of the adaptation response developed by a particular country, region or community. Risk associated with climate change impacts can be lessened by reducing a particular receptor's (e.g. a city, neighbourhood, household) exposure and vulnerability to an impact (e.g. flooding), thus increasing its resilience. Considering the form and function of rural-urban regions is vital to developing effective adaptation strategies. Greenspace (e.g. urban parks, established trees etc) can play a significant role in helping to adapt urban areas to climate change impacts such as flooding and heat stress. Further, the design of development can help to adapt to flooding through, for example, raising floor heights, using water resistant plaster, and locating electric cables above projected flood levels. Despite the extent of new development and urban sprawl across Europe, the turnover of building stocks is relatively slow. This increases the importance of retrofitting for both mitigation and adaptation. This refers to the modification of existing development to meet climate change challenges, for example through improving insulation or opening up greenspaces around buildings. The links between climate change adaptation and urban form are therefore strong.

During the design and implementation of adaptation strategies, potential conflicts between mitigation and adaptation responses must be considered. This is an area deserving of further consideration in urban planning and design. A good example of a potential mitigation/adaptation conflict concerns the issue of density in urban areas. Classically, increasing density is seen as a way of reducing energy use (and hence greenhouse gas emissions) by, for example, lowering travel demand and space heating requirements. However, by increasing density in urban areas green space resources may come under threat, leading to the loss of a vital adaptation resource. Clearly there is a sensitive balance to strike when thinking about the best ways to address the causes and threats of climate change in rural-urban regions. Carefully long term planning and strategy making is vital. Table 6 explores these issue relating to climate change and peri-urban land use in Europe in greater detail.

CLIMATE CHANGE IMPACTS		
Trend	***Environmental 'hotspots'***	***Peri-urban land use impacts associated with continuation of trend***
Temperature increasing	Arctic regions have warmed most in the recent past. Significant warming has taken place in the Iberian Peninsula, SE Europe and Baltic States (EEA 2007). In coming decades, significant rises are expected across Europe, with the north warming marginally faster.	- Increasing temperatures are expected to influence travel behaviour. Summer tourism in the Mediterranean may suffer (although shoulder seasons may benefit) as northern Europeans take more domestic holidays (Gosling and Hall 2006). Coastal and upland tourism may benefit from the 'flight' of urbanites from overheating cities. - Higher temperatures and CO2 levels could increase crop yields in middle and northern Europe (IPCC 2007). In the south, heat stress and water shortage could reduce yields (EEA 2007). Generally, the range of crops is likely to move northwards and upwards (to higher altitudes) (EEA 2007). Higher temperatures and CO2 levels will negatively impact on the quality of grazing pasture (IPCC 2007). All these changes will have socio-economic impacts. - Temperature increases will stimulate ozone formation, with negative impacts on human health, especially in urban areas. - Permafrost melting will lead to landslides and infrastructure damage (EEA 2007).
Precipitation patterns changing	Annually, by the 2080s, parts of Europe (e.g. Scandinavia) may experience up to 25% more precipitation, whilst areas within southern Europe (e.g. Spain, Italy and Greece) could see falls of up to 25% (EEA 2007).	- Low river flows impact hydropower, recreation, tourism potential, electricity generation etc with knock on socio-economic impacts. - Agriculture is at risk from precipitation change. For example, higher levels encourage leaching of nutrients and water logging of soils, whilst lower levels lead to salination, soil erosion and desertification. Growing seasons are expected to shorten (EEA 2005). The farming industry is likely to suffer. - Saturated soils increase flood risk as absorption capacity

		decreases.
Flooding increasing	Between 1987-2002, NW Romania, SW France, central and southern Germany and East England suffered the greatest number of large flood events (Schmidt-Thome (2006)), indicating areas at risk of future flooding.	- Floodplains, which are often prime agricultural land, risk being waterlogged and eroded to the detriment of agricultural production. - The protection of floodplains by spatial planning procedures raises development pressure on surrounding land. - Communities in areas at risk of flooding may become blighted as insurers refuse to provide cover, lowering housing values. - Spending on flood defences may divert significant amounts of money away from other public infrastructure projects.
Drought increasing	Western Spain and Portugal has the highest drought potential (in terms of deficiency of precipitation) Schmidt-Thome (2006). Much of southern Europe is at increased risk of drought in the future.	- Loss of soil moisture content will affect forest management and agriculture, and can also exacerbate heat wave events (IPCC 2007). - Abstraction rates (from ground and surface water) increase to meet higher demand (from agriculture, households etc) for water. But, as there is less available, competition will increase between users. - Droughts have significant economic impacts, which are generally higher than the cost of flood events. The total cost of the 2003 drought has been estimated at $13billion Eisenreich (2005) - Drought increases forest fire risk. In 2003, forest fires in Portugal had an economic cost of almost 1 billion Euros (UNEP 2004) - During drought conditions, nuclear power generation, which requires large volumes of cooling water, may be threatened. France is at particular risk, evidenced during the 2003 heat wave (UNEP 2004).
Heat waves increasing	Continental regions show higher temperature extremes than marine regions (Schmidt-Thome 2006), and may experience more heat waves as a result.	- Heat waves impact on human health and comfort, particularly in urban areas where the 'heat island effect' amplifies temperature increases. Around 35000 deaths (many in S France) were attributed to the summer heat wave of 2003 (EEA 2004a). In some areas, people may migrate from urban centres to cooler rural areas. - Heat waves lower the quantity and quality of agricultural harvests, both of crops and animal fodder, with impacts on farming industries. The heat wave of 2003 led to reductions in crop yields of up to 30% in some areas of Europe (EEA 2007).
Sea level rising	Sea level rise is a global process, although regionally sea level rise can differ according to isostatic adjustment and rate of thermal expansion. Ultimately, however, all areas are expected to experience sea level rise, the rate of which will depend on the magnitude of climate change.	- Sea level rise and coastal erosion threatens housing, infrastructure, natural habitat and agricultural land. - Loss of housing, jobs, infrastructure etc may pressure services in surrounding peri-urban and rural areas. - One third of the EU population live within 50km of the coast (EEA 2007). Although not all will be directly affected by sea level rise, jobs and recreation opportunities may be lost, for example. - Considerable expenditure will be required to protect against sea level rise, diverting resources from public projects in other areas.
Wind speed patterns changing	The largest fall (by 10-15% by 2080s) is projected for the eastern Mediterranean (e.g. Italy and Greece). The largest increases (by around 10-15% by 2080s) is expected in the Baltic States and Scandinavia (IPCC 2007)	- Increased dispersal of pollutants may generate health benefits in northern European cities, but worsen problems in areas down-wind of major urban centres. - Negative impacts on agriculture could arise in areas down-wind of major pollution hotspots e.g. due to increased ozone levels. - Combination of lower wind speeds and higher temperatures over southern Europe would increase the threat of urban pollution incidents, with associated human health problems. - Increased wind speeds in northern Europe could encourage the development of wind energy instillations. The reliability of this form of renewable energy may decline in parts of southern Europe.
Snow cover decreasing	Temperature increases across the continent ensure that falls in snow depth will be universal, apart from the far north and high Alps (IPCC 2007).	- A 2°C increase in temperature will decrease the number of naturally reliable Alpine snow zones from 609 to 404 (EEA 2007), with negative impacts on skiing tourism in these areas. - Melt waters decline reduces flow rates in rivers impacting on water availability, hydro and nuclear power, recreation etc.

Table 6: Climate change impact trend and associated peri-urban land use relationships

Climate change futures

Climate change projections involve significant levels of uncertainty, and hence the scope of projected changes to variables such as temperature and sea level rise is broad. The use of scenarios can assist in the analysis of issues such as this where there is an inherent degree of uncertainty. Table 7 assesses each of the climate change trends expected to affect Europe against the four PLUREL scenarios. This demonstrates how, under different sets of global drivers, climate change impacts can vary considerably. In the context of the PLUREL project, the most important point to take from this is that it is not possible to predict precisely how climate change will affect peri-urban landscapes. What is certain is that change can be expected, and it will be necessary to build flexibility into policy and strategy frameworks to respond to the opportunities and challenges that climate change will bring.

Key issues arising from the assessment of climate change futures through the lens of each PLUREL scenario include:

A1b Hypertech
In this scenario economic growth, material consumption and technological progress are central to politics, economics and society. Environmental awareness is low, and government policy frameworks regulating issues relevant to climate change, such as land use development and greenhouse gas emissions, are weak. Peri-urbanisation and urban sprawl are widespread. Drivers such as these combine to raise energy use and hence emissions levels leading to an acceleration of climate change impacts. Technological progress and the development of a balanced energy supply portfolio (with some development of renewable energy) provides solutions to climate change challenges, but the lack of commitment to addressing the issue at all levels of society and rocketing energy demand leads to significant changes to the global climate system. Adaptation to climate change is limited, and many communities suffer from flooding and drought with increasing regularity. Natural habitats and ecosystems are also affected with environmental quality worsening in most areas.

A2 Extreme Water
Climate change impacts are most severe under this scenario. This is due to a combination of scenario drivers which include the dominance of fossil fuels in the energy supply mix, a lack of commitment to the development and implementation of climate change policies, regional patterns of governance which preclude coordinated cross boundary climate change responses, and rapid population growth (and associated increases in energy consumption). Few regions divert resources to adaptation responses leading to widespread negative impacts (particularly those relating to water) across the economy and society. Environmental quality also worsens considerably with impacts including desertification, forest fires, eutrophication of inland water bodies and loss of biodiversity.

B1 Peak oil
This scenario sees projected climate change at its most benign, and depends on rapid action at the global scale over the next decade to reduce emissions of greenhouse gases. Nevertheless, impacts are still significant with temperature rising to almost 2°C above 1990 levels and flooding, drought and heat waves becoming more commonplace. However, the difference with this scenario is that due to factors such as concerted global responses to climate change, greater spending on adaptation measures, and aggressive government policy in the spatial planning and energy arenas, societies are able to respond to all but the worst of the impacts that are experienced. Consequently, Europe's environment fairs better than under the other PLUREL scenarios, although negative

impacts (particularly in the Arctic and Mediterranean regions) are experienced. Also, it is impossible to predict how ecosystems will respond to even the more moderate changes in climate projected under this scenario. Positive feedback loops and the intensification of climate change impacts could happen even with temperature rises below 2°C.

B2 Fragmentation

Under this scenario, climate change is significant yet does not reach the extent of the impacts experienced under the A1b or A2 scenario. It is greater societal commitment to environmental sustainability that forms the framework around which climate change responses are organised. However, this takes place at a regional level and the lack of global consensus and action on emissions reduction lessens the effectiveness of mitigation measures. As some regions and countries are more prosperous and politically enlightened that others, the comprehensiveness and effectiveness of adaptation responses to impacts such as flooding and drought varies. Some communities are left much more vulnerable as their infrastructure, economies and social structures are less resilient in the face of a changing climate.

	PLUREL scenarios			
Issue and current trend	A1b hyper-tech	A2 extreme water	B1 peak oil	B2 fragmentation
Temperature increasing	IPCC best estimate: **2.8 °C** by 2090-2099 relative to 1980-1999. Steady increases, accelerating after 2050.	IPCC best estimate: **3.4 °C** by 2090-2099 relative to 1980-1999. Significant increases over northern Europe.	IPCC best estimate: **1.8 °C** by 2090-2099 relative to 1980-1999. 'Dangerous' climate change does not materialise.	IPCC best estimate: **2.4 °C** by 2090-2099 relative to 1980-1999. Moderate increases in southern Europe.
Precipitation patterns changing	Regional split is maintained – N Europe drier summers and wetter winters, S Europe drier all year round.	Intensification of regional and seasonal precipitation changes take place, with extremes of flood and drought.	Increases/decreases in rainfall are less acute, with the worst impacts managed by adaptation responses.	Precipitation patterns continue to change, although local adaptation responses manage impacts in some cases.
Flooding increasing	All forms of flooding – fluvial, pluvial and coastal – increase significantly. Flood risk management is limited.	Flooding becomes worse due to climate change, development pressure, and a lack of a policy response.	Spatial planning limits flood plain development. Investment made in flood defence and resilience measures.	Watershed scale responses are effective in reducing much flood risk. 'Favoured' locations receive most attention.
Drought increasing	Problems are to widespread and severe to mitigate in all cases. Southern Europe suffers most.	Population growth and climate change increase demand for water. Little resource or will to create adaptation responses.	Water-efficient technologies in households and agriculture. Impacts of climate change are less severe.	Successful regional responses reduce pressure on water resources. Some communities suffer e.g. migrants, rural poor
Heat waves increasing	City centres endure the worst of the impacts. Spending is targeted at high-tech responses in some locations.	Continental areas of southern Europe are worst hit by severe and frequent heat waves. Farming and tourism suffer.	The problem is less prominent and responses reduce negative impacts considerably although some remain evident	Heat waves continue to increase, but adaptation responses mitigate the most severe impacts.
Extreme weather events increasing	Extreme events related to heat, rainfall and storminess all increase in line with major changes in climate.	Lack of global climate change response see extreme events increasing. Adaptation outside wealthy cities is patchy.	Occurrence of extreme events increase, although strong international adaptation responses are developed.	Local responses to events increases resilience in some areas particularly where capital resource is available.
Sea level rising	IPCC estimate: **0.21-0.48m** by 2090-2099 relative to 1980-1999. Resulting impacts are experienced in many places.	IPCC estimate: **0.23-0.51m** by 2090-2099 relative to 1980-1999. Coastal flooding and erosion worsen considerably.	IPCC estimate: **0.18-0.38m** by 2090-2099 relative to 1980-1999. Impacts of sea level rise moderated by defences.	IPCC estimate: **0.20-0.43m** by 2090-2099 relative to 1980-1999. Defences mitigate some resulting impacts.
Wind speed patterns changing	Significant uncertainly exists over wind speed projections. Regional differences are expected in the future.	Changes in wind speed are more pronounced under more intense climate change scenarios.	Lower emissions scenarios produce less intense climate change and corresponding changes are moderated.	Broadly, parts of N Europe are projected to be windier, whilst some S European regions see lower wind speeds.
Snow cover decreasing	Further significant decreases across most of the continent, particularly the arctic north.	Many areas become almost entirely snow free by mid-century.	Loss of snow cover continues, although some mountain and northern latitude areas maintain significant cover.	Some alpine mountain tops and arctic regions maintain year-round snow cover. Significant loss in many areas.

Key		
	Acceleration of current trend	(dark green)
	Continuation of current trend	(light blue)
	Reversal of current trend	(red)

Table 7: 'Wind tunnelling' climate change trends through the PLUREL scenarios

Climate change: conclusion

The EU has stated that climate change must be kept to no more than 2°C above pre-industrial levels if 'dangerous' climate change is to be avoided. Deep cuts in emissions of greenhouse gases will be necessary if this is to be achieved, requiring huge social, economic and political changes. The scale of this challenge is evident when it is considered that globally, the contribution of renewable energy to the total energy mix is projected to grow by just 1% by 2030, with fossil fuels dominating for the foreseeable future and demand for energy rising across the world (EEA 2007). Moreover, greenhouse gases remain in the atmosphere for decades and their impact on the climate can take many years to occur. Consequently, there is considerable inertia in the climate system and further climate change can be expected even if emission reduction strategies are successful in the short term. Realisation of the inevitability of climate change impacts, which some scientists now believe are likely to be more rapid and severe than previously expected (EEA 2007), has increased attention to climate change adaptation (European Commission 2007).

Under each of the scenarios developed by PLUREL the majority of the current trends in the climate system will accelerate and intensify. Europe's environment will be profoundly effected by these changes, as will its peri-urban landscapes. The impacts of climate change in rural urban regions and their peri-urban areas fall into several separate yet interlinked categories. These relate to climate change mitigation and adaptation agendas and include biophysical impacts (e.g. loss of biodiversity, increase in forest fires, droughts and flooding), social/cultural impacts (e.g. impacts on human health and wellbeing, lifestyle changes), economic impacts (e.g. financial cost of flooding, development of new energy markets and technologies), and political impacts (e.g. development of new legislation and policies that then affect issues such as energy generation and urban form). The variation in climate change projections across Europe demonstrates that the nature and extent of peri-urban land use impacts will differ according to geographical location.

Due to the inertia in the global climate system, it is only in the longer term (by around the middle of the 21st Century) that the effect of choices made today will translate into changes in the extent of climate change impacts. Short term changes in temperature and precipitation may well be certain, but the way that societies respond to these impacts can have a significant effect on the extent to which these impacts affect societies and natural environments. Actions taken at the EU scale, and even right down to the level of local communities, can exert considerable influence over certain climate change impacts. It is now the responsibility of planners, stakeholders and decision makers to take action to ensure that Europe's peri-urban landscapes are prepared for climate change and are in a strong position to contribute to its mitigation.

Climate change: references

Bates, B.C., Z.W. Kundzewicz, S. Wu and J.P. Palutikof, Eds., (2008) Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change, IPCC Secretariat, Geneva.

European Commission (2007) Adapting to Climate Change in Europe: Options for EU Action, European Commission, Brussels.

European Environment Agency (EEA) (2004) Air pollution and climate change policies in Europe: exploring linkages and the added value of an integrated approach, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2004a) EEA Signals 2004: A European Environment Agency update on selected issues, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2005) European environment outlook, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2005a) Vulnerability and adaptation to climate change in Europe, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2005b) The European Environment State and Outlook 2005, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2006) Air quality and ancillary benefits of climate change policies, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2006a) Progress towards halting the loss of biodiversity by 2010, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2007) Europe's environment: the fourth assessment, European Environment Agency, Copenhagen.

European Environment Agency (EEA) (2007a) Greenhouse gas emission trends and projections in Europe 2007, European Environment Agency, Copenhagen.

Eisenreich, S.J, (coordinating author) (2005) *Climate and the European Water Dimension*. European Commission — Joint Research Centre, Ispra.

Giorgi, F.; Bi, X.; Pal, J., 2004. Mean, interannual variability and trends in a regional climate change experiment over Europe. II: climate change scenarios (2071–2100). *Climate Dynamics*, 23, 839–858.

Giorgi, F.; Bi, X.; Pal, J., 2004b. Mean, interannual variability and trends in a regional climate change experiment over Europe. I. Present-day climate (1961–1990). *Climate Dynamics*, 22, 733–756.

Gossling, S and Hall, C (2006) Uncertainties of predicting tourist flows under climate change scenarios, Climatic Change 79: 163-173.

Intergovernmental Panel on Climate Change (IPPC) (2007) Climate Change 2007: Synthesis Report, IPCC, Geneva.

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis, Island Press, Washington DC, USA.

Thuiller W, Lavorel S., Araújo M B., Sykes M. and I. C Prentice (2005). Climate change threats to plant diversity in Europe (2005). Proceedings of the National Academy of Sciences of the United States of America. June 7, 2005 , vol. 102, no. 23, pp 8245–8250.

Schmidt-Thome, P. ed (2006) The spatial effects and management of natural and technological hazards in Europe, ESPON Monitoring Committee, Luxembourg.

Schröter, D., L. Acosta-Michlik, A.W. Arnell, M.B. Araújo, F. Badeck, M. Bakker, A. Bondeau, H. Bugmann, T. Carter, A.C. de la Vega-Leinert, M. Erhard, G.Z. Espiñeira, F. Ewert, U. Fritsch, P. Friedlingstein, M. Glendining, C.A. Gracia, T. Hickler, J. House, M. Hulme, S. Kankaanpää, R.J.T Klein, B Krukenberg, S. Lavorel, R. Leemans, M. Lindner, J. Liski, M.J. Metzger, J. Meyer, T. Mitchell, F. Mohren, P. Morales, J.M. Moreno, I. Reginster, P. Reidsma, M. Rounsevell, E. Pla, J. Pluimers, I.C. Prentice, A. Pussinen, A. Sánchez, S. Sabaté, S. Sitch, B. Smith, J. Smith, P. Smith, M.T. Sykes, K. Thonicke, W. Thuiller, G. Tuck, G. van der Werf, J. Vayreda, M. Wattenbach, D.W. Wilson, F.I. Woodward, S. Zaehle, B. Zierl, S. Zudin, andW. Cramer, 2004: *ATEAM Final Report*. Potsdam
Institute for Climate Impact Research (PIK),Potsdam, Germany, 139 pp.

UNEP (2004) Impacts of summer 2003 heat wave in Europe, UNEP, Geneva.

UNESCO (2003) Water for People, Water for Life - Executive Summary, UNESCO Division of Water Sciences, Paris.

4. Energy – trends, projections and impacts

Introduction and context

The generation and distribution of energy is central to society. Currently energy supply is fossil fuel focused, a situation that brings with it huge challenges and opportunities. Challenges relate to the numerous impacts of the mining and burning of fossil fuels including climate change, pollution of air, land and water, and habitat loss. Further, abundant fossil fuels have enabled societies to evolve patterns of habitation, leisure and commerce that generate significant land use and environmental impacts. However, acknowledgement of the problems associated with fossil fuel use presents real opportunities also. Policy makers, businesses and society must develop ways of capturing and utilising more ‘sustainable’ and renewable sources of energy. Essentially, this entails moving towards a low carbon economy.

Drivers behind the need to move towards a low carbon economy in Europe are numerous and wide-ranging. These forces are set to reshape the energy sector across the continent with significant impacts on the environment and peri-urban landscapes.

Climate change
Addressing climate change is now one of the EU’s central policy goals, as established by the Gothenburg Agenda. In Europe, the use and supply of energy (electricity generation, households, industry etc) accounted for 59% of Europe’s greenhouse gas emissions in 2005 (EEA 2007). Along with transport, the energy sector is the key driver of climate change on the continent. Climate change legislation and policy at national and supranational levels will impact on the energy sector as policy makers attempt to control emissions. This is already taking place through initiatives such as the EU Emissions Trading Scheme and Kyoto targets.

Increasing import dependency
Energy security is becoming an increasingly prominent issue on policy making agendas. Indigenous energy production in the EU 25 is projected to decline by around 25% from 2000 to 2030, principally as a result of falls in hydrocarbons, solid fuels and nuclear (EC 2006). By 2030, it is projected that 70% of Europe’s energy needs will be imported, in comparison to 50% in 2006 (EEA 2006). By 2030, over 90% of oil and 85% of natural gas consumed within the EU is expected to be supplied by Russia (EEA 2007). Efforts to reduce import dependency and increase energy security can be expected, permanently changing the energy landscape.

Availability of fossil fuels
Whilst demand for fossil fuels is projected to continue to escalate, it is possible that supply will increasingly struggle to meet demand. With rising demand from rapidly developing nations such as China and India, this is particularly the case for oil where global demand is at present approximately equal to available supply, at roughly 84 million barrels per day. If demand for oil increases further, which it is expected to do (IEA 2007), competition for the resource will increase with price rises likely. As the European Commission (EC 2006) has noted, the era of cheap energy resources is coming to an end. This provides a greater incentive for EU member states to exploit indigenous renewable sources of energy in order to secure supplies, which would bring with it significant environmental and land use impacts.

Rising EU energy demand
Within OECD Europe, it is believed that energy consumption will increase by 16% between 2004 and 2030 (EEA 2007). This is due not to population growth, which is likely to remain relatively stable in the long term, but as a result of other demographic changes such as the decline in average household size and associated increases in the number of households. Indeed, across the EU 25, number of households is predicted to increase from 185 million in 2000 to 227 million in 2030 (EC 2003), with energy use per capita therefore increasing. Set within a policy arena targeting climate change and energy security as key issues, growth in energy demand will increase pressure for change within the energy sector in an attempt to decouple energy demand from economic growth.

The energy sector in Europe is currently in a state of flux. Several key drivers are currently converging to fundamentally change the arena within with energy policy is created and implemented. This is already impacting on energy infrastructure ‘on the ground,’ with increased use of renewable technologies, and further evolution of the energy landscape is on the horizon. The generation, supply and use of energy bring major environmental impacts. Changes to the sector will impact on environmental quality, positively and negatively. Peri-urban landscapes will also be affected. However, the nature of these changes will depend on the future evolution of global scale drivers of change such as those discussed above. The following discussion expands on these issues with several key topics addressed. These include:

- A summary of key environmental impacts associated with the energy sector.
- Assessment of trends and projections that characterize the energy sector, and an analysis of how these issues impact on environmental quality.
- Investigation of the relationship between energy trends and projections, environmental quality and peri-urban land use.
- Application of the PLUREL scenario framework to the analysis of the energy sector in Europe.

Summary of the relationship between energy and environmental quality

One of the most significant effects of the energy sector on environmental quality concerns its contribution to climate change and associated impacts. The environmental impacts of climate change are considered in greater detail within a separate chapter of this report. The following summary focuses on additional impacts of the energy/environment nexus. Four key elements of environmental quality (air, biodiversity, soil and water) are discussed in turn, impacts on which stem from the generation, distribution and use of energy. However, it is important to note that synergies and feedback loops exist between different environmental resources. For example, reduction in soil quality due to acid deposition can threaten soil structure (for example through loss of plant growth) with knock-on effects for water quality as soils become more susceptible to erosion and leaching of nutrients. Impacts such as this extend far beyond environmental quality, and can have severe social and economic repercussions.

Air quality

EU legislation and regulation aimed at the energy sector has led to marked improvements in air quality over recent decades (cross reference to air quality baseline profile). Nevertheless, significant problems remain with the burning of fossil fuels during energy generation contributing to a number of these issues. Aside from greenhouse gases, it is the release of particulates, toxic chemicals, ozone, nitrogen oxides and sulphur dioxide that is most harmful to the environment. These pollutants (particularly nitrogen oxides and sulphur dioxide) contribute to the two damaging processes of acidification and eutrophication. Ozone can damage plant growth. Air pollutants do not respect international boundaries, and the associated environmental impacts are often trans-national in nature.

Biodiversity
Through its contribution to the eutrophication and acidification of soil and water, the energy sector has considerable negative impacts on terrestrial and aquatic biodiversity. This can lead to species loss and in extreme cases, habitat loss. For example, eutrophication can generate algal blooms in lakes and coastal waters, and the acidification of soils can harm tree growth and associated biodiversity. Also, ozone damages plant growth through harming foliage and seed production. Aside from natural ecosystems, this may also impact negatively on agricultural crops. Toxic chemicals, including cadmium, lead and heavy metals can accumulate in the food chain, and some of these substances may act as endocrine disrupters in fish populations for example. Aside from fossil fuels, other forms of energy, for example biofuels and hydropower can have significant negative impacts on biodiversity.

Soil
The energy sector, particularly the burning of fossil fuels, contributes directly and indirectly to different elements of soil degradation, including erosion and contamination. Impacts on soil processes can be insidious and cumulative leading to a gradual yet sustained loss of soil function and associated ecosystem stability. The release of pollutants during the burning of fossil fuels can lead to soil contamination through acidification and pollution by heavy metals. As soil function deteriorates, it becomes less able to perform its valuable services such as absorbing pollutants and retaining moisture. Loss of soil function and structure can lead to erosion with knock-on impacts to water quality and biodiversity. As soil is effectively a non-renewable resource over human lifetimes, these impacts can have huge repercussions for the natural environment and beyond to sectors including agriculture.

Water
The impacts of the energy sector on water quality relate particularly to the emission and subsequent deposition of air pollutants, which can lead to acidification and eutrophication. These processes impact on aquatic biodiversity and can also reduce the amenity value of water bodies. Some energy generation technologies (e.g. nuclear and coal fired power stations) also demand huge volumes of water for cooling purposes. The abstraction and subsequent release of water (often at a higher temperature) can affect river flows and associated aquatic biodiversity. The mining and distribution of fossil fuels also has negative consequences for water, including runoff from mining sites and oil spills. Renewable sources of energy, principally hydropower and tidal power, can impact negatively on the water environment, for example through the alteration of flow regimes and the disruption of tidal patterns.

There now follows (see Table 8) an overview of some of the most significant issues impacting on the energy sector in Europe. Trends and projections relating to these issues are summarised, with the environmental impacts associated with a continuation of these trends highlighted. This provides a platform to explore the relationship between the energy sector, environmental quality and peri-urban land use.

Energy trends and projections: impacts on environmental quality

The energy sector is experiencing significant changes due to forces including rising global energy demand, oil production reaching a plateau in recent years, and increases in climate change related legislation. A range of trends are becoming more visible that relate to this emerging energy future and the continuation of established patterns within the sector. Each of these trends has related environmental impacts, some positive and others negative. These are explored in Table 8 below. Key issues can be summarised as:

- ***Total energy consumption*** is rising over Europe, and is expected to continue to do so for the foreseeable future. Environmental impacts depend on the nature of the fuel used to generate the energy.
- ***Energy intensity***, that is the use of energy in comparison to another factor (e.g. GDP), is falling. Effectively, energy efficiency is increasing, particularly in the industrial and service sectors.
- ***Fossil fuels*** remain the dominant energy source in Europe. The fossil fuel mix has changed in recent years, and will continue to do so in the future.
- ***Consumption of solid fuel*** has decreased, a trend that is projected to continue into the future. As coal burning is particularly environmentally damaging, benefits to air and water quality, for example, can be expected.
- ***Natural gas usage*** has increased considerably over the past two decades. Environmental impacts are less than those associated with other fossil fuels.
- ***Consumption of oil***, the largest provider of energy in Europe, has increased slightly over recent years. Its share of total energy consumed is projected to fall, yet still remain significant.
- ***Nuclear energy*** has increased over Europe, but its share of the fuel mix is projected to decline in the future as power stations are decommissioned.
- ***Renewable energy generation*** has increase, although its share of total energy generated remains low. Projections indicate that renewables will become more significant in the future.
- ***Electricity usage*** has increased significantly, and is expected to grow at a steady rate with demand particularly high in the service sector. Related environmental impacts are dependant on the fuel source.
- ***Electricity generation fuel mix*** has changed in recent years, with coal and oil loosing out to natural gas, which is a ‘cleaner’ fuel in environmental terms. Increases in renewable electricity generation are projected.

ENERGY		
Issue	***Trends and projections***	***Impacts on environmental quality (air, biodiversity, soil, water)***
Total energy consumption	Between 1990-2003, total energy consumption in the EU 25 rose annually by 0.8%. From 1999-2003 this figure was higher at 1.3% (EEA 2006). Annual growth of around 0.6% from 2000-2030 is expected across the EU 25 (EEA 2005). In OECD Europe, total energy consumption is projected to rise by 10% by 2015 and 16% by 2030 (from a 2004 baseline) (EEA 2007). Increases in energy consumption are therefore higher in the short term. Post 2020, lower economic and population growth, and greater efficiency measures help to stabilize consumption (EC 2006), although increases in energy demand nevertheless continue to 2030 and beyond (EEA 2005).	The environmental impacts associated with growing energy consumption depend on the source of fuel used to provide that energy. The current dominance of fossil fuels in energy generation is projected to continue. As fossil fuel use has significant negative environmental impacts, it is likely that environmental quality will suffer as a result. Potential impacts, which are discussed in greater detail below, include climate change and associated impacts on environmental quality, acidification of soils, and air pollution (particularly in urban areas).
Energy intensity	Energy intensity fell by 15% from 1990-2003, or 1.2% annually. Transport and households showed limited declines compared to industry and service sectors (EEA 2006). From 2000-2030, EU GDP is expected to double, with energy consumption increasing by 20% (EEA 2005). Factors behind this projected fall in energy intensity include higher energy transformation efficiency due to replacement of coal with gas fired power stations, more efficient electricity generation, greater use of combined heat and power, increased prominence of the service sector, and decline of energy intensive industries (EC 2006). However, increased demand for electricity and greater material consumption will offset some of these gains.	Falling energy intensity means that less energy is used per unit of another measure (e.g. GDP, population). Essentially, energy is being used more efficiently, which on the surface should have environmental benefits. This does not mean, however, that less energy in absolute terms is used or that fuel sources become less environmentally harmful. Nevertheless, if energy intensity continues to fall, the environmental impacts associated with projected increases energy consumption will be moderated to a certain extent, although they may still increase.
Fossil fuel consumption (overall)	Fossil fuels are the dominant source of energy consumed, and are set to remain in this position for the foreseeable future. In the EU, their share of total energy consumption has remained fairly constant since 1990 at around 80% (EEA 2006). The mix of fossil fuels has nevertheless changed and will continue to evolve, as discussed below.	Impacts on environmental quality associated with change in the fossil fuel mix are described below. Moving forwards, increased consumption of natural gas at the expense of coal and oil could have some environmental benefits compared to the current situation, although absolute volumes of pollutants may still rise.
Fossil fuel consumption (solid fuel)	Annually, coal consumption decreased by 2.4% from 1990-2003 in the EU 25. Coal accounted for 18.2% of energy consumed in 2003. However, from 1999-2003, annual consumption increased by 1.3% due to rising gas prices energy supply security worries (EEA 2006). In the EU 25, the share of total energy consumption provided by solid fuels (coal and lignite) is projected to fall to 15.5% by 2030 (EC 2006).	Coal mining, particularly strip mining, has negative landscape and environmental impacts including soil degradation and water pollution. Coal burning releases oxides of sulphur and nitrogen which can acidify soils and water bodies, and also mercury which is a harmful bio-toxin. Large amounts of green house gases are also emitted.
Fossil fuel consumption (natural gas)	In the EU 25, annual consumption increases of 3.5% were experienced from 1990-2003 (EEA 2006). From 1992-2004, consumption increased by 54% in WCE, although declines of 5% were seen in parts of eastern Europe due to economic decline (EEA 2007). In 2003, gas provided 23.6% of energy consumed in the EU 25 (EEA 2006), and is use particularly for power generation. The share of gas in total energy consumption is projected to grow from 22.8% in 2000 to 27.3% in 2030 (EC 2006). Gas for heating purposes rises by 28% during this period (EC 2006).	The increasing importance of natural gas over fuels including coal and lignite has some environmental benefits. Gas is the cleanest of fossil fuels having 40% less carbon content than coal and 25% less than oil, and contains low levels of sulphur (EEA 2007) and lower levels of particulates. Nevertheless, natural gas has its own negative impacts, principally its contribution to climate change (via carbon dioxide and methane) and the release of pollutants.
Fossil fuel consumption (oil)	In the EU 25, oil is the largest provider of total energy consumed at 37.4% in 2003 (EEA 2006). Relatively small annual increases in consumption of 0.6% were	Oil exploration and production (extraction, refining and transportation) has significant impacts, e.g. pollution from spillages, habitat

	seen between 1990-2003 (EU 25) (EEA 2006). Since the late 1990s, oil consumption has been rising across the EU. Nevertheless, oil's share of total energy consumption in the EU 25 is projected to fall from in 38.4% 2000 to 33.8% in 2030 (EC 2006).	loss/fragmentation. Burning oil releases pollutants impacting environmental quality and contributing to climate change. Also, the activities that oil facilitates e.g. car use and suburbanisation, fertilization of soils, have profound environmental impacts.
Nuclear energy consumption	In 2003, 14.6% of energy consumed in the EU 25 came from nuclear fuel. Energy consumption from nuclear grew by 1.8% annually from 1990-2003 (EU 25) (EEA 2006). Across the EU, consumption of nuclear fuel increased by 22% between 1992-2004 (EEA 2007). In the EU 25, nuclear's share of total energy consumption is projected to fall from 14.4% in 2000 to 11.1% in 2030 (EC 2006). However, recent interest in nuclear energy has grown due to climate change and energy security fears.	Environmental benefits of nuclear over fossil fuel centre on its lack of direct emissions of pollutants and greenhouse gases. However, unresolved issues concerning radioactive waste, routine emissions of radioactive substances (to air and water), the use of significant amounts of cooling water, and the impacts of uranium extraction, mean that nuclear is far from environmentally benign.
Renewable energy generation (overall)	Currently renewable generation in Europe is dominated by hydro and biomass. EU renewable energy generation increased by 11% between 1999-2004 (EEA 2007). However, increase in energy consumption slowed growth in renewables share in absolute terms, from 4.4% to 6% between 1990-2003 in the EU 25 (EEA 2006). This figure is projected to hit 12.2% by 2030 (EC 2006). Renewables share of power generation is predicted to grow from 18% in 2010 to 28% by 2030 (EC 2006). Wind energy is key to growth with 20x increase in capacity projected from 2000-2030. Biomass also sees significant growth (EC 2006). In 2003, biomass accounted for 4% of energy consumption. Due to agricultural liberalization and productivity increases, 'environmentally compatible' biomass could provide 15-16% of EU 25 primary energy requirements by 2030 (EEA 2006a).	Renewable energy generation avoids the environmental and climate change impacts associated with fossil fuel burning. However, there is 'embedded' fossil fuel energy within renewables infrastructure, e.g steel for wind turbines, copper for solar cells. Land use and landscape impacts issues are also raised, e.g. by wind turbines. Increasingly, it is acknowledged that some biomass and biofuels pressures biodiversity, water and soil resources (Scharlemann and Laurance 2008). However, biomass can make a positive contribution to renewables targets even with strict environmental controls in place (EEA 2006a). Large scale hydro generation has environmental impacts including habitat loss and sedimentation of water courses.
Electricity usage	Electricity's share in final energy consumption grew from 17.4% to 20% between 1990 and 2002, at 1.9% annually in absolute terms (EEA 2006). Electricity consumption per capita is projected to increase by 38% in OECD Europe between 2004 and 2030 (EEA 2007). Across the EU 25, demand for electricity increases by 58% between 2000 and 2030 (EC 2006) with large increases in use in the service sector.	Environmental impacts associated with energy generation depend significantly on the fuel source. Fossil fuels account for around 55% of electricity generation in 2003 (EEA 2006). Nuclear is also an important element of the mix. Electricity transmission also has land use and landscape impacts.
Electricity generation (changing fuel mix)	From 1990-2003, the mix of fuels used to generate electricity changed in the EU 25 (EEA 2006). Most significantly there has been a reduction in use of coal (37% to 31% of generating capacity) and an increased use of natural gas (8% to 19%). Oil's role has also lessened (9% to 6%). Nuclear fuel is important for electricity generation making up 31% of capacity in 2003, as it did in 1990. Renewables share of total generating capacity has been steady at around 13% (EEA 2006), although by 2010, this could rise to 21% for the EU 25 (Eurostat). Looking forwards, high oil and gas prices and concern over security of energy supply underlie projections of growth in coal fired electricity generation (EEA 2007).	Electricity generation is currently an energy inefficient and environmentally harmful process. Between 2.5 and 3 units of fossil fuels are required to produce one unit of electricity (EEA 2007). Looking forwards, electricity generation will become marginally less fossil fuel intensive, with environmental quality benefits, although increasing demand may effectively negate these improvements. Related issues including climate change forcing, acidification of water and soil, and air quality problems will therefore continue, with associated loss of biodiversity.

Table 8: Energy trends and related environmental impacts

Energy, environmental quality and peri-urban land use: exploring the linkages

Trends in the energy sector and their associated environmental effects impact directly on the core PLUREL agenda; namely peri-urban land use relationships. Table 9 demonstrates how land use may change in the future as trends in the energy sector continue to evolve. The dominance of fossil fuels has clear environmental impacts that affect peri-urban areas, for example in terms of air quality and the appearance of water courses. Further, renewable and non-renewable energy generation infrastructure affects peri-urban landscapes in a visible way. As energy is central to many aspects of society, its relationship to peri-urban areas is often more subtle. For example, cheap oil has supported sprawling patterns of development, the associated dominance of the car culture, and global logistics operations. These factors have profoundly affected the shape of peri-urban areas, and it is clear that energy will remain central to the form and function of these landscapes.

It is possible to highlight several cross cutting issues affecting the relationship between energy, environment and peri-urban areas.

- **Legislation and policy:** Legislation relating to topics including climate change mitigation, transport, and agriculture all affect activity in the energy sector. Related targets, for example concerning the proportion of energy to be generated by renewable sources and the increased use of biofuels, have direct impacts on the nature of energy generation options and energy usage. In addition, subsidy payments continue to impact on the energy sector and contribute greatly to the continued dominance of fossil fuels over renewable energy sources. In a policy environment where issues such as climate change and energy security are central concerns, these agendas could change with significant impacts on peri-urban environments and landscapes.
- ***Climate change mitigation:*** Climate change policy has particularly significant links to energy and peri-urban areas. Policies to reduce greenhouse gas emissions will impact directly on peri-urban landscapes. Aside from the growth of renewable technologies, initiatives such as the development of carbon markets in response to the climate change challenge could lead to an evolution in energy markets. This will increasingly influence activities of energy companies, for example by increasing the incentive to develop cleaner and more efficient electricity generation technologies. Peri-urban areas may well see more infrastructure related to low carbon economies, for example energy from waste plants, biomass crops, wind turbines etc. Mitigation policy will also target the users of energy in an effort to increase efficiency and reduce demand. Urban form and transport are likely to be key targets for policy efforts, with significant knock-on effects for peri-urban areas.
- **Sectoral changes in energy demand:** In the EU 25, increases in energy demand are projected to be highest in the services sector (growth of 49% between 2000-2030). During this period, household energy demand is projected to rise by 29%, with the fastest growth in the new EU 10. Similarly, transport energy demand rises by 21%, but with growth gradually slowing due to vehicle efficiency improvements (EC 2006). If the EU is to meet stated policy goals, for example regarding greenhouse gas emissions reduction, steps will need to be taken to either curtail growth in energy demand in these sectors, or to develop ‘cleaner’ energy supplies to fuel their activities. In both cases, associated peri-urban impacts can be expected, for example relating to public transport, housing provision and location of new office and retail space.

Changes in the energy sector in the future will play out differently across the EU. Consequently, consistent patterns of change in peri-urban form are unlikely. A range of factors will dictate the nature of changes in peri-urban landscapes. For example, some member states are likely to fare worse than others in a future of declining indigenous energy production. Ireland, Spain, Italy and Portugal rely on imports for over 80% of their energy needs, whilst Norway, Denmark, UK and Poland either have energy surpluses or rely on imports for less than 20% of energy needs (data from Eurostat). Policy makers in these different countries will be faced by different sets of challenges which will express themselves in variations in energy options and patterns of peri-urban development. For example, high net energy importers may be more strongly motivated to promote renewable energy. Indeed, Spain has invested heavily in renewable energy, particularly wind, which may be a result of their low levels of indigenous fossil fuel energy supplies. Other regional differences that are significant in this respect include political motivation, availability of capital investment to reshape energy infrastructure, and public support for 'green' taxation.

With these issues in mind, Table 9 offers further insights into these peri-urban land use relationships. The list is by no means exhaustive due to the extent of the related synergies, although it does highlight the close connection between energy, environment and peri-urban land use. Where relevant, environmental hotspots that are at higher risk of experiencing certain peri-urban land use impacts are identified.

ENERGY		
Trend	***'Hotspots'***	***Peri-urban land use impacts associated with a continuation of the trend***
Increasing total energy consumption	Highest gross final energy consumption in Germany, France, UK and Italy. Lowest levels in Malta, Cyprus and the Baltic States (Eurostat). Highest per capita levels in Luxembourg, Finland, Sweden and Belgium. Lowest in Latvia, Malta, Poland and Lithuania (EEA 2006).	- Increases in energy consumption will mirror greater activity in sectors such as transport, services and households. Related impacts include urban sprawl, change in employment patterns and greater demand for water. - More energy generation and transmission infrastructure will be needed, with land use and landscape impacts. - If this consumption is fuelled by fossil fuels, peri-urban environments and landscapes may decline in quality.
Falling energy intensity	Investment in infrastructure and technology to increase energy efficiency is expensive. Before costs reduce or technology is transferred, economically stronger nations will see larger reductions in energy intensity.	- Although energy intensity is falling, in absolute terms, it is projected that more energy will nevertheless be used. - Increasing energy efficiency has the potential to reduce, but not eliminate, impacts of rising energy consumption. - Investment in infrastructure and technology to reduce energy intensity may have positive socio-economic change.
Continued dominance of fossil fuels	Different fossil fuels predominate in different EU nations.	- Peri urban land use impacts associated with fossil fuels vary according to fossil fuel type and intensity of use. Common impacts include air pollution and associated human health problems, and landscape disruption. The energy sector is a provider of wealth and employment.
Falling share of solid fuel in the energy mix	Germany, Poland and UK consume largest amounts of solid fuel. Croatia, Latvia and Norway consume small amounts (Eurostat).	- Significant amounts of solid fuels are burnt in Europe. - Coal burning releases mercury, which is linked to health impacts such as learning difficulties in children. - Although much coal is now scrubbed prior to burning, particulates are released leading to respiratory illness. - Decline of mining activities can bring socio-economic problems and disruption of communities.
Growing share of natural gas in the energy mix	UK, Germany, Italy and France use the largest amounts of gas. Estonia, Sweden and Slovenia use the least. (Eurostat)	- Emissions contribute to the creation of ground level ozone linking to respiratory illness e.g. childhood asthma. - Fine particulates are released, which can be the most damaging to health as they penetrate deep into the lungs. - Increased gas use, much from outside the EU, raises

		issues of security of supply and potential supply disruption.
Falling share of oil in the energy mix	France, Germany, Italy and UK use the largest amounts of oil. Malta, Iceland and the Baltic States use the least (Eurostat).	- Oil remains heavily used, particularly for heating and transportation, with resulting air quality and health impacts. - As oil becomes scarcer whilst global demand increases, resulting price increases could threaten numerous activities including commuting patterns, logistics and tourism.
Falling share of nuclear in the energy mix	France, Germany, UK and Sweden produce the most energy from nuclear fuel. Many EU countries either produce no or very little nuclear energy (Eurostat).	- Some communities rely on power stations for employment, particularly as they are often in remote areas. - New power stations provide socio-economic opportunities arise, but bring negative effects on landscapes. - Power stations require large amounts of cooling water, potentially diverting it from other uses during droughts.
Growing share of renewables in the energy mix	See Table 10 for details of national patterns concerning renewable energy generation mix.	- Impacts depend on the type of renewable energy source. - Significant employment benefits are likely. In 2004, 157000 people were employed in the German renewables sector, potentially rising to 300000 by 2020 (BMU 2006). - Wind turbines may negatively impact landscape and recreation/tourism potential in some areas. - Biofuels production will impact agricultural markets and landscapes, with potential socio-economic effects.
Increase in electricity consumption	From 1990-2003, negative growth was experienced in some Baltic states. Especially strong growth in countries including Cyprus, Ireland and Portugal (EEA 2006).	- Growth in generation and transmission infrastructure will be necessary, bringing potential socio-economic benefit at the expenses of loss of landscape character. - Increased electricity consumption reflects greater activity in the service and household sectors.
Change in electricity generation fuel mix	In 2006, Germany, France, UK and Italy generate the largest amounts of electricity. Malta, Luxembourg, Cyprus and Latvia generated the least (Eurostat). Table 11 provides data on patterns concerning the electricity generation fuel mix.	- Impacts depend on the fuel used to generate electricity. Peri urban land use impacts associated with the use of different fuels are discussed above. - As demand for electricity increases, pressure will be put on land use to provide for different generation options, whether the energy comes from nuclear, renewables etc. - Increased electricity demand is associated with growth of infrastructure and spread of the built environment, which will impact on peri-urban landscapes.

Table 9: Energy trends and associated peri-urban land use relationships

Renewable energy sources	
	Patterns and projections across EU 25 nations and regions
Overall	In 2005, countries generating over 20% of energy from renewables included Austria, Finland, Latvia, Norway and Sweden. Ireland, Netherlands and UK were amongst those generating less than 4% in this way (Eurostat). Slowest growth (from 4% to 7% of total energy consumption) is projected for transition countries from 2004-2030 (EEA 2007).
Regional patterns	Hydropower and biomass fuelled a 31% increase in renewable energy generation in SEE (1992-2004). Wind and biomass accounted largely for a 39% increase in WCE (EEA 2007).
Combined heat and power	In 2002, Denmark produced close to 50% of electricity via combined heat and power. Finland and Latvia produced over 30%. Most EU countries produced less than 10% e.g. Spain 8%, UK 5% (EEA 2006).
Biomass	Seven member states, which include Germany, France, UK, Poland, Italy, Lithuania and Spain account for 85% of biomass energy potential (EEA 2006a). In the short term the waste sector has greatest potential to produce biomass energy, and agriculture the most long term potential (EEA 2006a). Currently, Finland and Sweden are world leaders in biomass use.
Wind	In 2006, Germany and Spain generated 65% of the EU 25's electricity energy generated by wind.
Hydro	Norway, Sweden and France led the way in terms of electricity generated from hydro

	plants (Eurostat).

Table 10: Renewable energy in Europe – spatial patterns and projections.

Electricity generation fuel mix	
	Patterns and projections EU 25 nations and regions
Coal	UK, Germany, Poland and Spain produce the largest amounts of electricity from coal fired power stations. Countries including Greece, Latvia and Sweden produce no electricity in this way (Eurostat).
Oil	Italy and Spain account for over 50% of electricity produced from oil fired power stations. Nordic countries and Baltic states generate relatively low amounts of electricity in this way (Eurostat).
Gas	Italy, UK ,Spain and Turkey generate the largest amounts of electricity from gas fired power stations. Cyprus, Malta and Switzerland have no gas fired power stations. Of those countries that do, Norway, Sweden and Slovenia produce the least electricity in this way (Eurostat).
Nuclear	France, Germany, UK and Sweden produce the most electricity from nuclear power. Many nations produce no electricity in this way.
Renewables	In 2005, countries generating over 40% of electricity from renewables included Austria, Latvia, Norway and Sweden. Belgium, Hungary and UK were amongst those generating less than 5% in this way (Eurostat). By 2010, the share of electricity generated from renewables is projected to be highest in Austria, Sweden and Latvia, and lowest in Hungary, Malta and Estonia.

Table 11: Energy generation fuel mix – spatial patterns and projections.

Energy futures

It is very unlikely that many of the current trends in the energy sector will remain static in the future. Change is certain, although it is difficult to predict precisely how the future will unfold for the energy sector. The PLUREL scenarios provide a means of exploring different possible futures, and can help to generate thinking on the impact of key global drivers of change on energy issues. Table 12 provides an insight into how different sets of global driving forces (as reflected in the PLUREL scenarios) may impact on energy issues and specifically the significant trends currently shaping the sector. These changes will have huge consequences across a wide spectrum of social, economic and environmental issues. Under each scenario peri-urban landscapes will be affected, whether this is through the increased prevalence of wind turbines and biomass forestry or the reinvigoration of previously derelict coal mines. There follows are more detailed discussion of the impact of each of the PLUREL scenarios on the energy sector. The point of this exercise is to demonstrate that if trends in the energy sector change direction, for reasons such as technological progress or political change, that Europe's environment and peri-urban areas will change also.

A1 Hypertech
Rapid economic growth, technological progress, increases in material consumption and trends towards peri-urbanisation all require significant amounts of energy. Demand for energy increases at the fastest rate under this PLUREL scenario. Although energy intensity falls as a result of technological progress and resulting efficiency gains, relentless increases in demand lead to a significant jump in overall energy consumption. This is met through a combination of fossil fuels and renewable sources, although due to lower costs, entrenched interests and weak environmental policy it is fossil fuels that dominate the energy supply mix. Nuclear plays an increasingly important role stimulated by increased research and investment. Europe's environment experiences many negative impacts as a result of the high use of fossil fuels and associated climatic change.

A2 Extreme Water
Although population growth and economic growth are relatively high under this scenario, the lack of a global network of business and cultural exchange limits energy demand to a certain degree. Nevertheless, energy usage rises significantly over the coming decades. Scenario drivers including limited technological progress in the energy sector, government inaction on issues including climate change, low price of fossil fuels (especially coal) and little investment in renewables combine to lock societies into a future of high energy use fuelled by the fossil fuel sector. Climate change impacts also increase energy usage. For example, air conditioning becomes more common in cities which overheat during the summer months, and energy intensive desalination plants are increasingly used to make up for water shortages. Under such a scenario, many of the costs associated with this approach to the sourcing and consumption of energy are borne by the natural environment.

B1 Peak Oil
Energy issues are at the heart of the 'shock' experienced within this scenario where oil prices increase rapidly and remain high. It is high oil prices and the systemic changes that this forces on economics, politics and society that usher in a new energy era. Equally important in stimulating this change are scenario drivers including high environmental responsiveness and awareness, low rates of peri-urbanisation and urban sprawl, low population growth and supportive government policy and business practices. The net effect of these changes involves a shift from fossil fuels to renewables, and a simultaneous decoupling of economic growth from energy use via energy demand reduction and efficiency gains. Although energy usage continues to grow, the source of this energy changes. This has knock-on benefits for Europe's environment stemming from a lessening of the threat of climate change and the use of less 'dirty' fuel.

B2 Fragmentation
Key drivers of change operating within this scenario include the emergence of strong regional and local governance structures, increased environmental awareness, and greater public sector involvement in decision making. These factors lead to significant changes in the energy sector with the dominance of large scale fossil fuel energy generation infrastructure challenged by smaller local renewable technologies. Community based generation schemes including energy from waste sites, small scale coppice and biomass generation and micro solar and wind installations become more common. This scenario also includes an element of social division and fragmentation. Regions with stronger governance structures and more resources are better able to implement progressive energy policies. In regions where these frameworks are not in place, communities are reliant on fossils fuels which become increasingly expensive as supplies dwindle and carbon taxes raise prices.

	PLUREL scenarios			
Issue and current trend	A1b hyper-tech	A2 extreme water	B1 peak oil	B2 fragmentation
Total energy consumption increasing	Economic and population growth, low energy prices and high consumption fuel increases in energy use.	Growth stimulated by high population, but curtailed by slower economic progress. On balance, consumption grows.	Low population growth, high oil prices, compact cities, high environmental awareness converge to reduce usage.	Some reductions in energy use stimulated by recession led demand reduction and environmental policy drivers.
Energy intensity falling	Energy efficiency technology and research brings further decoupling of economic growth from energy use.	Slow further reductions in energy intensity – limited by under investment in efficiency and lack of policy drivers.	Decoupling of energy use from economic growth driven by efficiency measures, high urban densities, high oil price.	Locally based energy saving activity for environmental and economic reasons. Some regions see increases.
Fossil fuel dominance maintained	Alternatives to fossil fuels cannot meet rising energy demand. Gas and coal see significant increases.	Investment in renewables falls. Nuclear makes some inroads. Coal rises sharply, particularly in E Europe.	Fossil fuel prices increase due to carbon taxes. 'Clean' energy becomes a priority. Policy supports renewables.	Energy independence policies encourages renewables. External costs of fossil fuels are legislated against.
Share of solid fuel in energy mix falling	With limited concern for environmental consequences and high demand for cheap energy, coal use increases.	Coal is seen as a central pillar of energy supply sources due to its abundance, low price and established market share.	Legislation limits carbon intensive fuels. Remaining coal fired power stations retrofit CCS technology.	Some regions, particularly in E Europe, maintain high coal use. Environmental legislation limits widespread use.
Share of natural gas in energy mix growing	Imported gas, principally from Russia, is a mainstay of the energy mix. Rapid economic growth stimulates demand.	Demand accelerates to meet rising energy usage, tempered little by legislation or supply constraints.	Gas use steadily falls due to rising prices, growth of renewables, carbon legislation and environmental values.	EU has little domestic supply, and therefore concentrates on indigenous energy resources, especially renewables.
Share of oil in energy mix falling	Investment in new extraction technology increases supply. Deep ocean fields are accessed. Demand increases.	Population growth and poor energy efficiency increases demand. Rising prices fund supply enhancement.	Urban planning, carbon taxes, environmental awareness and public transport investment reduces travel demand by car.	Local economies reduce global logistics operations. Private car use falls. Low GDP growth reduces demand.
Share of nuclear in energy mix falling	Significant investment in research and infrastructure where resources permit. Limited public concern.	Little concern for the potential impacts of nuclear technology. Growth in wealthy nations who can afford the technology.	Power stations steadily decommissioned as international agreements phase out nuclear power.	Low investment and greater environmental concern lessens demand for new generation nuclear power.
Growing share of renewables in energy mix	Low energy prices discourage high renewables investment. Wealth creation potential spurs some growth e.g. solar.	Low levels of environmental concern and limited R+D constrain growth. Fragmented increases in micro generation.	High oil price, political support and strong environmental values encourage widespread substitution to renewables.	Local small scale initiatives e.g. biomass cropping, micro generation, energy from waste become more common.
Electricity consumption increasing	High economic, population and material consumption growth lead to much greater demand for electricity.	Moderate population growth and economic development limit any significant growth in electricity consumption	High economic growth spurs large increases in consumption. Electric cars become more common.	Moderate increases in consumption, particularly in areas where incomes and development activity is higher.
Electricity generation fuel mix evolving	Fossil fuels remain dominant, although nuclear sees a significant increase in its share of the total fuel mix.	Coal is more prominent in the fossil fuel mix, with slight increases in nuclear and falls in renewables.	Renewables play a much stronger role in electricity generation, to the detriment of fossil fuels and nuclear.	Electricity generation becomes 'cleaner' although some regions maintain high use of fossil fuels.

Key		
	Acceleration of current trend	(dark green)
	Continuation of current trend	(light blue)
	Reversal of current trend	(red)

Table 12: 'Wind tunnelling' energy trends through the PLUREL scenarios

Energy: conclusions

A transition to a low carbon economy will bring with it a range of opportunities and challenges that will have a major impact on the energy sector. It is not possible to predict exactly how this process will unfold as there are barrier (political, economic, social, technical and environmental) that will need to be overcome to make this a reality. Indeed, at present, many global drivers are actually moving in the opposite direction, effectively compromising efforts to reduce reliance on fossil fuels and to increase the share of renewable sources of energy. Although growth in renewable energy is expected in Europe at a higher rate than other world regions (EEA 2007), fossil fuels will nevertheless dominate the continent's energy mix for the foreseeable future. Globally this division is even more pronounced, with growth in renewables of just 1% in absolute terms projected by 2030 (EEA 2007). Fossil fuels are projected to provide for 84% of the world's

increased energy demand between 2005 and 2030. Investment in energy supply infrastructure (e.g. the boom in coal fired power stations in China for electricity generation) seem to be tying the world into a fossil fuel future for the coming decades. Seen within a context of rising world marketed energy demand, which is projected to increase considerably at a rate of 1.8% annually between 2003 to 2030 (US Department of Energy 2007), this does not bode well for climate change mitigation efforts.
Although these drivers if change in the energy sector are global in scope, their impact on Europe will be great. The preceding discussion has highlighted the impact that energy has on environmental quality and peri-urban land use. Moreover, it has also demonstrated through the use of the PLUREL scenarios, that considering the direction of possible future change in global drivers is clouded with uncertainty. What is clear is that energy will remain a fundamental force impacting on peri-urban agendas. Decision makers must be aware of this fact and be prepared to develop strategies to encourage the development of sustainable relationships between the energy sector and peri-urban environments.

Energy: references

European Commission (EC) (2003) EU 25 Energy and Transport Outlook to 2030, Office for official publications of the European Commission, Luxembourg.

European Commission (EC) (2006) World Energy Technology Outlook – WETO H2, Office for official publications of the European Commission, Luxembourg.

European Commission (2006) European Energy and Transport – Trends to 2030: Update 2005, Office for Official Publications of the European Communities, Luxembourg.

European Environment Agency (2005) European environment outlook, European Environment Agency, Copenhagen.

European Environment Agency (2006) Energy and the environment in the European Union: tracking progress towards integration, European Environment Agency, Copenhagen.

European Environment Agency (2006a) How much bioenergy can Europe produce without harming the environment?, European Environment Agency, Copenhagen.

European Environment Agency (2007) Europe's environment: the fourth assessment, European Environment Agency, Copenhagen.

Eurostat: http://epp.eurostat.ec.europa.eu. The Eurostat webpage provides a wide range of statistical data on various topics. There is a section on energy statistics

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) 2006, Renewable Energy: Employment Effects, Frotscher Druck, Darmstadt.

International Energy Agency (IEA) (2007) World Energy Outlook 2007 – Executive Summary, International Energy Agency, Paris.

Jörn P. W. Scharlemann and William F. Laurance (2008) How Green Are Biofuels? Science 4 January 2008: Vol. 319. no. 5859, pp. 43 – 44.

US Department of Energy (2007) International Energy Outlook, US Department of Energy, Washington DC.

5. Transport – trends, projections and impacts

Introduction and context

Transport is a major industry in the EU, accounting for 7% of GDP and 5% of employment. Transport is intimately linked to patterns of urban development, and the existence or absence of good transport links can have a huge bearing on spatial growth patterns. In this respect, transport brings with it opportunities for socio-economic progress. Despite these benefits, transport has significant environmental costs, for example relating to air pollution, habitat fragmentation and climate change. These environmental costs are estimated at 1.1% of EU GDP. Traffic congestion is thought to cost an additional 1% of EU GDP (EC 2006). The car culture, which dominates EU transport, also has negative impacts on individuals and communities with limited access to private vehicles. Indeed, as car use has grown, numbers of shops have fallen and those that remain have become increasingly centralized (EEA 2004).

Due to its impact on society and the environment, transport is an important issue for EU policy makers. However, EU transport policy has failed to reduce transport demand, and there has been little success in decoupling growth in transport volumes from economic growth. Similarly, decoupling of transport energy consumption from GDP growth has not been achieved. Instead, EU policy now focuses on managing the negative impacts associated with transport. Greater emphasis is now placed on the supply side of transport management, and increasing success in reducing transport pollutant emissions for example demonstrates ways in which this policy direction is working effectively (EEA 2007a). Significant challenges remain, particularly in relation to the links between transport and climate change.

There has been an implicit recognition that transport demand is difficult to manage due to the influence of drivers of change that operate outside the scope of transport policy (EEA 2007). Central to these drivers is economic growth patterns. In the EU 15, annual growth in GDP of 2.2% (1995-2025) is projected (IFPRI 2002), with GDP/capita doubling between 2010 and 2050 (EC 2006). It is likely that these increases in GDP will be accompanied by growth in transport demand and associated energy use. Indeed, as societies become richer, distance travelled per capita increases and transport choices evolve to become more energy intensive. Similarly, demand for particular lifestyles and production methods pressures policy makers to provide for the transport sector through the development of associated infrastructure and settlement patterns (EEA 2007). Over the coming decades, significant challenges will be faced by policy makers seeking develop strategies to balance the costs and benefits associated with transport in the face of powerful forces that shape the direction of the sector.

Through its interplay with society and the environment, transport exerts a significant impact on peri-urban areas. This discussion demonstrates the scope and complexity of the ways in which transport affects the fabric of urban landscapes and the quality of environments, and these two key issues (environmental quality and peri-urban land use) provide the boundary for this investigation. Several key topics are addressed, which include:

- Summary of the impacts of transport on environmental quality.
- Assessment of trends and projections relating to the transport sector, and an analysis of how these changes are impacting on the environment.
- Investigation of the relationship between transport trends and projections, environmental quality and peri-urban land use.
- Application of the PLUREL scenario framework to the analysis of transport impacts in Europe.

Transport: summary of impacts on environmental quality

Transport is one of Europe's most environmentally damaging sectors. Impacts on environmental quality stem from a wide range of related issues. These include the manufacture of vehicles, the use of energy by the transport sector, the infrastructure that is needed to allow the sector to function (roads, train lines etc), and the patterns of housing, economic growth, logistics etc that can only exist as a result of transportation. These activities and processes impact on the full range of aspects of environmental quality, often in interconnected and synergistic ways. Key environmental effects of transport on air quality, biodiversity, soil and water are discussed below.

Air quality
Despite improvements in air quality over recent decades, Europe faces significant air quality problems particularly in urban areas and coastal areas around major ports. Transport has a key role to play in creating these problems. Air pollutants released from the combustion of transport fuels include oxides of sulphur and nitrogen, particulates, and toxic chemicals. Aside from negative impacts on human health (tens of thousands of premature deaths are attributed to air pollution in Europe every year), air pollution has significant environmental impacts. It is the deposition of air pollutants in water bodies and soils that generates some of the most severe of these environmental impacts through processes including acidification and eutrophication which affect biodiversity, soil and water. Direct effects of air pollutants on the environment include the negative impact that ozone has on plant growth. The climate change impacts associated with the release of greenhouse gases from transport are considered in a separate section of this report.

Biodiversity
Transport exerts a range of negative impacts on Europe's biodiversity. Fossil fuels (principally petroleum based products in the context of transport) contribute to climate change, which is regarded as one of the most serious threats to biodiversity (MEA 2005). Further, their combustion also releases pollutants that impact on biodiversity through acidification, eutrophication and toxic accumulation. Recent growth in demand for biofuels, as promoted by the EU Biofuels Directive, also has environmental consequences related to the increased use of agricultural inputs, habitat loss, and energy consumption. Transport infrastructure impacts on habitats. For example, roads and rail lines fragment habitats and can disrupt migration routes, and roads often open up new areas to development leading to further habitat loss and degradation. Also, through transports relationship with urban sprawl, which is increasingly prevalent across Europe (EEA 2006), the sector exerts additional stress on habitats and ecosystems.

Soil

Soil degradation encompasses a range of different issues including erosion, contamination and sealing. Transport exacerbates each of these problems. For example pollutants released by fuel combustion, salt spread on roads during the winter, and oil on road surfaces contaminate soils. Increased use of biofuels also impacts on soils via the intensification of agriculture. Polluted and degraded soils become less resilient as their structure breaks down, which can increase the threat of soil erosion by wind or water. Transport infrastructure impacts on soils through surface sealing. Once soils surface has been sealed it cannot perform the services that it provides to society as effectively, including flood regulation and absorption of pollutants. Consequently, environmental quality can suffer further through increased flood risk or pollution of water courses.

Water
Transport and water resources are closely linked. The impact that transport infrastructure has had on the built environment and patterns of housing and development has impacted significantly on the hydrological cycle. Extensive surface sealing (carparks, roads, driveways etc) reduces absorption of rainwater and therefore increases the speed and volume of runoff reaching water courses increasing flooding problems. This runoff is also often contaminated with pollutants which can impact on water quality, as can the deposition of airborne pollutants such as oxides of nitrogen and sulphur which are released during fuel combustion. Reduced percolation of water into soils also reduces groundwater recharge with potential impacts on the availability of water resources. Transport therefore impacts negatively on water quality and quantity issues.

Transport trends and projections: impacts on environmental quality

Although there has been some decoupling of transport growth from GDP growth, transport volumes have nevertheless increased considerably over recent decades with road and air transport showing particularly strong growth. The impact of transport on the environment remains very significant. Key trends in the transport sector, each of which has environmental impacts (which can be positive and negative), are summarised below and explored in greater detail within Table 13. This analysis provides a springboard to consider the linkages between transport and peri-urban areas, and how this relationship may evolve in the future.

- ***Passenger transport volumes*** have increased considerably, and further growth is projected. Environmental impacts depend on the transport mode.
- ***Passenger air transport*** volumes have increased faster than any other mode since 1990. Further rapid growth is projected to 2020, with major environmental impacts, especially on the stability of the climate system.
- ***Car transport*** is the dominant passenger transport mode, and is projected to remain so for the foreseeable future. The car 'culture' is central to many of Europe's environmental problems such as air quality and habitat loss.
- ***Passenger rail transport*** has grown marginally in recent years. Due to slow projected increases in future rail transport volumes, a slight reduction in rail's overall share of passenger transport is expected.
- ***Freight transport volumes*** have grown, and are projected to continue to grow at a rapid pace. As with passenger transport, environmental impacts ultimately depend on the specific mode being considered.

- ***Road freight transport*** costs have fallen over recent years which coupled with its high flexibility is driving an increase in demand for this transport mode. For these same reasons, further increases are expected in the future.
- ***Rail freight transport*** has grown in absolute terms, but has seen its share of overall freight volumes fall as other modes have grown more quickly. This pattern is expected to continue in the future.
- ***Freight transport by water*** (intra-EU sea shipping and inland waterways transport), has grown. Continued growth is expected, particularly for sea shipping, which will negatively affect air quality around some coasts.
- ***Transport energy demand*** has risen faster than any other sector over recent years, and despite vehicle efficiency improvements is expected to increase more in the future. Fossil fuels are the principal provider of energy for transport, and are central to the sectors negative environmental impacts.
- ***Greenhouse gas emissions***, and hence contribution to climate change, has grown and continues to increase particularly from the aviation sector.
- ***Pollutants from transport*** have declined due to legislation stimulating changes in fuel and vehicle technology. Pollutant levels nevertheless remain high and are harmful to environmental quality.
- ***Biofuels*** use has increased significantly, although remains low as a share of overall fuel usage. Rapid growth is projected. Depending on the production method, the environmental impact of biofuels can be positive or negative.
- ***Car technology*** remains dominated by gasoline and diesel engines. Slow growth in alternatives is taking place (hybrids, electric cars etc), which are expected to increasingly challenge traditional technologies in coming decades.
- ***Motorways*** have grown rapidly in length in the last 30 years, particularly in western and central Europe. Further growth in projected, potentially fuelling growth in transport demand and associated environmental impacts.
- ***Car ownership*** has grown spectacularly stimulated by falling relative costs in comparison to other modes. Future growth is expected, especially in eastern Europe and the new member states.

TRANSPORT		
Issue	***Trends and projections***	***Impacts on environmental quality (air, biodiversity, soil, water)***
Passenger transport (overall)	Rapid growth in passenger transport in recent decades, both within and between member states. This has been fuelled by rising incomes, infrastructure improvements and land use change. Between 1990-2003, growth of 20% was seen, alongside a 30% growth in GDP. Decoupling of transport growth from economic growth has taken place in a small number of more developed member states. Further strong growth is projected in coming decades, particularly Eastern Europe and the EU 10 (EEA 2007). For the EU 25, 35% growth in passenger transport is projected for 2000-2020 (EC 2006).	The external costs of transport that link to the environment include climate change, air pollution and land use change. EEA (2004) estimate that 92% of these external costs are attributable to road transport. Ultimately, the environmental impacts associated with growing transport volumes depend on the particular mode of transport.
Passenger transport (air)	Air travel accounts for 8% of intra-EU passenger travel. Between 1990-2003, growth of 96% was experienced, the fastest growth of any transport mode (EEA 2007). There was a 100% growth in the number of intra-EU routes between 1992-2004 (EC 2006), and there has been a significant growth of low cost carriers. In the EU 25, 108% growth is projected from 2000-2020, with air's share of passenger transport increasing from 8% to 11%	Climate change impact is particularly notable - total impact is 2-4 times greater than the direct impact of CO_2 released by planes due to formation of contrails and cirrus clouds (IPCC 1999). Air pollution around airports (nitrous oxides, particulates etc) is significant. Associated infrastructure (terminals, runways etc) leads to habitat fragmentation and loss. Runoff from the airport site can lead to water

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	(EC 2006).	pollution (e.g. oil, runway de-icer).
Passenger transport (car)	Between 1995-2004, car use grew by 19% across the EU 25 (EC 2006). In 2002, cars accounted for 84.9% of passenger transport in the EU 15, up from 83.4% in 1991. Buses accounted for a further 8.6% of passenger transport in 2006 (Eurostat). Distance travelled by car increased by 16.4% across the EU 25 between 1995 and 2003 (Eurostat). Further growth is expected within the EU 25, with volumes potentially increasing by 36% from 2000-2020 and car's share of total passenger transport increasing from 76% to 77% (EC 2006).	Improvements in fuel and vehicle technology have slowed the environmental impacts of road traffic growth. Nevertheless, impacts on environmental quality are large and include pressure on habitats and biodiversity (land take and effect of pollutants), air pollution (direct impact of pollutants and contribution to climate change), soil degradation (compaction and deposition of air pollutants), and water pollution (deposition of air pollutants, contaminated runoff).
Passenger transport (rail)	EU 15 passenger transport by rail has remained fairly constant at around 6.5% of total kms (1991-2002) (Eurostat). Most is inter-urban travel (21.5% on high speed trains) as opposed to urban train travel (trams, metro etc) (EC 2006). EU 25 volumes increased by 11.6% from 1995-2003 (Eurostat). Between 1995-2004, there has been 8% growth in inter-urban and 14% growth in urban train travel in the EU 25 (EC 2006). Relatively slow further growth of 19% from 2000-2020 is forecast, with rail's share of total passenger transport decreasing from 6% to 5% (EC 2006).	Trains often run on electricity generated from fossil fuels, and therefore contribute to environmental problems including climate change and air pollution. However, relative to other transport modes, particularly planes and cars, CO2 and air pollutant emissions per passenger are generally low. There are also impacts on biodiversity associated with land take for rail infrastructure. On balance, however, rail is relatively benign in environmental terms.
Freight transport (overall)	Within the EU 25, freight transport volume increased by 6.2% relative to GDP between 1995-2006 (Eurostat). Decoupling has therefore failed to take place. In gross terms, freight transport volume increased by 43% between 1992-2004 (EEA 2007a). Freight transport is projected to grow by 50% between 2000-2020 in the EU 25 (EC 2006).	Patterns of modal change within freight transport sector, in particular increase in road freight and reductions in rail freight, are moving the EU away from environmental sustainability.
Freight transport (road)	44% of total freight (including international shipping) is transported by road (EC 2006). Within the EU 25 volume of goods transported by road increased by 35% (1995-2004), whilst the share of inland freight carried by road increased by 4.3% over this period to 76.4% of total freight volume (Eurostat). The cost of freight transport has fallen in recent years, helping to fuel increases in demand (EEA 2004). Road freight transport is projected to grow by 55% between 2000-2020 in the EU 25, by which point it is expected to account for 45% of total freight transported (EC 2006).	Growing road freight volumes runs counter to efforts to improve environmental quality, for the same reasons as the recent and projected future increases in passenger transport by car. Negative impacts on air, biodiversity, soil and water accompany increases freight transport by road. This is largely due to the use of fossil fuels and associated generation of pollutants, and the physical impact of transport related infrastructure on habitats and ecosystems.
Freight transport (rail)	In the EU 25, rail transport tonnage fell from a 20.9% to 17.5% share of total freight transported between 1996-2006. However, in terms of distance traveled by rail freight goods, an increase of 9.8% was seen from 1995-2005 (Eurostat). Rail freight transport is projected to grow by 13% between 2000-2020 in the EU 25, although its share of total freight transported falls from 11% to 8% (EC 2006).	As discussed above, rail does have negative environmental impacts, although they are generally less prominent than other transport modes. However, rail transport is not always more environmentally benign than road, with rail's benefits most apparent when freight is transported over long distances (EC 2006).
Freight transport (water)	Between 1995-2004, intra-EU maritime freight transport grew by 29%, with a 9% growth in freight transported on inland waterways. Short sea shipping has considerable potential with 59% growth projected from 2000-2020 in the EU 25, whilst 28% growth in transport on inland waterways foreseen (EC 2006). In terms of share of total freight transported, from 2000-2020 sea shipping increases from 39% to 41%, with shipping on inland waterways falling from 4% to 3% (EC 2006).	Regulation of maritime shipping pollutant emissions is much less stringent than for land based transport. Ships accounted for around 1/3 of EU 15 emissions of oxides of sulphur and nitrogen in 2000 (EEA 2005), and are set to exceed all land based sources of these pollutants by 2030 (EEA 2005a). Further, shipping accounts for between 20-50% of particulate pollution in port areas. (EEA 2005a). Shipping infrastructure impacts on coastal and marine habitats.
Transport	Transport has become the largest consumer of final	Fossil fuels power the transport sector, and

energy consumption	energy demand, and has seen the fastest growth in energy consumption (EC 2006a). Transport energy demand in the EU 25 is projected to be 21% higher in 2030 compared to 2000. Ongoing efficiency improvements slow the rate of growth in demand as time passes (EC 2006a).	alternative energy technologies have yet to make significant inroads. Rising energy demand essentially means increasing use of fossil fuels and associated negative impacts on environmental quality.
Greenhouse gas emissions from transport (road, rail, inland navigation, domestic aviation)	Between 1994-2004, greenhouse gas emissions from transport increased by 18% across the EU 25 (Eurostat), and in 2004 accounted for 21% of total emissions. In 2004, 93% of transport emissions came from road transport (Eurostat), although from 1990-2004 emissions from aviation grew by 86% making this the fastest growth source (EEA 2007a). EU 25 emissions are projected to grow by 13% between 2000-2030.	Transport is a significant contributor to climate change. Projected rises in emissions will worsen the problem and speed the onset of associated negative environmental impacts. Air transport is a real threat. Indeed, by 2030, the climate impacts of air travel could be twice that of passenger vehicles (EEA 2004).
Pollutant emissions from transport	Emissions have fallen (particulates (by 29%), ozone precursors (by 41%) and acidifying substances (by 32%)) in the EU 25 between 1990-2004. The most significant reductions have been for road transport where legislation is strongest. However, increasing demand for diesel cars is slowing declines of particulates and nitrous oxide. Sulphur dioxide emissions from road transport have lessened considerably, but have be transferred to the sea.	Despite recent declines in emissions, stimulated by legislation and associated technology change, pollutant emissions from transport remain significant. Related environmental impacts include acidification of soils, eutrophication of water bodies, and damage to vegetation from ground level ozone and toxic chemicals.
Biofuels	The share of biofuels in total transport fuel consumption has increased rapidly, from 0.05% to 1.1% in the EU 25 between 1994 and 2005. Supported by EU legislation and associated targets, biofuels share is projected to rise strongly in the future to 4% of total transport fuel consumption by 2010 and 8.3% by 2030 (EC 2006a).	The environmental credentials of biofuels depends on where and how they are produced. Imported biofuels from tropical areas have little positive environmental benefit due to associated land use change and release of carbon, use of nitrogen based fertilizer, and the energy intensive nature of the biofuel production process (Scharlemann and Laurance 2008).
Car technology	Around 60% of EU 15 new vehicle registrations in 2000 were gasoline. Almost all the remainder were diesel, with limited uptake of alternative technology (hybrid vehicles, fuel cells, electric cars) (ESTO 2003). Average purchase cost of hybrid cars is projected to fall by 28% between 2005-2020, with potential market growing from 250000 to 4 million vehicles. Fuel cell car cost falls by 58% from 2010-2020, with potential market growing from 13000 to 1.6 million vehicles. Gasoline vehicles see a significant loss of market share (ESTO 2003).	Slow uptake of alternative technologies and consumer trends towards larger, heavier and more luxurious cars (EEA 2007) is hampering emissions reduction efforts. Current efficiency and technology change is not sufficient to offset rising emissions from growing transport volumes (ESTO 2003). Further reductions in environmental quality can be expected if the market remains dominated by fossil fuel transport. Even if technology does change, transport infrastructure (and associated negative environmental impacts) will remain.
Length of motorway	Across the EU 15, motorway length has more than tripled over the last 30 years (Eurostat). Between 1990-2002, motorway length grew by 62% in the EU-10 and 35% in the EU 15 (EEA 2004).	Growth of motorways fragments habitats, disrupts migration routes, and ultimately leads to biodiversity loss. Further, urban sprawl is encouraged (with biodiversity loss), as is car ownership and related environmental impacts.
Car ownership	The relative cost of car ownership is falling (whilst cost of public transport is growing), increasing demand for private cars (EEA 2004). From 1970-2000, the number of cars on Europe's roads grew by 185%. In the EU 25, cars per 1000 inhabitants increased by 17.5% from 1995-2003, to 463 in 2003. In the EU 15, the number of cars is projected to grow by 23% between 2000-2020. Post 2015, saturation values of 600-650 cars/1000 inhabitants are expected to be reached (ESTO 2003).	Whilst powered by fossil fuels, increasing car ownership brings a host of environmental problems, not least accelerated climate change. Growing car ownership also stimulates increasing demand for roads and other infrastructure, with significant negative environmental impacts.

Table 13: Transport trends and related environmental impacts

Transport, environmental quality and peri-urban land use: exploring the linkages

Transport is fundamentally connected to the core PLUREL agenda of peri-urban land use relationships. Trends in the transport sector have been and will continue to be one of the most significant drivers of change in peri-urban landscapes. The linkages between transport, peri-urbanisation and environmental quality are strong, perhaps typified by the contribution of transport to climate change and the threats to environmental quality that this global phenomenon brings with it. Table 14 offers some insights into transport related peri-urban land use issues, drawing on the analysis of key trends in the sector presented in Table 13 above. The intention here is to provide an indication of the scope of the connections between transport and peri-urban landscapes through looking at the impact of relevant trends. Where appropriate, environmental hotspots more likely to experience these impacts are highlighted. Key cross-cutting issues emerging from this analysis include:

- ***Transport infrastructure:*** Much infrastructure is directly associated with transport (e.g. roads, service stations, logistics depots etc). Projected increases in road passenger and freight transport will generate additional infrastructure. This will affect peri-urban areas, impacting on landscape character through changing settlement patterns and commercial activity for example. Trends in the transport sector therefore impact on the built environment and urbanization patterns. They also influence environment quality through issues such as increasing transport energy consumption. However, positive socio-economic impacts also link to transport infrastructure, including greater employment and recreation opportunities.
- ***Societal issues:*** The transport sector is linked strongly to societal patterns, such as leisure choices and working arrangements. This is a two-way relationship. For example, if E-commerce and tele-working became more common, shopping habits and commuting patterns would change with related effects on transport. This may not necessarily mean that distance traveled per capita is reduced, but that people then use their spare time to travel for different reasons such as for recreation. Similarly, dominant transport modes affect commercial decisions such as the location of retail developments. Transport links closely with individuals prospects for socio-economic development. A wider range of transport choices brings more opportunities for individuals and communities, and may reduce problems such as congestion. Where car transport dominates, spatial development reflects this limiting access to services for those without cars.
- ***Policy and legislation:*** The European Environment Agency (EEA 2007a) has noted that the environmental performance of the transport sector is unsatisfactory. A range of policy measures are now in place to try to reduce the environmental impacts of transport, relating to issues such as fuel composition and biofuels production. Policy commitments to climate change mitigation will also impact on the transport sector. Legislation related to issues such as these will have spatial impacts affecting peri-urban areas, resulting in changes such as greater use of mass transportation and the promotion of mixed use developments to cut down on transport volumes.
- ***Spatial planning:*** Spatial planning is a particular area of policy that has a considerable effect on the relationship between transport and peri-urban landscapes. Due to its influence over the development and use of land, spatial planning profoundly affects any society's transport choices. Patterns of urban form can lock individuals and communities into a restrictive car-dominated transport system, or alternatively can provide people with a range of 'sustainable' transport choices. Moreover, spatial planning's influence over the location of

commercial and industrial development activities can affect transport patterns related to logistics operations. Through influences such as these, the nature and extent of transport's environmental impacts is affected by spatial planning policy.

TRANSPORT		
Trend	***'Hotspots'***	***Peri-urban land use impacts associated with a continuation of the trend***
Passenger transport (overall) increasing	In 2000, transport volumes (km/capita) were almost double in OECD Europe (12000 km/capita) than Eastern Europe (7000 km/capita). Growth of 193% is projected in Eastern Europe and some EU 10 nations from 2000-2050, and by 69% in OECD Europe. All EU regions are projected to reach around 20000km/ capita/year by 2050 (EEA 2007).	- The nature of impacts depends on the direction of change in passenger transport patterns. Projected change is generally 'unsustainable' with growth in car and air travel and decline in rail travel. - Looking forwards, passenger transport remains dominated by the car. Significant peri-urban land use impacts and socio-economic effects can be expected.
Passenger transport (air) increasing	In 2005, the UK accounted for almost 30% of EU 25 passenger air travel. Germany, France and Spain made up a significant proportion of the remainder (Eurostat). Growth in demand is likely across Europe.	- Air travel improves tourism prospects in destination locations, bringing positive and negative impacts to those areas, e.g. job opportunities, rural decline. - Increased air travel brings higher risks to communities of negative impacts including noise and air pollution. - Greater demand for air travel stimulates job opportunities at airports and businesses that congregate around them.
Passenger transport (car) increasing	Apart from Eastern Europe and the Baltic states, cars account for over 80% of passenger transport in most EU 25 nations. Germany, France, Italy and UK have the largest gross distances. From 1995-2003, rapid growth (over 50%) in distance travelled by car occurred in countries including Greece, Latvia, Poland and Portugal (Eurostat).	- Social impacts of car dependence e.g. falling numbers of shops, increasing centrality, lack of access to services to those without cars, are increasing (EEA 2004). - Car use creates quality of life impacts e.g. noise and air pollution, landscape impacts, which can make urban areas less attractive. - The 'car culture' can lock areas into urbanisation patterns that feed peri-urbanisation e.g. suburban housing developments, out-of-town shopping centres. - Increased car use and ownership reduces incentives for citizens to use public transport.
Passenger transport (rail) increasing but overall share declining	In most EU 25 nations, less than 10% of total journeys are by rail. Germany, France, Italy and the UK have the most rail travel (Eurostat). Recent declines were seen in Eastern Europe and Baltic States, with increases in countries including France, Spain and the UK (Eurostat). France, Germany, Poland and Spain saw the largest losses of railway lines from 1995-2003 (Eurostat).	- The cost of train travel is increasing proportionally faster than private car use (EEA 2004), potentially pricing some users out of train travel and limiting their travel options. - The length of railway line in the EU 25 fell by over 7% between 1995-2003 (Eurostat), reducing travel options and increasing car dependency for some communities. - Where investment in rail infrastructure is made and increases in train travel is forthcoming, pressure on road networks may drop, easing congestion problems and increasing accessibility.
Freight transport (overall) increasing	Declines in volumes of over 10% (1995-2006) were seen in countries including Denmark, France, Sweden and the UK. Over this period, rapid growth of over 30% was seen in Bulgaria, Greece, Spain and Portugal (Eurostat).	- Impacts associated with changing freight transport patterns depend on the nature of that change. - Significant projected growth in freight transported will increase job opportunities in this sector. - Projected changes are generally 'unsustainable' with growth in share of road and fall in share of rail transport.
Freight transport (road) increasing	In a number of countries, including Ireland, Greece and Spain, over 95% of goods are transported by road. In countries including the Baltic states, Netherlands and Sweden, this figure is below 65% (Eurostat). Virtually every country has seen recent increase in goods transported by road (in km), particularly Ireland, Spain, Latvia, Hungary and Portugal (Eurostat).	- Current and projected future dominance of road in inland freight transport will pressure transport networks leading to congestion, damage to road surfaces etc. - Lower freight cost has encouraged transport intensive economic activities and logistics (EEA 2004). Future increases in road freight will bring further supporting infrastructure, e.g. logistics depots in peri-urban areas. - Dominance of road freight encourages out-of-town shopping centres etc on major transport routes.
Freight transport (rail)	In 2006, countries including Ireland, Spain and the Netherlands transported	- Declining use of rail for freight transportation increases pressure on existing road networks, and raises the

increasing but overall share declining	less than 5% of freight by rail. Baltic States and Scandinavia have higher levels (e.g. 65.3% in Estonia and 35.5% in Sweden) (Eurostat). From 1995-2005, countries including the Baltic States, Germany and the UK saw growth in rail freight traffic (in km), whilst Eastern European countries and France saw declines (Eurostat).	prospect of future expansion of road networks to cope with expanding volumes of freight. - Where rail freight is more prominent, problems such as congestion and air pollution could potentially decline. - Higher demand for freight transport may strengthen the case for expansion and improvement of rail networks, with associated socio-economic benefits.
Freight transport (water) increasing	Four countries dominate inland the waterways freight market. In 2006, the Netherland, Belgium, Germany and Romania transported 32.3%, 14.7%, 12.8% and 10% of freight via inland waters (Eurostat). Growth in short sea shipping is projected across Europe.	- Inland waterways offer an underutilised resource in many countries, which has the potential to take lorries off the roads reducing air pollution, congestion etc. Recreation opportunities may be lost however. - Strong projected growth in short sea shipping could raise demand for port infrastructure, bringing jobs but pressuring costal landscapes and reducing air quality.
Transport energy consumption rising	Energy consumption will generally be highest where transport and freight volumes and levels of private car ownership are large. Germany, France, UK and Italy are likely to have the highest consumption levels.	- Rising transport energy consumption, as it comes predominantly from fossil fuel use, is associated with problems including climate change, air pollution (and related health impacts), soil degradation (with its effect on agricultural production) and water pollution (with impacts on recreation).
Greenhouse gas emissions from transport increasing	Emissions levels generally correlate with volume of passenger and freight transport. Germany, France, UK and Italy are the largest emitters, with the Baltic States, Cyprus and Malta the lowest (Eurostat).	- The impacts of climate change on peri-urban land use relationships are discussed within a separate section. - Efforts to reduce transport emissions e.g. by road pricing, increasing access to public transport, will affect housing choice, travel patterns, business location etc.
Pollutant emissions from transport falling	Where traffic volumes are highest (passenger and freight) emissions levels can be expected to also be high. The type of fuel used and the strength and enforcement of legislation will also affect emissions levels.	- Where emissions levels remain high, negative air quality results, with human health impacts. - Emissions can degrade soils and harm vegetation growth, to the detriment of agricultural production. - Emissions and associated runoff pollutes water bodies, decreasing opportunities for recreation. - Where emissions decline, these impacts are less likely.
Biofuels increasing	Germany, Sweden and France use the most biofuels – with 3.87%, 2.93% and 1.04% share of total transport fuel consumption respectively. Other EU nations use very small amounts (Eurostat) although EU targets are set to change this in the near future.	- Production of biofuels can have significant landscape impacts and will affect agricultural production patterns (potentially with loss of traditional agricultural methods). - If usage increases, biofuels can generate environmental benefits e.g. improved air quality, which can have knock-on positive socio-economic effects.
Car technology evolving	It is difficult to speculate which countries will see the most rapid uptake of alternative car technologies. Nations with higher fuel costs and greater levels of environmental awareness may see the greatest growth in the short term.	- Reduction of fossil fuel use will lessen associated environmental impacts, with socio-economic benefits. - Many of the negative impacts of car use relate not to fuel source, but to transport infrastructure and the dominance of the 'car culture.' These problems will not dissipate with evolution of technology.
Length of motorway increasing	Land fragmentation is greatest in Western and Central Europe where transport networks are most dense (EEA 2004). Greece and Spain have seen rapid growth in motorway length in recent years. Germany, France and Spain currently have the longest motorway networks (Eurostat).	- Investment in motorways and related infrastructure diverts funding from public transport expenditure. - As motorway networks expand, more people become exposed to the negative impacts of pollution and noise. - Motorway expansion improves public access to recreation opportunities and services in urban areas, and may encourage greater commuting and rural living.
Car ownership increasing	Of the larger nations within the EU 25, Austria, Germany, Italy and Portugal have the highest levels of car ownership. Eastern European countries and Baltic States have the lowest car ownership levels (Eurostat).	- Rising levels of car ownership locks communities into transport patterns, with associated habits and land use patterns, that take a long time to change (EEA 2004). - The risk of negative environmental impacts (and linked socio-economic challenges) increases.

Table 14: Energy trends and associated peri-urban land use relationships

Many of the peri-urban land use impacts related to transport are dependant on trends currently impacting on the sector, for example the dominance of car transport and rapid increase in air travel. It is not possible to predict precisely how these trends and associated impacts will unfold in the future. The impact of changes in economic growth patterns or governance structures for example will have a major effect on the relationship between transport and peri-urban landscapes. The PLUREL scenarios provide a route into this debate, and are explored in greater below.

Transport futures

Scenarios provide a well established means of exploring different possible futures and directions of change. Table 15 presents the results of a 'wind tunnelling' exercise where the trends currently impacting on the transport sector are considered in the context of the driving forces that shape the PLUREL scenarios. The scenarios demonstrate that future change in this sector depends significantly on how key issues (such as population growth, economic development, cultural and political trends) play out in the future. It is important to emphasise that Table 15 reflects only one possible interpretation of scenario impacts, and as with other scenario frameworks (e.g. the IPCC SRES) degrees of probability and likelihood are not ascribed to this assessment. However, it does help to summarise the possible evolution of key trends impacting on the transport sector. Seen in tandem with Table 13, which considers environmental impacts linked to transport issues, an indication of the effects on Europe's environment of changes to transport trends under the PLUREL scenarios can be ascertained. Issues of note relating to the effect of the four scenarios include on the transport sector:

A1b Hypertech
The assumptions forming the basis of this scenario, which revolve around a globalised interdependent and increasingly peri-urban society experiencing rapid economic growth and technological development, impact significantly on transport patterns. Many current trends accelerate and intensify, including volumes of passenger and freight transport, emissions of GHG's and pollutants, and energy consumption. As these trends are associated with many of transport's most harmful environmental impacts, the quality of Europe's environment deteriorates. Weak spatial planning and laissez faire government policy do little to reign in transport's destructive impacts. However, technological progress (relating to second generation biofuels, hybrid vehicles, fuel efficiency etc) does help to moderate these impacts somewhat.

A2 Extreme Water
This scenario paints the bleakest picture for Europe's environment which suffers from a combination of transport related impacts. Pressures are similar to those experienced under A1b Hypertech, although without the technological progress or the scale of investment capital to boost infrastructure and technology development. Accordingly, rail infrastructure for example sees little expansion. GHG and emissions levels are highest under this scenario. Regionalisation and urban expansion reduce transport demand per capita, yet rapid population growth leads to significant overall increases in the majority of transport modes (both passenger and freight). Environmental impacts associated with these changes are profoundly negative.

B1 Peak Oil
This scenario represents the most significant departure from the conventional patterns and trends that currently dominate the transport sector. Key scenario assumptions include an energy price shock, increased environmental awareness across all sectors of society, the development of environmental and resource efficient technologies, and globally interdependent governments and economies. In an era of high oil prices, fossil

fuel based modes of transport and spatial development are no longer tenable, leading to structural changes in the transport sector and consequently in land use patterns. These generally favour more environmentally benign and fuel efficient transport modes (e.g. mass transit, inland waterways) at the expense of more harmful and less efficient technology (e.g. air travel, private car use). The net effect of these changes for Europe's environment is generally positive, with energy use, GHG emissions and pollutants falling.

B2 Fragmentation

This scenario exhibits some assumptions that are similar to those around which the Peak Oil future revolves, including stronger environmental ethics and commitment to less resource intensive patterns of society, yet operating within in a regionalised rather than globalised setting. Some regions are less prosperous than others, and not all are able to invest in sustainable solutions to problems associated with current transport agendas whereas others invest heavily in efficient and sustainable transport infrastructure. Spatially, there are nodes of high GHG emissions and pollutants, outdated rail infrastructure, poor public transport services etc. These sit alongside areas where the relationship between transport and the environment is more progressive and sustainable. Environmental quality varies as a result.

	PLUREL scenarios			
Issue and current trend	A1b hyper-tech	A2 extreme water	B1 peak oil	B2 fragmentation
Passenger transport overall increasing	Faster cheaper transportation, rapid economic growth, urban sprawl and higher commuting distances intensify demand.	Transport demand driven by population expansion, sub-urbanisation and regional economic activity.	Increase in transport costs, compact urbanisation, energy shock and low population growth all slow demand.	Local activities dominate economic and social relations. Low oil price is tempered by environmental taxation.
Passenger transport (air) increasing	Countries/regions are closely connected by global markets. High per-capita income. Lax environmental regulation.	Migratory lifestyles for the rich. Reduced Mediterranean tourism, growing domestic tourism market.	High costs, carbon taxes and markets, fewer budget carriers and strong legislation penalise air travel, denting demand.	Strong local communties. Domestic holidays. Local recreation supported. 'Full' cost of air travel is charged.
Passenger transport (car) increasing	Cars remain the dominant form of personal transport. Peri-urbanisation increases car use as land use disperses.	Particularly for local trips. Urbanisation in rural areas resilient to climate change increases travel distances.	Fuel costs prohibitive for many. Environmental awareness encourages public transport. Urbanisation.	Increased travel for domestic holidays. Regionalisation leads to fewer long trips.
Passenger transport (rail) increasing	Growth in urban areas to combat congestion. High speed trains connect regional capitals.	Resources cannot support expansion in most areas. GNP impacted by frequent extreme climate events.	Rapid growth and investment to enhance mobility in urban and rural areas. More domestic holidays by train.	Heavily urbanised regions benefit most. Some rural services decline where resources are limited.
Freight transport (overall) increasing	Globalisation, economic growth and peri-urbanisation combine to raise freight demand across all modes.	Regionalisation of logistics limits mileage, but greater demand leads to overall increases on volumes.	Service economy, reduced material consumption, legislation and logistics reduce pace of growth.	Local and regional economies require less freight transport. Culture of localisation in policy and society.
Freight transport (road) increasing	Rapid growth to service expanding economies. Technology streamlines supply chain logistics.	Road is the cheapest mode of freight transport, and thus its dominance is maintained. Policy does not restrict growth	Policies penalises road freight increasing costs. Investment in rail and inland waterways.	Regional patterns of contraction and expansion emerge according to wealth, strength of policy etc.
Freight transport (rail) increasing	Remains a small element of the freight mix. Some growth is funded by private sector investment.	Investment in infrastructure to stimulate growth is low. Rail cannot compete with low cost of road freight.	Low carbon policy framework stimulates increases. Strong growth in long distance freight.	Growth driven by public sector investment geared towards GHG reduction. Some regions cannot afford such spending.
Freight transport (water) increasing	Globalisation and high economic growth accelerates demand for sea freight. Inland water transport also grows	Regionalisation concentrates growth in inland and short sea shipping at the expense of long distance ocean transport.	By weight, volumes fall as shipping emissions are more heavily regulated increasing cost. Canals reinvigorated.	Regional economies have less demand for ocean freight. Environmental policy raises relative cost of shipping.
Transport energy consumption rising	High-tech solutions increase fuel efficiency but cannot offset rapid growth in demand for transport.	Steep increases as population, inefficient technology and limited regulation raise consumption.	Dematerialisation and higher resource efficiency – policy and private sector investment. Greater public awareness.	Continues to rise, particularly in prosperous regions. Some reductions where efficiency measures are promoted.
GHG emissions from transport increasing	Technology provides for some emissions reductions. Rising transport demand and lax regulation drive increases.	Rapid rise in emissions – limited technological progress, high population growth, weak policy framework.	Strong legislation + regulation, public aversion to climate change, efficient technologies, slow population growth.	Continued increases driven by population growth, lack of coordinated policy, and patchy technological progress.
Pollutant emissions from transport falling	Poor government policy response, increase transport demand and limited public concern drive up emissions.	As with GHG emissions, a range of similar factors combine to accelerate emissions.	Most pollutants decline as technology, policy and public awareness stimulate proactive responses.	Many areas introduce reduction measures. Pockets of high emissions around poorer and industrial regions.
Biofuels increasing	Biotech stimulates rapid growth. Policy exhibits scant regard to environmental impacts.	Little investment in alternative fuels. Climate impacts influence growing patterns and locations. High input costs	Biofuels backlash. Impacts on environment acknowledged. Some growth in more sustainable biofuels.	Some investment to increase regional fuel security where conditions are suitable.
Car technology evolving	Growth driven by bourgeoning technology sector. Takes decades for alternatives to become mainstream.	Economic growth and trade is not sufficient on a global scale to support significant expansion of alternatives.	Supported by technology and policy. Stimulated by a severe energy crisis. Reduces fuel consumption and emissions.	Capital investment and policy framework is not sufficient to stimulate growth. Some nodes of growth emerge.
Length of motorway increasing	Network becomes denser to connect groupings of small polycentric towns and cities. Unrestrictive planning policy.	High urban population growth. Expansion focused on prospering areas. Network deteriorates in poorer regions.	Maintenance and limited expansion of existing network connecting key cities and regions.	Some expansion, particularly of short motorways connecting prosperous peri-urban regions.
Car ownership increasing	Peri-urbanisation, wealthy society, dynamic rural areas. Population growth. Eventual market saturation.	Strong growth driven by wealthy regions. Cars remain affordable for the majority of Europe's expanding populace.	Growth slows in the medium term. Growth in long term with spread of alternative fuel technologies.	Slow growth in most regions. Used car market buoyant. Policy supports alternatives in some regions.

Key		
	Acceleration of current trend	(green)
	Continuation of current trend	(light blue)
	Reversal of current trend	(red)

Table 15: 'Wind tunnelling' transport trends through the PLUREL scenarios

Transport: conclusions

As transport ties together the physical elements of societies, there is considerable inertia behind the continuation of particular transport modes and patterns meaning that change ‘on-the-ground’ can be slow (EEA 2007). Ultimately, different transport modes require different physical structures to operate within, and related infrastructure can take years to develop. As a result, individuals and organisations become locked into particular transport choices, and may be reluctant to change once their activities become dependant on certain modes of transport. In Europe, the car has dominated passenger transport with road making up the largest proportion of freight transport, and infrastructure has been developed accordingly. These transport choices have brought with them a specific set of environmental impacts, which have been explored within this discussion. Also, the prevalence of the ‘car culture’ in many societies has brought with it patterns of spatial growth and development that have impacted hugely on peri-urban environments.

It is also important to see transport in the context of evolving corporate and political activity relating to the low carbon economy. Pressures including climate change, potential ‘peaking’ of oil supplies, demand for increasing energy security, and corporate profit motives are focusing attention on the need to diversify the energy mix and reduce the dominance of fossil fuels. Transport is at the heart of this debate as the sector relies on oil for 98% of its energy supplies. Policy makers face significant challenges relating to managing the balance between rising transport demand and the prevalence of fossil fuels in the sector. The outcome of this debate will have significant repercussions for environmental quality and peri-urban land use.

The future of the relationship between transport, environmental quality and peri-urbanisations will be affected by a range of drivers of change operating at the global level. There is considerable uncertainty related to such issues. Indeed, the PLUREL scenarios demonstrate that under a range of possible futures, that the form and function of peri-urban areas could be very different if, for example, fossil fuel prices rose to permanently higher levels, technology evolved rapidly or political support for public transport increased. Taking fuel prices as an example, in the EU 15 unleaded petrol prices have almost doubled since 1991, standing at an average of 1.225 Euros/litre (2006 figures from Eurostat). This trend could feasibly continue, as under the ‘peak oil’ hypothesis. Goodwin et al (2004) note that behavior change usually accompanies higher transport prices, and rising oil prices may ultimately force change in transport patterns. High prices stimulate efficiency improvements, policies to influence demand, and diversification of supply (EC 2006). Higher fuel prices, if sustained, could improve environmental quality if demand for fuel falls. Road transport (passenger and freight) may decline, with positive environmental impacts. If prices remain relatively low, such change may be slower to materialize. In either case, it is apparent that changes in a key factor such as fuel prices would have a considerable impact on peri-urban land use. Despite the uncertainty surrounding future directions of change in the transport sector, this discussion has demonstrated that the outcome of changes will impact on considerably on peri-urban landscapes. It will be important for policy makers to remain flexible in the face of this uncertainty, and to design transport strategies that help to ensure the sustainability of peri-urban areas that acknowledge the crucial role that transport has to play in this arena.

Transport: references

European Communities (2006) Keep Europe Moving – sustainable mobility for our continent, Office for Official Publications of the European Communities, Luxembourg.

European Commission (2006a) European Energy and Transport – Trends to 2030: Update 2005, Office for Official Publications of the European Communities, Luxembourg.

European Environment Agency (2004) Ten key transport and environment issues for policy makers, European Environment Agency, Copenhagen.

European Environment Agency (2005) Air pollution in Europe 1990-2000, European Environment Agency, Copenhagen.

European Environment Agency (2005a) The European environment – state and outlook 2005, European Environment Agency, Copenhagen.

European Environment Agency (2006) Urban sprawl in Europe: the ignored challenge, European Environment Agency, Copenhagen.

European Environment Agency (2007) Europe's environment: the fourth assessment, European Environment Agency, Copenhagen.

European Environment Agency (2007a) Transport and environment: on the way to a new common transport policy, European Environment Agency, Copenhagen.

European Science and Technology Observatory (ESTO) (2003) Trends in vehicle and fuel technologies: scenarios for future trends, European Commission Joint Research Centre and Institute for Prospective Technological Studies, Seville, Spain.

Eurostat: http://epp.eurostat.ec.europa.eu. The Eurostat webpage provides a wide range of statistical data on various topics. There is a section on transport statistics.

International Food Policy Research Institute (IFPRI) (2002) Water and Food to 2025 – dealing with scarcity, IFPRI, Washington DC.

Intergovernmental Panel on Climate Change (IPCC) (1999) Aviation and the global atmosphere - A special report of IPCC working groups I and III. Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, UK and New York, USA.

Scharlemann, J. and Laurance, M (2008) How Green Are Biofuels? Science 4 January 2008: Vol. 319. no. 5859, p.43 - 44

Millennium Ecosystem Assessment (2005) Ecosystems and Human Well-being: Synthesis, Island Press, Washington DC, USA.

Annex A: scenario variables
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Environmental scenario variables

This is a general summary table of the key variables from the scenario framework report D1-3-2:

SRES family. note: growth refers generally to period 2020-2050	A1 – type 'hyper-tech' world globalizing / privatizing	A2 - type 'extreme water' world localizing / privatizing	B1 - type 'peak oil' world globalizing / collectivizing	B2 - type 'fragmentation' world localizing / collectivizing
climate change: CO2 eq emissions (summary of SRES variables)	0.9%	1.4%	0.5%	0.7%
climate change: temperature rise, drought, extreme events	high	high	medium	medium low
environmental driving force: energy prices	low	high	medium	high
environmental infrastructure; peri-urban land % for water, waste, energy	medium	high	medium	high
environmental functions: organic / stewardship agricultural area%	medium	low	high	high
general environmental quality: air, water, soil, biodiversity	medium	low	medium	high
environmental spatial policy: protected / ecological land area as % of total:	low	medium	high	high
environmental 'resilience' of ecological systems under socio-economic pressures	*high*	*low*	*medium*	*medium*
supply side environmental values: business environmental management & CSR	medium	low	high	medium
demand side environmental values: low-impact lifestyles & consumption choices	medium	low	medium	high

Annex B: causal path analysis

These notes are on research work still in progress on the completion of the D1-3-3, Report on Environmental Drivers. The results are due to be published in an academic paper.

At present the notes form an Annex to D1-3-3.

Towards an environmental "causal path framework"

In order to coordinate with the other WPs in Module 1, we are developing a practical 'model' of environmental driving forces. This has been developed as a conceptual framework, i.e. a ***'causal path framework'***, rather than a technical software model, for several reasons:

- There is a need to summarize and formalize the range of detail in the review of environmental driving forces D1-3-3.
- The scope of environmental driving forces is beyond any single technical model:
- The peri-urban is part of a complex city-region system: environmental driving forces affect this alongside many other drivers of change, with synergistic and cumulative impacts.
- Within this there are many multiple causes and effect chains: e.g. when an economic activity causes environmental impact, which has an economic / social impact, which causes further landuse impacts.
- There are also multi-level and multi-scale effects: e.g. when global climate change causes local impacts, or vice versa: or when short term activity causes long term environmental damage, or vice versa.

The implication is that it may be not so useful or practical to identify single causes with single effects.

Rather, we need to identify the most probable and the most significant chains of causes and effects, for each type of location in each type of scenario. This is the approach taken here.

Alternative formats

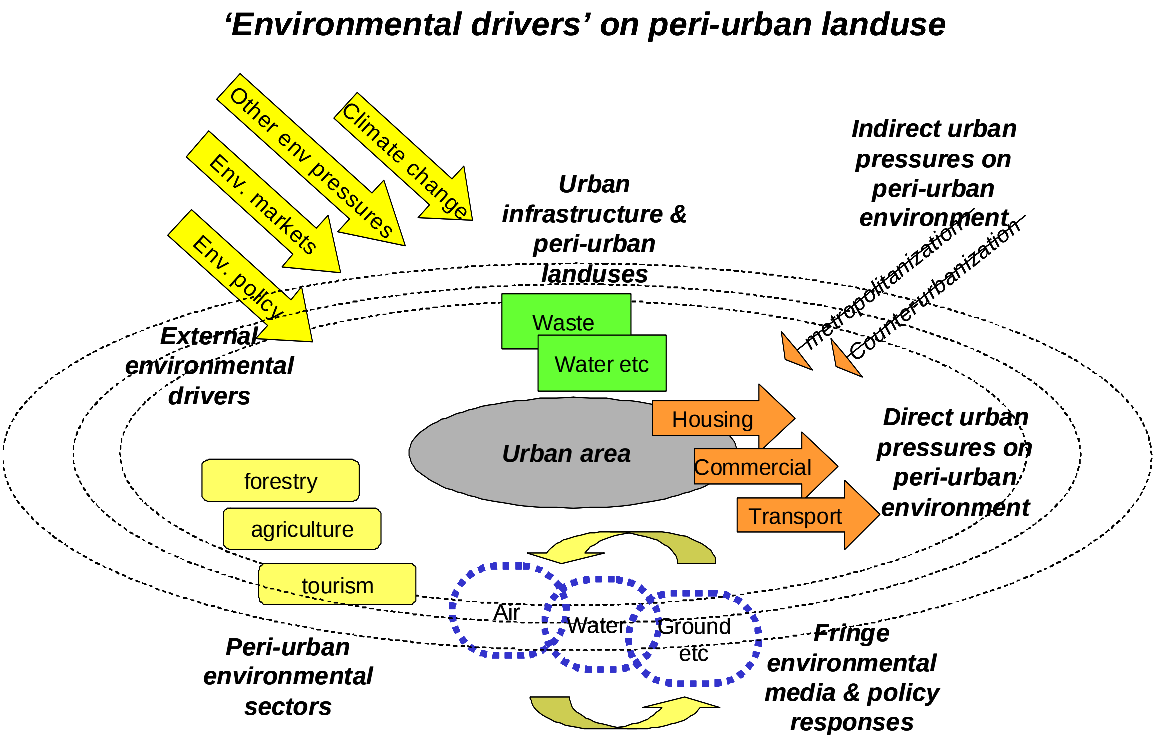
In response this causal path framework has been developed in two main formats:

- System mapping: i.e. flow charts / network diagrams which can form the basis for further technical development, stakeholder deliberation, conflict mediation etc.
- Summary tables, i.e. algorithms which summarize the most significant relationships between a range of variables: environmental driving force, impact type, scenario type and location type.

Scope of the causal path model

The causal path model puts together a set of parameter fields, in order to identify critical sensitivities (as in the concept diagram of Jan 2007):

- Environmental scenario variables: as defined in D1-3-2
- Exogenous environmental driving forces: e.g. climate change effects, energy prices
- Exogenous socio-economic driving forces, impacting on environmental variables: e.g. urban development, transport etc.
- Endogenous environmental sectors: e.g. agriculture, tourism,
- Geographical and peri-urban landuse variables: as defined by M2.
- Environmental / spatial policy & governance variables: as defined by M2.



The causal path framework is then described through a set of tables and a set of flow charts.

The main purpose is to identify in a structured way as far as possible, the 'critical paths', i.e. the chains of cause and effect, which are most significant and sensitive, to variations in one or more of the parameter fields above.

These critical paths can also be described as a set of 'archetypes', or common patterns of extended chains of cause and effect.

For instance the 'Mediterranean city-region archetype', might be driven by climate change in combination with rapid tourism development, which accelerates water shortage, agricultural restructuring, rural migration, and therefore the rate of peri-urbanization.

Each of these has cumulative causes and effects with the pattern of urbanization, socio-economic trends etc.

Environmental causal paths

There are several interesting features on the concept of ‘environmental driving forces’:

- Environmental drivers can cause environmental impacts, or social / economic impacts, as above. Social / economic drivers can cause environmental impacts etc.
- A driver from one perspective can be an impact or state from another perspective.
- Environmental impact and policy response can be drivers for social / economic change .
- Most such causal chains are cumulative and synergistic, as in the Mediterranean example above.
- Many or most environmental factors are deeply embedded and entangled with the social, economic and land use factors.
- ‘Environmental impact’ is not often a simple technical feature, rather very conditioned by cultural, political and institutional factors. For instance the impacts of the 2003 heat wave were magnified by a breakdown in community networks which particularly affected older people.

This all suggests that a method is needed for representing multiple causation, feedback loops and multi-scale effects.

This is the logic here, of the systems mapping approach to a causal path framework.

Scenario archetypes

These are structured by the scenario framework as set out in D1-3-2. These are based on the IPCC scenario set ‘SRES’, extended to include simulated shocks. They are constructed as plausible ‘upper and lower bounds’ of uncertainty in various fields.

The most obvious way to apply the scenarios is to look for geographic archetypes, i.e. typical combinations of location, climate and urban trends.

Below is a set of four geographic archetypes, where environmental factors are embedded into large multiple causal chains. These are arranged around an geographic axis (north – south), and an urbanization axis (growth – decline)

- **Northern climate / high growth** > counter-urbanization >> transport growth >> air quality & biodiversity impacts: Environmental drivers include – Landuse change, biodiversity impacts, transport impacts and policy responses.
- **Southern climate / high growth** > tourism & industry compete for water > displaces local agriculture. Environmental drivers include climate change, water resources.
- **Southern climate / slow growth:** > rural poly-centric region > rural decline > land access problems > soil erosion & flooding. Environmental drivers include soil loss through farm decline, transport & development impacts of new in-migrants.
- **Northern climate / slow growth** > restructuring & perforating city > dis-investment > sporadic development > flooding vulnerability > agriculture decline. Environmental drivers include local pollution & derelict land, and social-economic effects.

These could be mapped simply onto the 4 main scenarios, to produce a set of combined archetypes:

- A1 – (hyper-tech) – landuse demand drivers
- A2 – (extreme water) – climate change drivers
- B1 – (peak oil) – decarbonisation policy, local energy resources
- B2 – (fragmentation) – resource shortages drivers

Summarized in table format, and mapped approximately onto the available case studies:

	SCENARIO TITLE	**MAIN ENVIRONMENTAL DRIVER**	**GEOGRAPHICAL TYPE**	**POSSIBLE CASE STUDY** (note: none of the case studies are perfect matches to the archetypes)
A1	hyper tech	rapid counter-urbanization	northern / high growth: counter-urbanization, transport impacts	Hangzhou ? Warsaw ?
A2	extreme water	rapid climate change, water resource shortage	southern climate / high growth: tourism & rapid change	Koper? Montpelier?
B1	peak oil	rapid decarbonisation policy	southern, slow growth: rural & farm decline	Koper? Montpelier?
B2	fragmentation	rapid decline in resources & environmental quality	northern, slow growing, re-urbanization	Manchester ? Leipzig ? Haagland ?

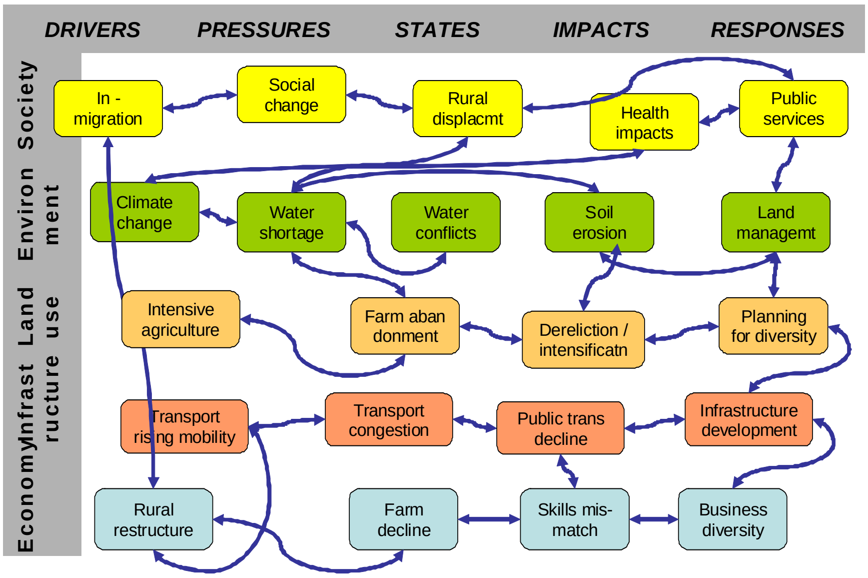
2. Causal path mapping

The flow charts / causal path mappings are shown here in two alternative formats. Each has a purpose and application.

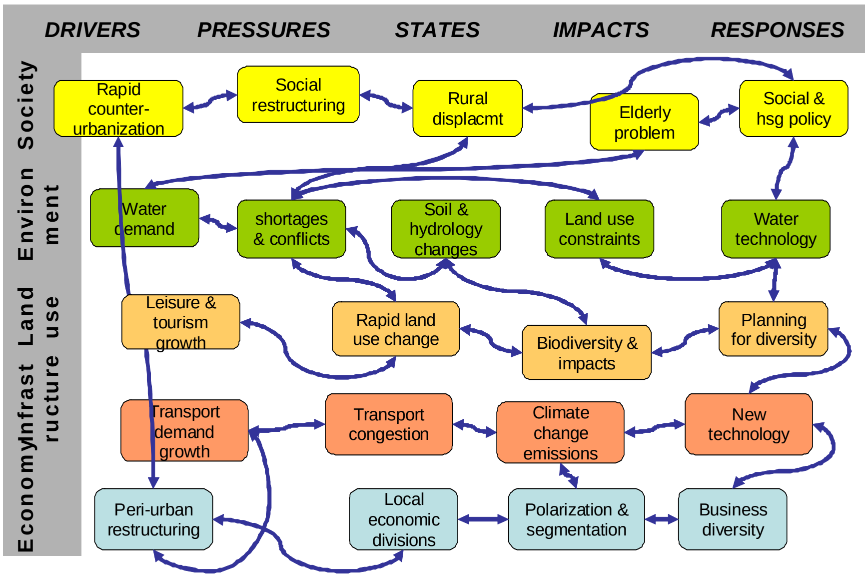
- 'Causal path scenario mapping' looks at the main causal chains on a linear basis, from driving forces to impacts and responses. These are divided into layers – social, environmental, landuse, infrastructure and economic issues.
- Soft systems mapping. This takes a more comprehensive view of many possible links and variables. Using this as a context, then by further analysis, critical paths for different scenarios can be charted out.

Causal path scenario mapping

Causal paths: scenario A2 - extreme water



Causal paths: scenario A1 - hypertech



Soft systems mapping

From experience it is clear that conventional network analysis models are often not very effective in representing such systems, which are multi-level, qualitative and complex. However there is still a crucial task in identifying key linkages, tipping points, sensitivities, policy impacts and so on. We find this is best done in a participative and iterative process with close involvement of experts, users and stakeholders. Some of this may be done within the case studies, but otherwise within the PLUREL this will be a desk study.

The mapping components then each follow a common format, which can be set out in easily accessible graphic form:

- Drivers and upstream factors:
- Impacts, outputs and downstream factors:
- Context and macro-scale factors:
- Responses and interventions

Then the particular systemic qualities can then be explored using the system mapping as a backdrop:

- Feedback loops (reinforcing and balancing)
- Systemic emergence (where the whole is greater than the sum of the parts)
- Analysis of critical paths, sensitivities, pinch-points and thresholds.
- Identifying points for intervention to improve the functionality of the system.

It is then the task of the ‘system mapping framework’ to assemble these into a picture which can be larger as a context mapping, or more focused on one particular problem or policy agenda.

Soft systems mapping approach

The general approach moves from a general expansion and brainstorm stage, through successive steps in analysis. This has the potential to arrive at policy responses to perceived problems.

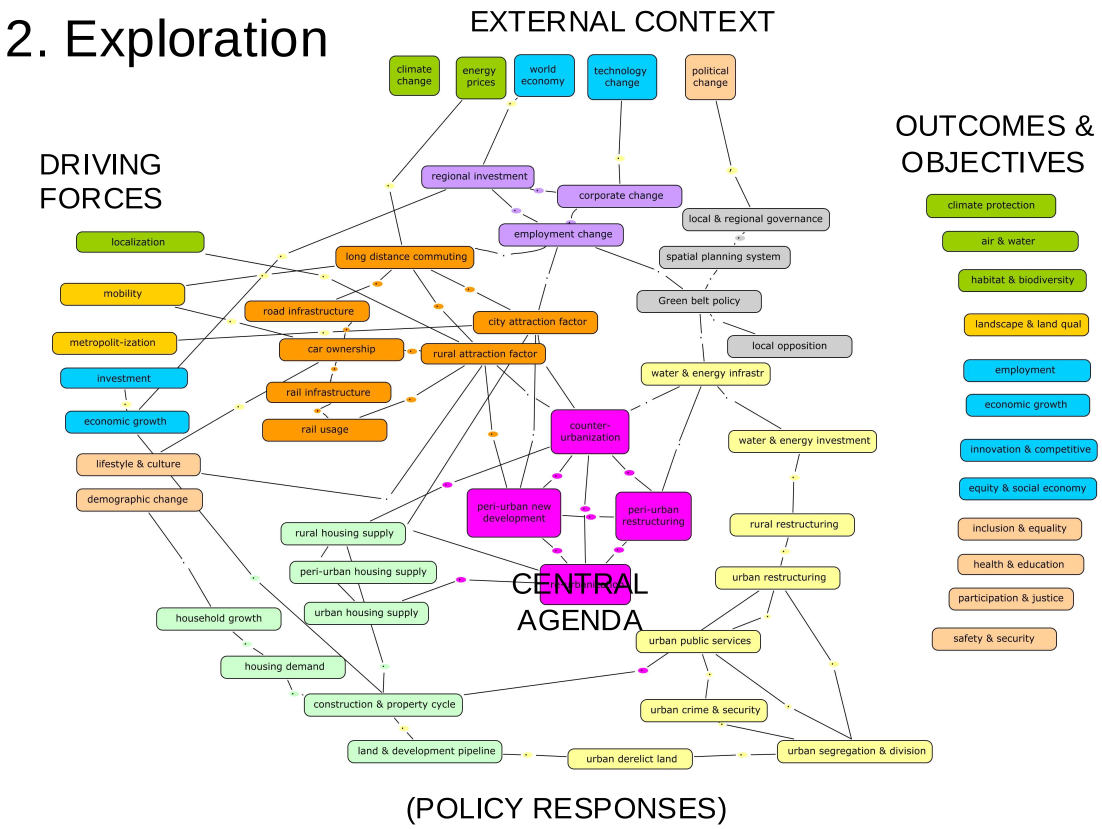
(based on current CURE work with UK Foresight programme).

1. Agenda setting
2. Exploration
3. Clustering
4. Priority links
5. Causal loops
6. Scenario analysis
7. Link analysis
8. Responses
9. Connections

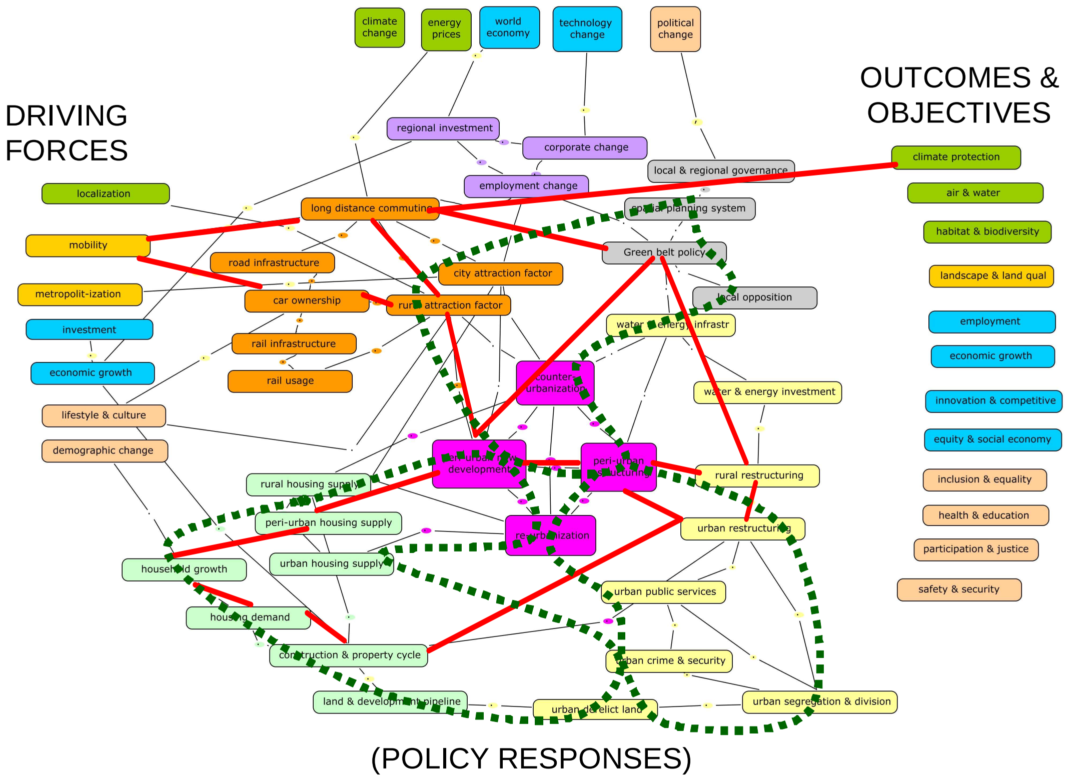
The inputs to this can be from a variety of sources:

- Stakeholder and expert judgements, either direct or through Delphi processes.
- Technical model structures and results, if available and relevant
- Empirical evidence, where available and relevant
- Desk analysis where resources allow

Two examples are shown from a series under development:



5. Causal loops



3. Causal path analytic tables

The approach of the 'causal path analytic tables' is to formalize the results of a) the desk study and b) the systems mapping approach, in terms of critical paths or most significant causal chains. A simple scoring system of 1-5 can be used to evaluate priorities, alongside more detailed notes.

This is done by analysing key combinations of parameters:

- Scenario type by geographical type summary (as above)
- Combined archetypes: Social / economic / environmental themes, by environmental driver, pressure, state, impact & response (i.e. the first set of flow charts)
- More detailed if necessary: environmental driver by peri-urban land / environmental impact

Causal path archetype table

This is a more formal version of the flow charts above.
This table is to be re-iterated for each scenario / geography combination.
The example shown is the 'extreme water scenario / Mediterranean location' combination.
This archetype is sensitive to the climate change driver (shown in capitals), but this then enters a complex system of causes and effects.

	CLIMATE CHANGE SCENARIO/ MEDITERRANEAN LOCATION						
		DRIVING FORCES	**PRESSURES**	**STATES**	**IMPACTS**	**RESPONSES**	**CONTEXT FACTORS**
	social issues	growth in leisure & tourism	traditional patrimonial tenure systems	decline in social resilience	social change & disruption	community re-vitalization programmes	
	environmental issues	**CLIMATE CHANGE >>>>>>**	droughts & water shortage	falling water tables & decline in quality	vulnerability of water intensive sectors	climate resilience & increase water efficiency	
	landuse issues	rapid peri-urban development, esp on coast	pressure on low yield agriculture	farm abandonment	acceleration of peri-urbanization	integrated spatial planning	
	infrastructure issues	spread of transport infra	spread of treated water infrastructure		obsolete tradition water management	responsive infrastructure development	
	economic issues	foreign direct investment	diversion of water to leisure & intensive agri	decline of traditional rural economy	rapid re-structuring & economic migrants	rural diversification programmes	

Scenario / location matrix

This is the summary of the causal path framework, i.e. it should be derived from the more detailed studies in the environmental baseline and drivers reports.

This then identifies the most significant environmental drivers: with a more detailed spatial analysis for each of the environmental location types:

- Green infrastructure: i.e. in and around urban areas
- Urban fringe: i.e. close proximity to urban areas and settlements
- Peri-urban areas: i.e. the ‘water-shed’, ‘commuter-shed’ or ‘functional economic zone’.
- Rural-urban region: a more strategic regional level

PLUREL

ENVIRONMENTAL VARIABLES	A1 – type ***'HYPER-TECH' WORLD*** rapid counter urbanization, hi-technology hazards	A2 - type ***'EXTREME WATER' WORLD*** accelerated climate change impacts & extreme events	B1 - type ***'PEAK OIL' WORLD*** responses & adaptation to decline in fossil fuels	B2 – type ***'FRAGMENTATION' WORLD*** decline in resource availability, environmental pollution
Geography Type				
HIGH GROWTH / SOUTHERN				
green infrastructure	technology solutions for blue-green infrastructure (BGI) in arid climate	use of BGI for climate change adaptation & flood resilience	use of BGI for non-motorized transport modes	fragmentation of BGI due to community tensions & environmental stress
urban fringe	new forms of suburban development for arid climates	development pressure on land subject to flooding / drought	re-urbanizing urban fringe development	fringe development struggles with environ. pollution legacies
peri-urban areas	land demand for housing, leisure etc: impacts on habitats	development pressure on land subject to flooding / drought	switch to public transport: consolidation of settlement patterns	community enclaves compete for best environments & water availability in arid region.
rural urban region	restructuring of urban pattern and landscape management for arid region	restructuring of water & agriculture etc to cope with extreme events, in privatized world	new renewable energy sources: strategic infrastructure for public transport	localized resource extraction e.g. minerals, forestry, agriculture: water resource conflicts
HIGH GROWTH / NORTHERN				
green infrastructure	Etc			
urban fringe	Etc			
peri-urban areas				
rural urban region				
LOW GROWTH / SOUTHERN				
green infrastructure				
urban fringe				
peri-urban areas				
rural urban region				
LOW GROWTH / NORTHERN				
green infrastructure				
urban fringe				
peri-urban areas				
rural urban region				