5. The Potential Environmental Impacts of Climate Change in London

5.1 Introduction

There are several approaches to climate change impact assessment. These include: extrapolating findings from existing literature; fully quantitative, model-based simulations of the system(s) of interest; or eliciting the opinions of experts and stakeholders. All three approaches will be implemented in this section by a) reviewing the formal literature where appropriate, b) undertaking exemplar impacts modelling for specific issues identified through c) dialogue with stakeholders. Two workshops were held in May 2002 in order to engage expert and stakeholder opinion regarding the most pressing potential climate change impacts facing London. Following stakeholder consultation, five environmental areas were highlighted: 1) urban heat island effects (including London Underground temperatures); 2) air quality; 3) water resources ; 4) tidal and riverine flood risk and 5) biodiversity. Although these are addressed in turn – and where appropriate, case studies have been included – it is also acknowledged that many of these are cross-cutting (for example, river water quality impacts relate to flood risk, water resources and biodiversity). The final section delivers a summary of the most significant environmental impacts of climate change for London. Policy responses are addressed elsewhere.

5.2 Higher Temperatures

5.2.1 Context

Throughout this section the reader is invited to refer to the downscaling case study provided in Section 4.7). Heat waves may increase in frequency and severity in a warmer world. Urban heat islands exacerbate the effects of heat waves by increasing summer temperatures by several more degrees Celsius relative to rural locations (see Figure 3.2b). This can lead directly to increases in mortality amongst sensitive members of the population (Kunst et al., 1993; Laschewski and Jendritzky, 2002). For example, the heat waves in the summers of 1976 and 1995 were associated with a 15% increase in mortality in greater London (Rooney et al., 1998). Conversely, it has been estimated that 9000 wintertime deaths per year could be avoided by 2025 in England and Wales under a 2.5ºC increase in average winter temperatures (Langford and Bentham, 1995).

5.2.2 Stakeholder Concerns

Rising ambient air temperatures in central London may have significant impacts on air temperatures experienced across the London Underground network. However, projecting future summer temperatures in the network is not straightforward because the outcome depends on assumptions about the number of passengers, frequency of trains, station design and depth below the surface, as well as on air humidity and levels of ventilation (typically low, with mixing ratios ~10%). Furthermore, passenger comfort often reflects the difference in temperature between above ground, the stations and the trains, rather than the absolute temperature *per se*. Nonetheless, an intensified heat island combined with regional climate warming, could pose difficulties for the future operation of cooling and ventilation equipment. The siting of intakes, for example, must take into account the vertical heat profile, whilst cooling effectiveness is largely governed by minimum ambient air temperature. (The Chartered Institute of Building Services Engineers has recently revised design temperatures from 28ºC to 30ºC). Although some data and model results are available for the new terminal at King's Cross, there are no long-term temperature records for the wider network. Until such monitoring systems are in place, claims of rising underground temperatures and possible links to climate change will remain largely anecdotal.

In addition to the issues raised above, stakeholder engagement highlighted further potential impacts related to increased urban temperatures arising from the *combined* effect of regional climate change and an intensified urban heat island (Table 5.1).

Table 5.1 Potential temperature related impacts identified by stakeholders

Associated Impacts
• Increased demand for water for irrigating green spaces; • Higher risk of fires on scrub and heathland; • Lower incidence of winter 'fuel poverty' and related cold-weather mortality; • Outdoor lifestyles change levels of exposure to air pollution (see below); • Modes of transport could shift (more walking and cycling); • Energy use for summer cooling could exceed energy saved through less winter warming; • Higher rates of refuse decay implying need for more frequent waste collection; • Successive hot summers could have a compound impact exceeding isolated hot summers.

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A case study of changes to London's heat island intensity is given in Section 4.7.

5.2.3 Adaptation Options

There exist a range of established but non-trivial techniques for countering the effect of rising temperatures in urban areas. These include: reducing building densities; changing building height, spacing and street orientation to increase shade and reduce insolation receipt; enhancing natural ventilation through a variation of building height and density; achieving effective solar shading using trees and vegetation; use of high-albedo (reflective) building materials; improved building and cooling system design; and incorporation of large areas of vegetation and water features within the urban landscape (Oke, 1987). For example, detailed monitoring shows that air moving along the edge of the River Thames, or within urban parks, is on average 0.6ºC cooler than air in neighbouring streets (Graves et al., 2001). In Chicago's Urban Heat Island Initiative there is a programme of greening hard spaces by installing rooftop gardens and replacing hard surfaces such as school playgrounds with grassed areas (see: http://www.cityofchicago.org/Environment/AirToxPollution/UrbanHeatIsland/). As well as countering urban heat island effects, more widespread green space and vegetation in the City is also beneficial for flood control (see Section 5.5.3).

5.3 Air Quality

5.3.1 Context

Air pollution is already a serious health problem in many cities even under the current climate (Anderson et al., 1996; COMEAP, 1998). Climate change is expected to cause further deterioration in air quality in large urban areas. This is because future weather will have a major influence on the production, transport and dispersal of pollutants. Any increase in the frequency of hot, anticyclonic weather in summer will favour the creation of more temperature inversions trapping pollutants in the near-surface layer of the atmosphere. For example, it has been estimated that a 1 degree Celsius rise in summer air temperatures (also a proxy for the amount of catalysing sunshine) is associated with a 14% increase in surface ozone concentrations in London (Lee, 1993).

Higher air temperatures increase natural and man-made emissions of volatile organic compounds (VOCs) (Sillman and Samson, 1995), exacerbating the health effects of ozone pollution (Sartor et al., 1995). Climate change is also expected to affect the seasonality of pollen-related disorders such as hay fever (Emberlin, 1994). Meteorological factors are shown to exert strong controls on the start date and length of the pollen season (Emberlin, 1997), as well as the total pollen count (Takahashi et al., 1996). Acute asthma epidemics have also been linked to high pollen levels in combination with thunderstorms (Newson et al., 1998). During one such event in 1994 London health departments ran out of drugs, equipment and doctors (Davidson et al., 1996). Finally, deteriorating air quality as a result of climate change could have secondary impacts on the vitality of urban forests and parkland. For example, surface ozone has adversely impacted the structure and productivity of forest ecosystems throughout the industrialised world (Krupa and Manning, 1988). Levels of acid deposition are also closely linked to the frequency of large-scale weather patterns across the UK (Davies et al., 1986).

5.3.2 Stakeholder Concerns

In addition to the issues raised above, stakeholder engagement highlighted further potential air quality impacts related to climate change (Table 5.2).

Table 5.2 Potential air quality impacts identified by stakeholders

Associated Impacts
• Outdoor lifestyles change levels of exposure to air pollution;
• Air pollution damages building fabric and aesthetics of urban landscapes;
• Homeowner preference for relatively unpolluted suburbs (but higher ozone levels here);
• Indoor and underground air quality may change;
• Greater incidence of fire-related air pollution (smoke);
• Higher dust and VOC concentrations are associated with building programmes;
• Greater odour problems associated with waste disposal and standing water bodies;
• Export of pollution to surrounding regions through increased tourism and air travel.

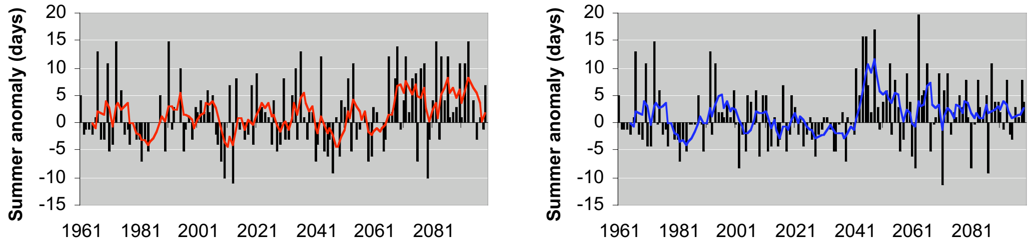
5.3.3 Case Study

Changes in the frequency of weather-related pollution episodes

As noted previously, weather patterns are a strong determinant of ambient air quality and pollution episodes (O'Hare and Wilby, 1994). Therefore, future air pollution concentrations in London will reflect local and regional patterns of emissions, as well as the frequency of large high-pressure systems over the south-east. Whilst it is beyond the scope of the present study to model the complex interactions between pollutant emissions, photochemistry, transport and dispersal, it is possible to speculate about the future frequency of 'pollution-favouring' weather patterns. Whereas vigorous westerly airflows favour the dispersal of pollutants, stagnant anticyclonic weather provides ideal conditions for *in situ* pollution episodes (e.g., Bower et al., 1992).

Figure 5.1 shows the change in the frequency of high pressure systems over the EE grid-box (Figure 4.2) under the Medium-High Emissions and Medium-Low Emissions scenarios. Under the Medium-High Emissions there is an average increase in the frequency of pollution episodes of over 4 days per summer by the 2080s compared with the 1961 to 1990 mean. The change under the Medium-Low Emissions is a little over 2 days per summer by the 2080s. A shift to more frequent airflows from the east and south-east (shown in Figure 4.8) would also favour more frequent incursions of (polluted) air from continental Europe (O'Hare and Wilby, 1994). However, Figure 5.1 indicates considerable inter-annual variability in the frequency of summer pollution episodes, and caveats related to future airflows projections by HadCM3 apply (see Section 5.2). Notwithstanding significant reductions of diffuse emissions over north-west Europe, the model projections are still indicative of deteriorating air quality conditions for London under future climate change.

Figure 5.1 **Change in the number of summer weather patterns favouring pollution episodes over the Eastern England grid-box under the Medium-High Emissions (left column) and Medium-Low Emissions (right column) scenarios, with respect to the 1961 to 1990 average.**



5.3.4 Adaptation Options

Actions to improve air quality in London cannot be considered in isolation from those designed to reduce greenhouse gas emissions, however, more attention needs to be paid to diffuse sources - in particular, those linked to the transport infrastructure (Wade et al., 2001). This could take the form of: new fiscal and voluntary initiatives to control emissions; traffic restrictions; improved public transport systems; incentives to promote carpooling; pollution warning services (e.g. London Air Quality Network, http://www.erg.kcl.ac.uk/london/asp/home.asp). Such endeavours should be underpinned by regional inventories of pollution sources, as well as by systems for continuous monitoring of key pollutants and relevant weather variables.

The Association of London Government is working with the Greater London Authority and others on a feasibility study for creating a Low Emission Zone for London which would ban disproportionately polluting vehicles such as heavy goods vehicles, This would be done using statutory mechanisms. A licensing regime to clean up buses and taxis is also being considered.

5.4 Water Resources

5.4.1 Context

Climate induced changes in water resources may have far reaching consequences for society, the economy and terrestrial ecosystems. Global patterns of change are broadly in line with changes in annual precipitation, resulting in decreased summer soil moisture (Gregory et al., 1997) and annual runoff at mid-latitudes (Arnell, 1999). However, it is important to recognise that natural variations in rainfall-runoff (which are typically large) can exceed human-induced climate changes to runoff for many regions (Hulme et al., 1999). At the national scale, several studies have suggested increases in UK winter runoff, accompanied by decreases in summer runoff, most notably in the south (Arnell, 1998; Arnell and Reynard, 1996; Pilling and Jones; 1999; Sefton and Boorman, 1997). Most recently, the UKCIP02 scenarios indicate a decrease in average soil moisture both annually and in summer that is most severe, again, in the southeast (Hulme et al., 2002). In the Thames region, 55% of the effective rainfall that falls annually is abstracted, amounting to about 5000 Ml/d, of which 86% is used for public water supply. Even without climate change, the present balance of supply and demand is in deficit by some 180 Ml/d (EA, 2001c).

Catchment-scale studies undertaken in the Thames region highlight the control exerted by local variations in geology (Davis, 2001; Wilby, 1994), landuse change, surface and groundwater abstraction on river flows (Wilby et al., 1994). For example, using monthly factors from the UKCIP98 scenarios, summer baseflows in chalk catchments are slightly enhanced as a result of greater winter recharge, but decline in clay and urban catchments where the potential for enhanced groundwater recharge is lower (Davis, 2001). Nonetheless, all UKCIP98 scenarios and gauging stations considered showed an overall increase to water resources of 2.5% to 6% by the 2020s, noting that by this time the temperature change is less than 1.4ºC. Unfortunately, no studies have evaluated the risks beyond the 2020s, or those associated with back-to-back drought years, to which the aquifers of the southeast are vulnerable. It is also anticipated that the (hotter/drier) UKCIP02 scenarios will yield a less favourable resource situation than UKCIP98 (see below).

Water supplies can be disrupted through deteriorating quality, and climate change has the potential to affect river water quality in several ways. For example, lower summer flows in clay catchments will reduce the volume available for dilution of treated effluent in receiving water courses, and increase the potential for saline intrusions. River water temperatures will increase with higher air temperatures, but the overall climate sensitivity will be least for catchments with large groundwater components (Pilgrim et al., 1998). Higher nutrient concentrations and river water temperatures can in turn encourage the growth of algal blooms and other plants which deoxygenate the water body. In the absence of mixing, decreased cloud cover and higher summer temperatures over the southeast also favour the thermal stratification of standing water bodies, leading to increased algal growth and raw water treatment costs (Hassan et al., 1998). Finally, warmer, drier conditions enhance the decomposition of organic nitrogen, thus increasing the potential for river and groundwater contamination (Murdoch et al., 2000). Crack formation through clay shrinkage will result in more direct hydrological links between the soil surface and groundwater, further increasing the risk of nutrient losses to aquifers (Rounsevell et al., 1999).

In addition to water availability and impact on the natural environment, climate change also affects water resource planning through changing patterns of water demand (Herrington, 1996). For example, domestic water use is expected to increase as a result of hotter summers leading to increased garden watering and personal washing. According to Environment Agency estimates, outdoor water use will increase public water supply demand in the Thames Region by approximately 50 Ml/d by 2025 due to climate change (EA, 2001c). The impact of climate change on industrial water use will be felt most keenly where consumer demand for products is temperature dependent (e.g., the food and drinks industry), or where industrial processes are less efficient at higher temperatures (e.g., water cooling for power generators).

5.4.2 Stakeholder Concerns

In addition to the issues raised above, stakeholder engagement highlighted further potential water resource impacts related to climate change (Table 5.3).

Table 5.3 Potential water resource/quality impacts and responses identified by stakeholders

- London's water supply will be affected by climate change impacts outside of the Thames Region;
- Higher winter temperatures will reduce leakage due to burst pipes as a result of freezing;
- Wetter winters will lead to expansion of clay and more leaks/bursts in the mains network;
- Drier soils and subsidence of clay soils will increase leakage in summer;
- Greater competition for finite resources between domestic and environmental needs;
- Greater variability in water supply could be reflected in seasonally variable water tariffs;
- Development of any new reservoir(s) will compete with other land use demands;
- Public health and hygiene issues associated with reduced water supply/increased cost;
- Greater use of grey water and rainwater harvesting;
- More local abstractors, treatment and usage of rising groundwater;
- Greater use of artificial groundwater recharge;
- Reluctance of metered water users to respond to water-saving appeals;
- Increased awareness of environmental 'costs' of water consumption;
- Development and deployment of more innovative water resources options;
- Increasing awareness amongst the population to use water wisely.

5.4.3 Case study

Soil moisture and water balance changes in the Rivers Kennet and Loddon
For this study, a preliminary assessment was made of potential water resource impacts for two tributaries of the Rivers Thames. Soil moisture deficits (SMDs) were modelled for the Rivers Kennet and Loddon under the Medium-High Emissions and Medium-Low Emissions scenarios (Appendix C). Figure 5.2 shows the anomalies in the annual maximum SMD, and the length of the recharge season with respect to the 1961-1990 average for the River Kennet. Table 5.4 reports mean changes in the water balance and recharge for the 2020s, 2050s and 2080s. Figure 5.3 and Table 5.5 provides equivalent results for the River Loddon. In both catchments, there is a general decline in annual precipitation of between 1 and 9% by the 2080s, accompanied by a reduction in AET of 6 to 10%, despite higher air temperatures. This apparent

paradox is explained by drier summer soils limiting the rate of surface evaporation – a feature supported by recent PE observations (Marsh, 2001). The net effect of lower precipitation and reduced AET amounts is a rise in the annual maximum SMD, most notably from the 2060s onwards. Drier soils, in turn, imply more clay shrinkage induced subsidence and mains leakage (Doornkamp, 1993).

Figure 5.2 Changes in maximum soil moisture deficits (SMDs) and length of recharge season in the River Kennet catchment (Medium-High Emissions, and Medium-Low Emissions, downscaled), with respect to the 1961 to 1990 average

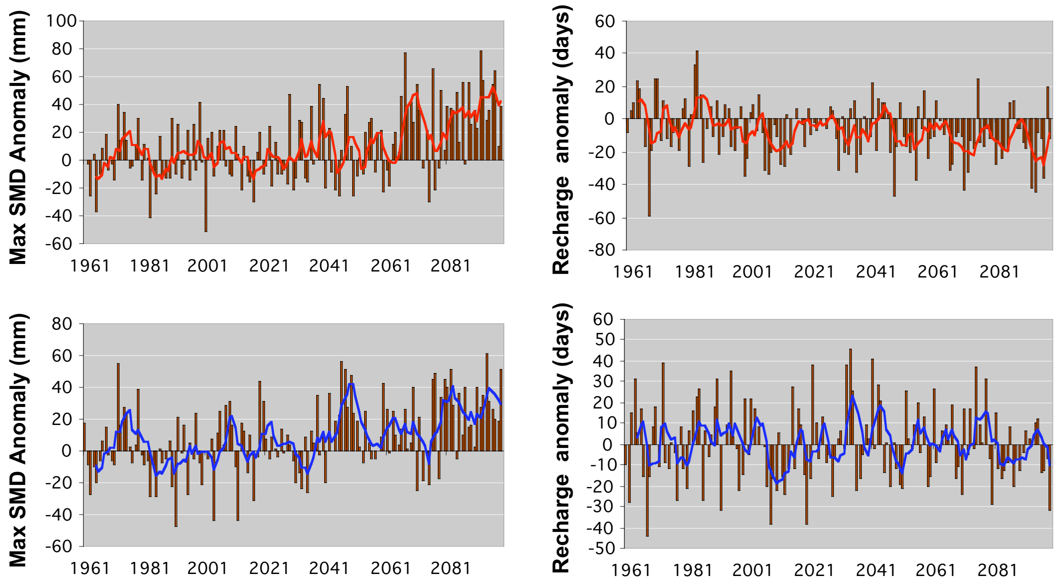
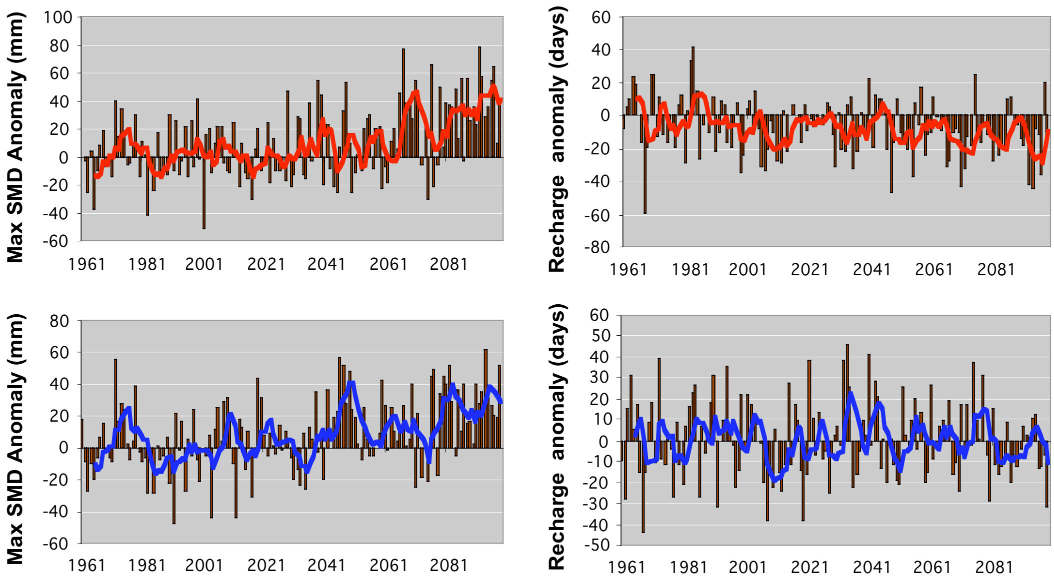


Figure 5.3 Changes in maximum soil moisture deficits (SMDs) and length of recharge season in the River Loddon catchment (Medium-High Emissions, and Medium-Low Emissions, downscaled), with respect to the 1961 to 1990 average



Drier soils at the end of the water year also mean that more precipitation is required for re-wetting to saturated conditions under which groundwater recharge or surface runoff is assumed to occur. As a consequence, the length of the recharge season declines by up to 8 days in the 2050s and by as much as 14 days by the 2080s, compared with an average recharge season of 60 days between 1961 to 1990. In the River Loddon, autumn and winter recharge declines by 4 to 6% by 2050s, and by 3 to 10% by 2080s. The change for the River Kennet is not so consistent with a 7% increase in recharge with little or no apparent change in the annual precipitation under the Medium-Low Emissions scenario, suggesting that there has been a greater concentration of precipitation during the active recharge period. In contrast, the 8% decline in precipitation under the Medium-High Emissions scenario nets a 10% reduction of recharge by the 2080s.

Finally, although runoff was not explicitly modelled in either case study it approximates recharge in the long-run (assuming zero abstraction), suggesting that the annual resource might change by between +7% (Kennet, Medium-Low Emissions) and –10% (Kennet and Loddon, Medium-High Emissions) by the 2080s.

Table 5.4 Changes in River Kennet water balance terms, the annual maximum soil moisture deficit (SMD), and length of the recharge season under the Medium-High Emissions and Medium-Low Emissions scenarios (downscaled)

	Precipitation (%)		Actual evaporation (%)		Recharge (%)		Maximum SMD (%)		Recharge season (days)*	
	M-H	**M-L**	M-H	**M-L**	M-H	**M-L**	M-H	**M-L**	M-H	**M-L**
2020s	-2	+2	0	0	-5	+6	+4	+1	-8	+1
2050s	-2	0	-2	-5	-1	+8	+10	+14	-8	+1
2080s	-8	-1	-7	-6	-10	+7	+23	+18	-14	-1

* Change in the number of days resulting in potential groundwater recharge from saturated soils

Table 5.5 The same as Table 5.4, but for the River Loddon

	Precipitation (%)		Actual evaporation (%)		Recharge (%)		Maximum SMD (%)		Recharge season (days)*	
	M-H	**M-L**	**M-H**	**M-L**	**M-H**	**M-L**	**M-H**	**M-L**	**M-H**	**M-L**
2020s	-8	+2	-3	+1	-18	+4	+8	+1	-6	-2
2050s	-3	-5	-4	-5	-3	-6	+12	+14	-5	-7
2080s	-9	-6	-10	-7	-10	-3	+27	+19	-10	-8

* Days resulting in potential groundwater recharge from saturated soils

5.4.4 Adaptation Options

Water managers are already accustomed to adapting to evolving resource situations, and extreme events in the recent hydrological record (e.g., droughts of 1921, 1934, 1976, 1988-1992, 1995-1997) provide useful analogues of future climate change. Nonetheless, there are a range of supply- and demand-side adaptive options currently under consideration for the Thames Region (EA, 2001c). On the supply-side: development of new resources including additional reservoir capacity (Abingdon), strategic bulk transfers (Grafham to Three Valleys), desalination, transfers via the Grand Union and Oxford canals, small local use of rising groundwaters and artificial recharge (in the London Basin), indirect reuse of wastewater, transfers (River Severn to Farmoor reservoirs), improved infrastructure, treatment and supply systems. On the demand-side: reductions in leakage, extension of household metering, development and promotion of water conservation measures for domestic and industrial users (including water efficient appliances), time-limited or flexible abstraction licenses. In addition, it is recommended that water efficient fittings should be a requirement of planning permissions for all new developments (Wade et al., 2001).

The question naturally arises as to what extent the Thames water resource strategy (EA, 2001c) might be affected by climate change? This can only really be answered through an integrated regional water resource modelling exercise, that incorporates more climate change detail within the Agency's four socio-economic scenarios. Alternatively, research could be targeted at critical elements in the strategy, such as modelling the reliable yield of a new reservoir, or levels of leakage, under the full set of UKCIP02 scenarios.

5.5 Flood Risk

5.5.1 Context

Both observations (Frei and Schar, 2001; Karl and Knight, 1998; Osborn et al., 2000) and climate models (Jones and Reid, 2001; McGuffie et al., 1999; Palmer and Räisänen, 2002) support the view that the frequency and intensity of heavy rainfall increased during the 20th Century, and will continue to increase in coming decades, particularly during the non-summer seasons. However, there have been very few credible studies of riverine flood risk in relation to climate change. This is a reflection of the difficulties associated with adequately modelling high-intensity precipitation (or snowmelt) events at catchment-scales, and of representing land-surface controls of storm runoff generation (Bronstert et al., 2002).

Assessing flood risk for London is problematic, not least because of the extent of the urban drainage system, and the localised effects of blocked culverts (open watercourses which have been covered over i.e. at road crossings, culverts may also run under buildings) and/or exceedance of hydraulic capacity of sewers. In addition, future flooding of the Thames estuary will require consideration of complex interactions between sea level rise, runoff from land areas and storminess (Holt, 1999; Lowe et al., 2001; Von Storch and Reichardt, 1997). Accordingly, flood risk will be considered from three overlapping perspectives: 1) riverine flood risk; 2) the design capacity of urban drainage systems and; 3) tidal surges/sea level rise.

5.5.2 Case Study

Riverine flood risk in the Thames Region

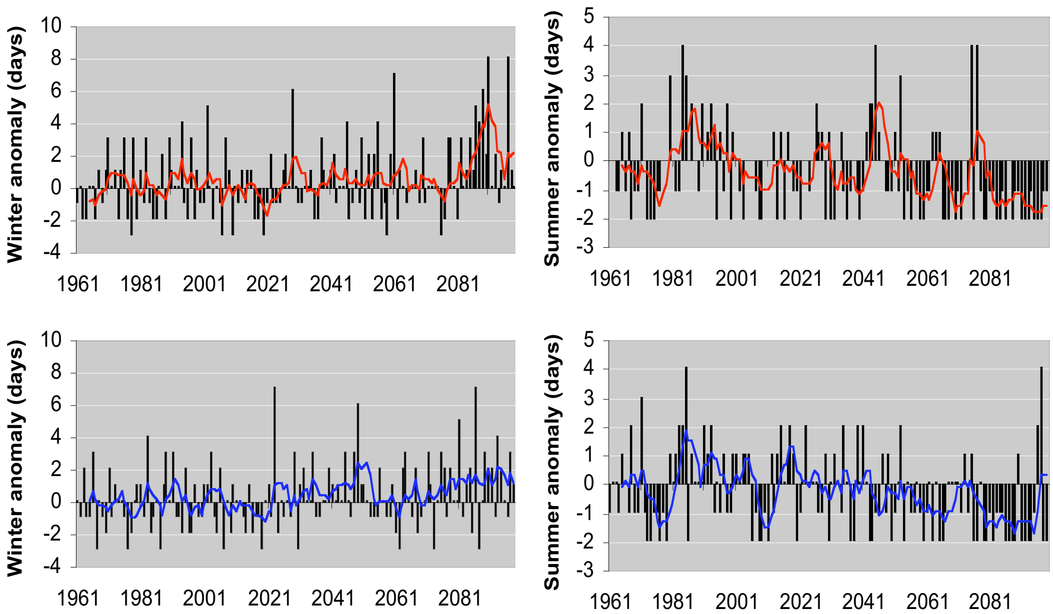
A simplistic climate change impact assessment – illustrated below – is to infer future riverine flood risk from future changes in extreme precipitation events. For example, in a recent pilot study, the regional climate model HadRM2 (the predecessor of the model used in UKCIP02) predicted future increases in the magnitude of rainfall extremes of 30- and 60-day duration (as experienced in the flooding of October/November 2000) over catchment areas influencing river levels in Lewes, Shrewsbury and York (CEH and Meteorological Office, 2001). Other studies have examined changes in effective rainfall (as a proxy for discharge) obtained directly from global climate models for large river basins (e.g., Milly et al., 2002), or downscaled meteorological variables to the scale of an experimental watershed for hydrological modelling (e.g., Pilling and Jones, 2002).

Government estimates suggest that the value of protected land and property within the Thames region tidal Thames flood risk area is £80 billion giving a flood damage estimate of the order of £30 billion (DEFRA, 2001). With growing demand for new housing in London and the preferred use of brownfield sites (often situated within the floodplain), these figures are set to increase notwithstanding changes in climate. The river defences of central London are designed to withstand floods of a 0.1% probability (i.e., a 1 in 1000 year event), however the standards of protection to some limited Thames-side areas and on many of the tributary rivers are lower. The effects of climate change are likely to reduce the standard of protection of existing defences through rising sea levels, rising groundwater, and/or increased storm magnitudes. For example, under the UKCIP98 High scenario, the 100 year return period (naturalised) daily flow at Kingston on the Thames is predicted to increase by 13% by the 2020s (Davis, 2001). Flood risk maps in catchments with significant groundwater contributions will also need to be re-evaluated in the light of enhanced winter recharge and antecedent baseflows (Wade et al., 2001).

For the purposes of this current study the statistical downscaling model SDSM was calibrated using 1961 to 1990 areal average daily precipitation totals for the Thames Region (see Section 3.3), and climate variables for the SE grid-box (Figure 4.5). Significant correlations were found between the daily precipitation amounts and several regional climate indices (near surface humidity, zonal airflow strength, vorticity, mean sea level pressure, and 850 hPa geopotential heights – a measure of the thickness of the atmosphere). Once calibrated, SDSM was then used to produce future estimates of the daily precipitation under Medium-High Emissions and Medium-Low Emissions scenarios.

Under both scenarios there is a slight increase in the number of winter rainfalls exceeding 12.5 mm/d by the 2080s, suggestive of greater flood risk by this time (Figure 5.4). Far more remarkable is the strong decline in the summer incidence of these events (which on average occurred just over twice per summer in the period 1961 to 1990). Under this scenario, the *frequency* of pollution events associated with the 'flushing' of combined sewer outflows (CSOs) would be expected to decline by the 2080s. However, this trend could be countered by an intensified heat island triggering more convective instability and localised thunder storms under marginal conditions (Atkinson, 1968). Furthermore, even with fewer events, the *polluting potential* from the flushing of CSOs could still be greater due to a combination of less diluted stronger sewage (due to lower summer infiltration to sewerage systems) and/or lower flows in the receiving water course(s). Wash-off pollutants, accumulated by impermeable surfaces such as roads during extended dry periods, could also adversely affect water quality.

Figure 5.4 Number of days in the Thames Region with winter (left column) and summer (right column) precipitation totals above 12.5 mm/d (Medium-High Emissions, and Medium-Low Emissions, downscaled), with respect to the 1961 to 1990 average



Longer-duration precipitation totals are also of interest following the October/November 2000 flooding (CEH and Meteorological Office, 2001). The annual rise in the 30- and 60-day duration autumn-winter totals is almost imperceptible under both the Medium-High Emissions and Medium-Low Emissions scenarios (Figure 5.5). However, beyond the 2050s, extreme precipitation events of 30- and 60-day duration do increase in magnitude (Table 5.6). For example, by the 2080s the 60-day precipitation event that occurs on average 1 in 10 years (i.e., probability 0.10) increases in magnitude by 10%, whereas the 1 in 20 year event (probability 0.05) increases by 16%. For both the 30- and 60-day events, the rarer the event (i.e., lower probability of occurrence) the greater the magnitude change. These results suggest that extreme precipitation events of the type experienced in late-2000 will become more common in the future – a result that is entirely consistent with UKCIP02 scenarios (Hulme et al., 2002).

Figure 5.5 **The 60-day duration autumn-winter maximum precipitation for the Thames Region (Medium-High Emissions, and Medium-Low Emissions, downscaled), with respect to the 1961 to 1990 average.**

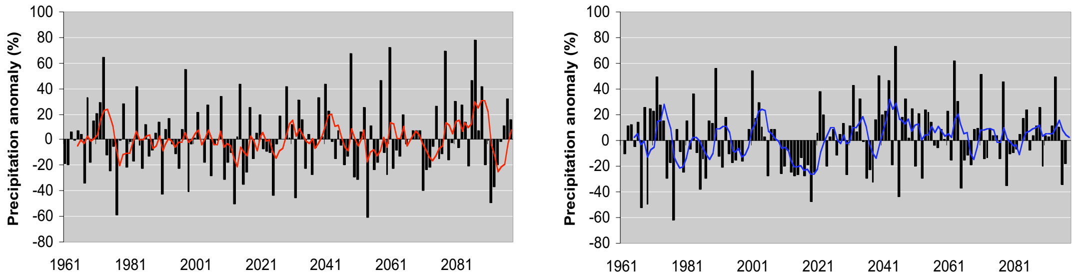


Table 5.6 **Percentage change in Thames Region 30- and 60-day duration autumn/winter maximum precipitation totals under the Medium-High Emissions scenario (downscaled)**

Scenario	Probability level (30-day event)			Probability level (60-day event)		
	0.5	0.10	0.05	0.5	0.10	0.05
2020s	-5	-6	+1	-4	+1	0
2050s	-5	-4	+10	-1	+11	+15
2080s	+4	+3	+8	-1	+10	+16

5.5.3 Urban Drainage Systems

Urban expansion over the last 200 years has resulted in the loss of several open rivers within central London such as the Fleet, Tyburn and Effra that now flow underground. A survey of the landscape status of London's river channels between 1992 and 1996 revealed that 29 per cent were natural, 56 per cent were artificially surfaced, and 15 per cent were culverted (EA, 2001b). This is of consequence, not only for the recreational assets of the City, but also for the rate and volume of runoff following excessive rainfall or snow melt (DETR, 2000a). In fact, a significant proportion of insurance claims are from non-riverine floods arising from intense rainfall events overwhelming urban drainage systems (ABI, 2002). The changes in future rainfall patterns shown in Figure 5.4, therefore, point to an increased likelihood of such flooding by the 2080s.

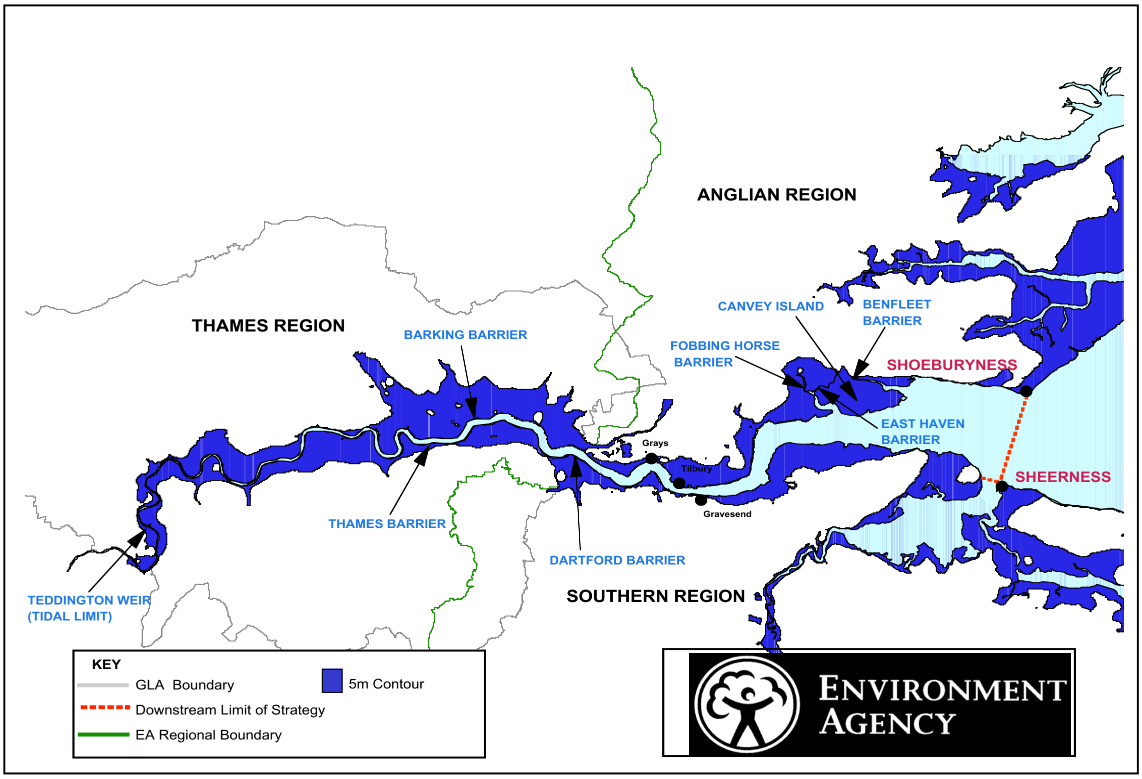
Research is currently underway to evaluate the performance of existing sewerage systems in relation to past patterns and future changes in rainfall event sequences and storm event profiles (UKWIR, 2002a). The project will also report on the significance of secondary factors in sewer system performance arising from groundwater infiltration, soil moisture deficits, and changes in water levels in receiving waters affecting sewer outfalls – all of which are potentially climate sensitive. For example, in catchments with significant groundwater contributions, enhanced winter re-charge and antecedent base flows will have implications for sewerage networks. Higher groundwater levels will mean that there will be both an increase of infiltration into sewer systems below ground level and in the ingress of surface water into sewers from above ground surface flow. The effects of both will be higher flows in sewers and associated pumping and treatment costs, and could potentially lead to increased incidents of sewer flooding from separate and combined systems. Climate change could also affect the capacity of receiving waters to assimilate discharges from sewer systems. For example, any increase in summer storms may cause combined sewer overflows to discharge pollutants into rivers which will have lower summer flows and thus reduced dilution capacity.

Sustainable Urban Drainage Systems (SUDS) are soft engineering facilities to help alleviate flooding associated with moderate rainfall events, involving the reduction of storm runoff volume (through 'peak-lopping') and increases to travel time of flood peaks to receiving water courses. For example, the restoration of natural wetlands in headwater catchments can provide source control of water derived from rainfall events as well as benefits to biodiversity. However, as with any drainage system SUDS have a capacity that can be exceeded given long duration events of the type experienced in the autumn of 2000 (see Table 5.6 and Figure 5.5), SUDS may be relatively cheap to install but can incur high maintenance costs and have limited operational life spans. There are also issues surrounding the legal ownership, maintenance and availability of appropriate sites for SUDS development in London given competing pressures to use brownfield sites for housing. The underlying London clay makes it difficult in some areas to use significant infiltration techniques.

5.5.4 Tidal Flood Risk

The potential implications of sea-level rise for Great Britain have been comprehensively reviewed by de la Vega-Leinert and Nicholls (2002). The most significant flood threat to London arises from tidal surges caused by low pressure systems travelling south or southwest over the North Sea, and the funnelling of water from the southern North Sea into the Thames Estuary (see Figure 5.6). The coastal flooding of 1953 resulted in over 300 fatalities in eastern England, but London was spared (Steers, 1953). Nonetheless, the event highlighted the potential threat to London, and resulted in a national flood defence strategy culminating with the completion of the Thames Barrier in 1983.

Figure 5.6 The area currently at risk from tidal flooding



Source: Planning For Flood Risk Management in the Thames Estuary, Environment Agency

The Thames Barrier and flood embankments provide protection for an estimated 1 million people against a 0.05% (or 1 in 2000 year) event currently, declining to 0.1% (or 1 in 1000 year) flood level by the year 2030. Thereafter, if improvements are not made the defence standard will continue to decline as a consequence of geological subsidence, natural climate variability and anthropogenic sea level rise (see Sections 3.8 and 4.3). By the 2050s, a 34 cm rise in sea level at Sheerness changes the 1 in 1000 year level, to a 1 in 200 year event (Wade et al., 2001). By 2100, it is estimated that the Thames Barrier will need to close about 200 times per year to protect London from tidal flooding (EA, 2001b). Future flood defence needs of London are, therefore, currently being reviewed by the Environment Agency, and will take into account increased peak flows in the Thames, sea level rise (natural and anthropogenic), and local changes to tidal conditions (Figure 5.6).

Rising sea levels and changes to the flow of the River Thames have potential consequences for the fine-grained sediment budget of the Thames Estuary system. Eroding cliffs at Sheppey currently provide 4.5 x 10^5 tonnes per annum of sediment, compared with an estimated 7 x 10^5 tonnes per annum fluvial supply from the Thames (Nicholls et al., 2000). The sinks for this sediment are unclear, but it is likely that the material is important to marsh development. Projected sea level rises are expected to increase rates of cliff erosion and supply of fine-grains to the regional sediment budget. The associated accretion in the estuaries and marshes could provide beneficial negative feedbacks to sea level rise in terms of flood defence. This is because a seawall fronted by 80 metres of saltmarsh need only be 3 m high (at a cost of £400/m), compared with a seawall without fronting/saltmarsh which may need to be 12 m high (costing £5000/m) (EA, 1996). However, successful recreation of intertidal habitats and added defence value requires a wider appreciation of coast cell functioning and sediment exchanges within the entire Thames Estuary system, plus wider North Sea. In other words, soft engineering solutions to rising sea levels involve a perspective that transcends the traditional limits of local administrative boundaries.

5.5.5 Stakeholder Concerns

In addition to the issues raised above, stakeholder engagement highlighted further potential flood risks related to climate change (Table 5.7).

Table 5.7 Potential flood impacts and responses identified by stakeholders

Associated Impacts
• Threat to Thames Gateway developments east of the Thames Barrier
• Greater public and corporate awareness of flood risk
• Loss of freshwater/riparian habitats (see below)
• Saline intrusion further up estuary and into adjacent freshwater marshland
• Greater demands placed upon emergency services
• Impact on existing floodplain landfill sites and loss of potential landfill sites
• Improved design and flood protection for new developments
• Mortgage and insurance difficulties leading to blighting of some communities
• Flooding of the London Underground (already being pumped)
• Greater threat to riverside developments and inundation of major assets such as sewage treatment works
• Access and aesthetics impaired by raised flood defences
• More foul water flooding
• Severe disruption to utilities and transport systems
• Intangible costs to the environment, recreation, and stress to flood victims

5.5.6 Adaptation Options

First order adaptation costs for future coastal flooding and storm risks have recently been produced by ERM(DETR, 2000b). The range of adaptation measures considered in this study included: accelerated investment in existing flood defence programmes; improved floodrisk identification, forecasting and awareness; and avoidance of at risk areas by new developments (or ensure adequate protection is in place). Other options include: low cost, ‘no regret’ measures such as improved flood warning systems; long-term planning for managed realignment (the discrete readjustment of existing defences to new proposed lines of defence located further inland); promotion of flood-proofing, building materials and design; the use/restoration of natural ecosystem buffers and floodplains (Bray et al., 1997; de la Vega-Leinert and Nicholls, 2002; Klein et al., 2001; Wade et al., 2001). Finally, increased collaboration between governmental bodies and insurance companies could provide an economic impetus to the planning of sustainable developments in the floodplain (ABI, 2002).

5.6 Biodiversity

5.6.1 Context

Global ecosystems are already subject to many human-induced pressures such as land-use change, pollution, loss of wildlife habitat, population change and resource demands (Vitousek et al., 1997). Global biodiversity is expected to decrease as a consequence of the continued destruction of natural habitats and increased land-use intensity (Heywood and Watson 1996). The introduction of exotic species and the differential effects of climate and/or chemical changes on species reproduction, dominance and survival may also be important at the global scale. For example, increases in nitrogen deposition and atmospheric CO_2 concentrations or new disturbance regimes may favour invasive species (Dukes and Mooney, 1999). Other studies suggest that northern temperate ecosystems will experience least biodiversity change because major land-use change has already occurred (Sala et al., 2000).

Climate change represents a further pressure that could change ecosystem functioning, spatial distribution and species composition (through changes in sea level, biological interactions, atmospheric composition, and disturbance regimes such as floods, droughts, frequency of fire, etc.) (McCarty, 2001). Climate change may also affect limiting factors and hence the ecological niche(s) of some species, both directly (as in the case of tolerable thermal ranges), or indirectly (as in soil nutrient cycling) (Schimel et al., 1991). For example, many different taxa around the world are already displaying poleward and elevational range shifts in response to key physiological controls such as temperature, moisture and length of growing season (e.g., Parmesan et al., 1999; 2000; Thomas and Lennon, 1999). Conversely, ecosystems exert significant controls over global water and carbon cycling – for example, terrestrial ecosystems may be net sinks for atmospheric carbon, even after losses due to land-use change are taken into account (IPCC, 2001b). The effects of climate change may also display long lag times as existing species survive but no longer reproduce.

Greater London covers nearly 158,000 ha of which two thirds is occupied by green open space and water, and nearly a fifth is considered valuable wildlife habitat (see Table 3.2). These green spaces support over 1500 species of flowering plant, and 300 types of bird have visited the City in recent years. As noted in Section 3.11, there are also a large number of nature conservation designations in London, and several nationally rare species of plants and animal. The London Biodiversity Partnership (2002) has prepared Species Action Plans (SAPs) for species regarded as special to London (bats, water vole, grey heron, peregrine, sand martins, black redstart, house sparrow, stag beetle, tower mustard, and mistletoe). A first round of Habitat Action Plans (HAPs) were also prepared for priority habitats identified by the UK Biodiversity Steering Group. This preliminary round included woodland, chalk grassland, heathland and wasteland. In addition, several other species and issues for discussion were covered by Statements, for example, the significance of exotic species to the cultural heritage of London, or the importance of private gardens (e.g., http://www.lbp.org.uk/action/statements/hsgardens.htm).

For the purpose of this report, it is convenient to group climate-related changes in London's biodiversity by the following major environments: 1) freshwater (including wetlands), 2) intertidal (including estuarine), and 3) terrestrial (including gardens). As previously indicated, current threats to biodiversity include loss of wildlife habitat to redevelopment, lack of, or inappropriate management (such as tree-planting) (Table 3.3). The following sections highlight factors that are directly and indirectly *climate* sensitive, such as loss of ecological niche(s), invasion by exotic species, incidence of disease and pests, air and water pollution, sea-level rise, impacts of changing river flow regimes, and summer drought stress.

5.6.2 Freshwater Habitats

Freshwater habitats – renowned for their high biodiversity and endemism – include lakes, permanent and temporary ponds, ephemeral streams, rivers, canals, and wetlands. The most important potential climate change impacts on lakes and streams include warming of waters (Webb, 1996); absence of shorter periods of ice cover (Magnuson et al, 2000); reduced summer flows and dilution of nutrients (Wilby et al., 1998); changes in physical habitat availability (Keleher and Rahel, 1996); changes in biogeochemical cycles including the mobilisation of heavy metals and pesticides (Schindler, 1997); increased primary production, eutrophic conditions, and oxygen depletion (Hassan et al., 1998). The importance of river corridors and wetlands to nature conservation across London is evident from their association with Sites of Special Scientific Interest (SSSIs) (EA, 2001b). For instance, the London Wetland Centre gained national recognition for its value to wildlife, having been designated a SSSI just 6 years after restoration work began on the site. Local Environment Agency Plans (LEAPs) provide a further framework for the integrated management of river catchments by, for example, enhancing marshland habitats created by new flood defence projects.

Changes in river flow regimes, water temperature and water quality can affect the survival, spawning times, reproductive success and growth of invertebrates, freshwater fish and amphibians (Beebee, 1995; Cowx, 2000). For example, the proportion of salmon migrating upstream in summer may be very low if the summer is dry – noticeable declines were evident in the droughts of 1989 and 1995 for instance. This pattern of behaviour may, however, be reversed if the flows are dominated by groundwater contributions (George, 1999). Given the slight decreases in summer flows from clay and urban catchments projected by Davis (2001), coupled with possible water quality changes, the outlook for the Thames salmon population is suggestive of further long-term decline. In some regulated rivers, however, there may be opportunities to maintain physical habitats by controlled releases from reservoirs.

London's wetlands are of ecological significance to a variety of plant communities, birds, amphibians and invertebrates (Table 3.3). Nationally, these habitats are under threat from altered flood regimes, drainage, groundwater abstraction, and development, in addition to global climate change (Dawson et al., 2001). Their vulnerability arises from the delicate balance between seasonal evapotranspiration, surface inflows and outflows of water, soil moisture, and groundwater discharges – changes to any one of these components can seriously impact the wetland. Following implementation of Water Level Management Plans (WLMPs), however, the Agency has been able to alleviate the effects of abstraction on a number of rivers and wetlands. For example, by redirecting a spring and installing water control devices at Ingrebourne Marshes, background water levels have been increased along with periodic flooding of the site. This has led to a dramatic improvement in the diversity of bird life and growth of reed and sedge (EA, 2001a).

The most important hydrological controls on wetland plant communities appear to be the mean, highest and lowest groundwater levels, together with inundation during the growing season (Wheeler, 1999). Moisture availability is critical to other habitats too. For example, by using the SPECIES model and simple water balance estimates for the future, the MONARCH study showed a drying of heathland and progressive loss of climate range for the shallow-rooted beech in southeast England under the UKCIP98 High scenario by the 2050s (Dawson et al., 2001). This is entirely consistent with observed high percentages of poorly foliated beech trees in years following the dry summers of 1987, 1989-1992, 1995 and 1997 (Cannell and Sparks, 1999). The 1995 drought stress has also been linked to an increase of deeper-rooted plants on grasslands (Buckland, 1997). This highlights a danger of extrapolating regional modelling to local impacts: the site-specific response of London's 273 ha of fragmented wetland is ultimately governed by the water level requirements of individual species as well as local water balance changes.

5.6.3 Intertidal Habitats

Situated at the highly dynamic interface between land and sea, intertidal zones are some of the world's most diverse and productive environments. The lower Tidal Thames is no exception, supporting as it does about 120 species of fish, 350 freshwater, estuarine and marine macro-invertebrate species, and nearly 300,000 over-wintering water birds (EA, 2001b). Areas of intertidal habitat are present along the entire length of the Tidal Thames, but the most extensive reaches are below Tower Bridge where the flood defences are set further back from the main channel (London Biodiversity Partnership, 2002). Other habitats, such as the reedbeds at Barking Creek have become re-established following the curtailment of dredging. The Thames estuary also provides a wide range of habitats such as shingle and mudflats, and salt marsh.

The biodiversity potential of the intertidal habitat largely depends on the local design, building materials and positioning of flood defences. Where the defences comprise sloping revetments there are opportunities for the establishment of saltmarsh (e.g., downstream of Tower Bridge); where the river is constrained by vertical concrete and metal piled walls, only a narrow fringe of foreshore is exposed at low tide (e.g., between Wandsworth Bridge and the Greenwich Peninsula). Under the latter circumstances, there are limited opportunities for vertical succession in the relative absence of 'natural' river banks. The Environment Agency is particularly concerned about further encroachment of riverside development on the Thames foreshore, and has suggested that unitary development plans for the London Boroughs adjoining the River Thames should include policies prohibiting development on the foreshore (EA, 2001b). The Agency is also seeking to protect river corridors and to enhance their ecological value through the planning process and best practice riverbank schemes. For example, at the Millennium site, Greenwich, the tidal defences were installed 130 m inland to create an additional 10 m of intertidal habitat, as well as an area of salt marsh with a series of terraces between the site and existing flood wall (EA, 2001b). Similarly, the recently announced reprieve from development for the western edge of the Rainham Marsh SSSI (FoE, 2002) is consistent with the wider objective of regeneration for the Thames Gateway zone, including riverside habitats.

The anticipated impacts of climate change and sea-level rise for London's intertidal habitat include increased levels of inundation and storm flooding; accelerated coastal erosion; sea water intrusion into freshwater tributaries; changes to the tidal prism, tidal range, sediment supply and rates of accretion; changes in air temperature and rainfall affecting growth of salt marsh plants with secondary effects on sedimentation (Adam, 2002; Kennish, 2002; Moore, 1999; Nicholls et al., 1999; Reed, 1990). One of the most significant threats to the biodiversity of the intertidal habitat is currently the flushing of storm sewage from London's Victorian sewers during intense summer storms (Section 3.5.2). However, intense rainfall events are projected to become *less* frequent in summer (but more frequent in winter) under the UKCIP02 scenarios. The net effect on biodiversity will depend on a host of related factors such as the volume of summer flow in receiving watercourses and rates of groundwater ingress to the sewerage network.

Although the MONARCH project did not explicitly consider intertidal habitats, the impacts of the UKCIP98 climate change scenarios on estuarine waterbirds and coastal geomorphology were assessed (Austin et al., 2001). Climate change was shown to affect Britain's over-wintering waterbird population in two main ways: firstly, through the *direct* effect of changes in (severe) weather on waterbird distributions and their invertebrate prey; second, through the *indirect* effect of rising sea levels on the availability and nature of coastal habitats. For example, projected increases in rainfall and gale-force winds under the UKCIP98 Medium-high scenario would be expected to harm wader populations by decreasing food intake (Goss-Custard et al., 1977). Managed realignment of Thames-side coastal defences may result in more extensive mudflats at the expense of salt marshes, improving habitat availability for the oystercatcher but reducing it for the redshank and dunlin.

As indicated previously, changes in estuary morphology depend on regional sources and sinks of fine-grained sediments (Section 5.5.4), as well as on the local history of land claimed from the sea. Natural features such as salt marshes can absorb wind and wave energy, retarding some of the effects of sea level rise, and contributing to the natural resilience of the system (King and Lester, 1995). However, the response of tidal marshes to sea-level rise depends on a host of local factors. Marshes located between coastal defences and rising sea levels may be subject to 'coastal squeeze' (i.e., progressive loss and inundation) if the tidal foreshore is lost to solid encroachments (Nicholls and Branson, 1998). Conversely, if the backshore slope is low enough or unimpeded by infrastructure, and there is sufficient sediment for accretion, the foreshore/wetland may expand landward (Brinson et al., 1995).

5.6.4 Terrestrial Habitats

The London Biodiversity Audit covered a wide range of terrestrial habitats (e.g., woodland, open landscapes, grasslands, meadows, heathland, cemeteries, urban wasteland, farmland, etc.; see Table 3.3). The most extensive natural habitats in London are unimproved and semi-improved neutral grassland, followed by woodland. The gardens and parks of London also represent a particularly important ecological resource for flora and fauna, with a combined area of approximately 20% of Greater London. Although gardens are heavily managed, climate is still a significant driving mechanism governing the potential ranges of species, timing of life-cycles (phenology), physiology, and behaviour. Furthermore, garden plants are susceptible to damage from extreme winter frosts, late spring frosts, summer drought and localised winter waterlogging (Burroughs, 2002), as well as from weather-related garden pests and disease (Hardwick, 2002).

Earlier springs, longer frost-free seasons, and reduced snowfall in southeast England (Sections 3.2 and 3.3) have affected the dates of emergence, first flowering and health of leafing or flowering plants (Sparks and Smithers, 2002). For example, warmer temperatures in early spring are associated with earlier dates of oak leafing at Ashted, Surrey, by about 6 days for each 1ºC increase (Sparks, 1999). This suggests that climate change will produce more first leafing dates in March unless other controls on leafing prevail. Tree *health* is more a function of air pollution concentrations (Ashmore et al., 1985;) and water stress, with major reductions in the crown density of beech coinciding with droughts in southern Britain (Cannell and Sparks, 1999). Natural woodlands suffering from drier summer conditions in the future may become more susceptible to insect pests, disease and windthrow during the stormier winter conditions. However, drought stress during summer can also afford protection from ozone damage by enforcing stomatal narrowing or closure (Zierl, 2002). Conversely, grass productivity is substantially reduced during hotter, drier summers (Sparks and Potts, 1999), pointing to increased water demand for lawn irrigation under the UKCIP02 scenarios.

Bird populations are sensitive to many types of environmental change and, because they occupy a position at or near the top of the food-chain, give indications of overall ecosystem functioning. For example, the recent increase in grey heron numbers in London has been attributed to the improvement in water quality (leading to higher natural fish populations) and the absence of severe winters (Marchant et al., 1990). Small birds, like the wren, are particularly prone to prolonged spells of cold, wet or snowy weather, and therefore provide an excellent index of very cold winters. Records of the wren population on farmland and woodland since 1962 are strongly related to mean winter temperatures in central England, and have maintained relatively high numbers since the 1990s (Crick, 1999). Similarly, annual variations in the first laying dates are often strongly correlated with variations in spring temperatures (Crick et al., 1997), but mismatches in the timing of laying relative to food supplies can reduce bird populations (Visser, 1998). Changes in migratory patterns and arrival dates have also been noted but this will depend on the specific trigger(s) for migration. For example, a 1ºC increase in spring temperature is associated with a 2-3 day earlier appearance of the swallow in the UK (Sparks and Loxton, 2001).

Thus, climate change has the potential to affect future bird migration, winter survival, and egg-laying. The MONARCH project assessed the impacts of six bioclimatic variables on the distribution of ten breeding birds at 10 x 10 km resolution under the UKCIP98 Low and High scenarios by the 2020s and 2050s (Berry et al., 2001). (Habitat, however, was not included in the training of the model and the ten birds studied are not all appropriate to London's avifauna). Under the High scenario the most significant reductions in southeast England climate space occur for the willow tit, nuthatch and nightingale, due to warmer and drier conditions affecting woodlands and insects. Since woodland is the second most extensive natural habitat of London, these reductions could be reflected in the range of birds visiting the back gardens of suburban London. Conversely, the potential distribution of the reed warbler increases nationally, along with the yellow wagtail and turtle dove (which is contrary to the current decline in the latter two), probably reflecting an affinity for a warmer, drier climate. These results should, however, be treated with caution because the science underlying the MONARCH assumptions is less than complete.

Insect distributions and the timing of insect activity are also highly weather dependent (Burt, 2002). For example, the ranges of butterflies in North America and Europe have shifted poleward in response to rising temperatures (Parmesan, 1999). Extensive records of insects throughout Britain since the 1960s and 1970s indicate that a 1ºC increase in temperature is associated with a 16-day advancement in the first appearance of the peach-potato aphid, a 6-day advance in peak flight time of the orange tip butterfly, and an 8-day advancement in the time of activity of the common footman moth (Sparks and Woiwod, 1999). Finally, it is recognised that climate plays a dominant role in vector-borne diseases – directly through its effects on insect development, and indirectly through its effects on host plants and animals. Although it has been suggested that the most lethal form of malaria can not be transmitted by mosquitoes in the UK

(Marchant et al., 1998), the number of cases of Lyme disease spread by ticks has approximately doubled in the UK since 1986 (Subak, 1999). Higher year-round temperatures in the future are likely to increase the risk of recreational exposure to Lyme disease, changes in tick numbers and activity.

Finally, London is home to numerous flora and fauna introduced from warmer parts of the world but now flourishing in the City. Many exotic species have been inadvertently introduced via imported materials such as foodstuffs, timber, minerals and birdseed. Others have 'escaped' from gardens to be naturalised (e.g., butterfly bush, michaelmas daisy, Japanese knotweed) or have formed spontaneous hybrids with their native relatives (e.g., Highclere holly, Spanish bluebell). The rich cultural botany that has developed around areas such as Deptford has become part of the local heritage. Part of this success has been attributed to the favourable climate of London's heat island (see Sections 3.2 and 5.2). Longer growing seasons, reduced incidence of night frosts and higher maximum temperatures in summer have allowed plants such as London rocket, Guernsey fleabane, hoary mustard and Chinese mugwort to thrive (see: http://www.lbp.org.uk/action/statements/ssexoticflora.htm). Projected increases in regional temperatures under the UKCIP02 scenarios together with possible intensification of the heat island will allow such flora, along with naturalised bird species (e.g., collared dove and ring-necked parakeet) to thrive in the future. However, the same conditions could also favour a small minority of introduced plants that cause significant problems in London's ponds and canals (e.g., New Zealand pigmyweed, parrot's-feather, floating pennywort), and terrestrial habitats (e.g., Japanese knotweed, giant hogweed).

5.6.5 Stakeholder Concerns

In addition to the issues raised above, stakeholder engagement highlighted further potential biodiversity impacts related to climate change (Table 5.8).

Table 5.8 Potential biodiversity impacts and adaptations identified by stakeholders

Associated Impacts
• Increased tourism and leisure pressure at conservation sites
• Increased soil erosion associated with more intense winter rainfall
• Increased expenditure on pest control
• Air quality impacts from incinerators, water quality impacts from landfill
• Use of building roofs for green space and water storage
• Restricted access to sensitive sites and habits (e.g., foreshore)
• Use of green spaces and river corridors to allow species to move to new climate space(s)
• Greater public education and involvement in 'biodiversity networks' (phonology)
• Greater recognition of dynamic ecosystems in site designation and management

5.6.6 Adaptation Options

The ability of ecosystems to adapt to the direct effects of climate change is largely a function of genetic diversity and the rate of change (IPCC, 2001b). A growing body of evidence suggests that climate change should be treated as a current, not just a future, threat to species (Hughes, 2000; McCarty, 2001). However, humans may intervene in the processes through a range of conservation methods. One approach to protect declining wildlife and plant populations is to establish reserves or designated areas. Unfortunately, the Institute of Terrestrial Ecology, estimate that 10% of all UK nature reserves could be lost within 30-40 years, and that species distributions could change significantly in 50% of designated areas in the same period (DETR, 1999). Moreover, nearly all land suitable for designation is already protected, and some habitats are relatively well protected compared with others (e.g., the distribution of SSSIs largely reflects endangered plants).

A further difficulty involves reconciling the disparity between the current distribution of reserves and future distributions of species due to climate forcing (e.g., due to coastal squeeze). In this respect London's 'green corridors', such as river corridors and railway lines, may be important for species migration, and should be protected (EA, 2001a). Another solution may be for planners to recognise biodiversity hotspots (Myers et al., 2000) – areas containing concentrations of endemic species facing extraordinary threats of habitat destruction (IPCC, 2001b). Under such a scheme, a wetland threatened by summer water-level drawdown would figure explicitly in regional water resource strategies. Such activities might fall within a wider remit of habitat restoration (Petts and Calow, 1996). Other options include captive breeding and translocation programmes for endangered species, but no techniques currently exist for translocating intact biological communities (even space permitting).

Area designations and planning controls should also be considered within the wider context of environmental improvement, recognising that fully pristine habitats are non-existent. For example, many aquatic species are sensitive to changes in river flow and associated water quality. Although chemical General Quality Assessment (GQA) has improved in recent years, the biological quality of London's rivers and of the tidal Thames continues to be variable as a consequence of rainfall fluctuations affecting urban runoff and effluent quality (EA, 2001b). In such circumstances, adapting to changes in climate might involve the introduction of new water treatment technologies for more stringent quality standards (as part of the work already being undertaken on Combined Sewer Outfalls (CSOs) under the AMP3 process). However, the benefits of more stringent effluent treatment should be weighed against associated increases in greenhouse gases (Colquhoun, *pers. comm.*), to evaluate the net environmental impact. Treatment of diffuse pollution sources arising from agricultural areas beyond London, could be addressed through raised awareness, and the establishment of riparian buffer zones along river corridors (Wade, 2001). Similarly, an appreciation of the complex (transdisciplinary) processes involved can lead to environmental enhancement in the face of change. For instance, effective coastal defence and habitat conservation can be accomplished through soft engineering measures that acknowledge the strong link between geomorphic and ecological processes (Lee, 2000).

5.7 Summary

The above sections provide an assessment of the most significant potential climate change affects on London's environment, identified through literature review, stakeholder consultation, and impacts modelling. The key issues are summarised in Table 5.9. These themes provide the basis for subsequent discussions of societal and economic impacts: the mandate of the two remaining work streams.

Table 5.9 Summary of key climate change impacts on London's environment

Issues	Climate variables	Potential impacts
Urban heat island	• Nocturnal temperatures • High pressure and low wind speeds • Dominant airflow direction	• Increased summer heat stress and mortality • Reduced winter space-heating • Higher underground temperatures • Increased use of air conditioning • Increased risk of fires • Higher rates of refuse decay • Increased water demand
Air quality	• Stagnant summer anticyclones • Airflow direction • Temperature inversions • Catalysing sunshine • Thunderstorms	• Increased concentrations of ozone, VOCs, SO_2, particulates and pollen • Acute asthma epidemics • Deleterious effects on urban trees and urban fabric • Export of pollutants to wider region
Water resources	• Winter and summer precipitation • Potential and actual evaporation • Soil moisture	• Reduced summer soil moisture • Shorter potential recharge season for aquifers • Lower summer flows • Higher winter flows • Deteriorating water quality • More leakage due to clay shrinkage/expansion • Increased domestic water demand • Use of rising groundwater • More conflict between environmental/societal demands
Flood risk	• Seasonal precipitation totals • Winter soil moisture • Heavy daily precipitation • Multi-day precipitation totals • Snowmelt • Sea level rise	• More heavy precipitation days in winter • Fewer heavy precipitation days in summer • Heavier multi-day precipitation totals in winter • More frequent flooding of underground network • More localised shallow groundwater flooding • More frequent closures of the Thames Barrier • Increased supply of fine-grain sediments • Saline intrusion to freshwaters

Issues	Climate variables	Potential impacts
Biodiversity	• Summer drought/low flows • Spring temperatures • Soil and groundwater levels • Air quality • Water quality and temperature • Sea level rise • Storminess, wave heights • Disturbance regimes e.g., wind throw and fire	• Changes in physical habitat availability • Increased primary production • Changes in species phenology, physiology, behaviour, health, reproductive success and community structure • Coastal squeeze of Thames estuary intertidal habitats • Increased coastal and salt marsh erosion • Increase accretion in estuary • Extended range of some exotic species • More pressure from tourism at conservation sites • More conflict between societal/environmental needs

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6. The Potential Social Impacts of Climate Change in London

6.1 Introduction

London is a large and complex city which has persisted as the dominant, and by far the largest, city within England, and more widely in the UK. For many hundreds of years over 10% of England's population have dwelt in London and its role in the national economy has always been pivotal, if sometimes controversial. Culturally, London is far more diverse than other UK cities, and has a higher percentage of Black and Minority Ethnic residents than anywhere else, at 27% of the population (compared to national average 7% and the next highest region at 10%). Arguably, social and cultural integration has advanced further in the capital than elsewhere. On average 4,550 people live in each square kilometre of London, over twice the population density found in most UK cities; within the European Union only Paris and Brussels are more densely populated. There are acute housing and office space shortage and rising housing and land costs. Large building programs are required to meet the latent and growing demand (500,000 houses over the next fifteen years) since Londoners are starting to live in smaller family units or by themselves: the number of households is growing at a faster rate than the population overall.

Nearly half of the Greater London workforce (48%) is classified as 'professional' or 'managerial and technical', compared to a national average of 38% in these two categories (ONS 2001). Per capita, Londoners also have higher incomes than elsewhere in the UK. (Compared to a UK average of 100, London's per capita GDP score is 128.5, whilst the North East is 83.9 and the West Midlands 91.8 for example) (ONS 2001). These higher-than-UK-average incomes, however, mask a very unequal distribution of incomes in London (GLA 2002a). The disparities in income are significantly higher in London than elsewhere in the UK, with unusually high incomes at the top end of the distribution and a greater proportion that the UK average in lower income brackets. One in five households have a weekly income of less than £150, in a city with the highest property prices in the UK (average property price £205,850). Five of the ten (and 13 of the 20) most deprived districts in England are in London. Unemployment is higher amongst the Black and Minority Ethnic than the white community (at 13.5% compared to 5.1%). The Bangladeshi community has a particularly high unemployment rate, followed by the Black African and Black Caribbean communities (LHC 2002).

Within this context, climate change will have both direct and indirect impacts on the social aspects of London life. We have used the following definition of 'social' and attempt in this section to bring discussion back to how these aspects of London life would be affected by climate change:

> *"overall health and well-being, social and economic equity, public safety, public health and infrastructure, civil cultural and political society (including political institutions), and who bears the costs and reaps the benefits in a future London."*

Most assessments of climate change in the literature have focussed on either the physical world, such as on biodiversity, or on the physical aspects of human systems such as crop production and water supply (e.g. ACACIA, 2000). This is because such impact areas are more readily quantified and numerical models and other techniques are available for assessment purposes. Social systems and behaviours are frequently more difficult to analyse using quantitative methods. There is a higher degree of subjective interpretation, for example in defining whether a community is 'vulnerable' or has a high capacity to adapt to climate change impacts. Unlike assessments of the environmental impacts of climate change, it is difficult to produce 'objective' numbers which give the 'right' answers in the social, political and cultural aspects of climate change impacts. Yet, many stakeholders in this study have expressed a strong interest in the social repercussions of climate change. We decided not to shy away from addressing these highly relevant issues even though the 'answers' will be more uncertain and subjective than those in Section 5 and depend upon what assumptions are made - about responses, for example. When feedbacks between social, economic and environmental impacts of climate change are addressed, one can see that even the assessment of the physical impacts of climate change is affected by social uncertainty.

In this 'Social Impacts' section of the report, we have used a ***scenario*** approach to address how climate change may affect social aspects of London. A scenario, or a picture of a potential future, is not a prediction but a vision of one possible way that the future may turn out. Using detailed descriptions of a possible future allows us to analyse what life would be like, and what the implications would be for every aspect of society. We are unable to predict exactly how the future will unfold, not least because *we have a choice as to how that future will look.* To a certain extent, the future social, economic and environmental aspects of London life are what we make them. This applies equally to climate change. The climate change scenarios presented in Section 4 consider two rates of emissions of greenhouse gases (Medium-Low and Medium High Emissions). The differences in climate between these are dependent on *socio-economic choices* we make as a society. It is therefore unrealistic to consider changing climate without also considering the social and economic circumstances which may bring those future climates about.

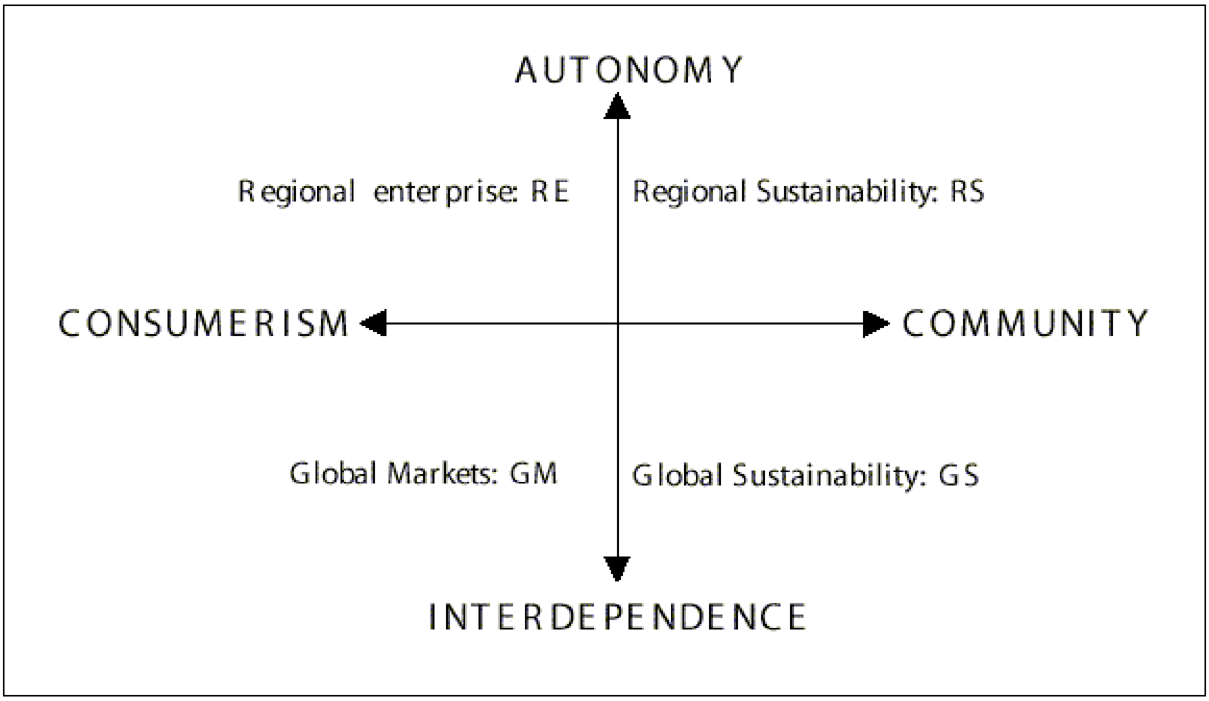
6.2 Combining Changes in Society with Changes in Climate: The Socio-Economic Scenarios

The climate change scenarios presented in Section 4 represent the consequences of many social and economic changes; the changed climate of 2050 will not occur in a world frozen in 2002 in every other way. All other aspects of London, UK and global society and economy will have moved 50 years into the future. We know that some things are likely to remain similar to today. For instance, many of the buildings and much of the infrastructure will be the same, unless some surprise event or disaster takes place, although cultural change could modify the way we view buildings and their desirable time-span. (In Tokyo it is common for modern buildings to be replaced after just 10 years: there is a very different attitude there than in London to the longevity of the urban landscape). The 'hardware' within which the city is lived will probably remain quite similar in many parts of the city, though major change could well be experienced in targeted redevelopment areas (e.g. parts of East London). London is defined to the external world through some of its principal monuments and sites (Tower Bridge, Trafalgar Square, Houses of Parliament, Westminster Abbey, St. Paul's Cathedral, Buckingham Palace, etc.) and it is highly likely that these will remain important reference points of London's identity through the next 50 years, just as they have been for the past 50 years (and much longer).

What is less certain is what will happen to the 'softer' emblems of London: double-decker buses, local markets, carnivals and festivals, local parks and heaths, to name but a few. What changes and what 'stays the same' is determined not simply by inexorable exogenous forces, therefore, but by social and political consensus on what represents London as a city and is important in formulating its internal and external identity.

As described in Section 4, the UKCIP02 climate change scenarios are based on a methodology for thinking forward 50 years developed by the Intergovernmental Panel on Climate Change (IPCC, 2000), the Foresight scenarios and their UKCIP derivatives. These provide conceptual and coherent descriptions of future social, economic and political-policy issues. The UKCIP scenarios framework has taken social and political values, and the nature of governance to be fundamental and independent determinants of future change. By examining a continuum scale between 'Autonomy' and 'Interdependence' and between 'Consumerism' and 'Community' the worldview and subsequent actions of future societies can be constructed. A version of the typology is shown in Figure 6.1 below (UKCIP 2001). The precise definition of the scenarios is tailored to the regional character of this study; this is possible because there is no single 'correct' definition (they are in the end social constructions which can be formulated in infinite ways).

Figure 6.1 The Adapted UKCIP Socio-Economic Scenarios



The IPCC has explicitly linked greenhouse gas emissions associated with similar socio-economic scenarios to climate change, providing an 'integrated' picture of how climate, society and economy may change (IPCC, 2000; 2001). Although these relate to the global scale, the links between the IPCC and the UK-based Foresight scenarios allow some interpretation at regional scales. The Global Markets (GM) and Regional Sustainability (RS) scenarios are worlds in which greenhouse gas emissions are equivalent to the UKCIP02 Medium-High and

Medium-Low Emissions levels respectively. We now present in more detail how these worlds would look.

6.2.1 Global Markets (GM)

This scenario could be described as 'Dynamics as usual' - very rapid economic growth, population peaks mid-century; globalisation of economic relations and, to some extent, socio-cultural forms; market mechanisms dominate, accompanied by public choice approaches within governance; reliance on fossil fuels. London continues to play key role as one of a handful of global centres of capital and trading, and continues to dominate the UK economy. There would be medium-**high greenhouse gas emissions** associated with this scenario, producing a correspondingly high level of climate change, e.g. London summer temperatures 3°C above 1961-90 average by the 2050s and 4.5°C above by the 2080s.

6.2.2 Regional Sustainability (RS)

In this scenario, there is a significant shift in London away from the pursuit of economic growth for its own sake, and a much greater emphasis on sustainability. Local solutions to local and global problems are sought and there is encouragement of 'green' technologies and lifestyles. London's population stabilises by 2010 and then starts to decline slightly. Policies are put in place to reduce inequality. There is a genuine attempt to reduce the ecological 'footprint' of London. There would be medium-**low greenhouse gas emissions** associated with this scenario, hence a 'medium-low' level of climate change, e.g. London summer temperatures 2.5°C above the 1961-90 average by the 2050s, and 3.5°C above by the 2080s.

6.2.3 Using the Scenarios

Why, then, have we chosen to examine these two scenarios in detail? Firstly, we decided on the basis of past experience, that examining all four scenarios was not practicable in the time available. Secondly, we reasoned that 'global markets' and 'regional enterprise' are rather similar scenarios in the London context, this being because London is already (along with Tokyo and New York) a regional site of the global marketplace. Thirdly, we decided that Regional Sustainability would be a more interesting, because it is a more challenging scenario to explore than Global Sustainability. This is because for a mega-city such as London to become sustainable on a regional basis is far more challenging than for it to do so globally (where its high population density could allow trade-off with lower population density areas).

Examples of issues which can be considered in the socio-economic scenarios are:

- Movement of people across and between countries, bringing with them fresh ideas, new cultures and skills;
- Change in incomes and wealth;
- Changes in lifestyle and values, in the environmental imperative, and in information technology will all have an effect;
- Change in opinion and values that mean many people are more or less willing to tolerate discrimination, the misuse of resources or pollution.

Table 6.1 suggests how each variable might change under each scenario based upon the authors' interpretation and the scenarios literature (e.g. UKCIP 2001).

Table 6.1 Key Features of the Global Markets and Regional Sustainability Scenarios

Variable	Global Markets	Regional Sustainability
International Migration	High, driven by economic demand for more employees.	Low since the aim is to make each region more sustainable and self-sufficient. Rather than people moving, the objective is to improve standards of living elsewhere.
Change in incomes & wealth	Greater disparity in incomes emerge due to market forces. Ranks of super rich and super poor grow.	Drive to reduce disparities in income and wealth. Assistance provided for lower-income workers to buy property, etc.
Change in lifestyle & values	Increasing choice of goods and services allow individuals to exercise personal lifestyle choice. High pressure jobs and long work patterns become more wide spread.	Tendency to prefer higher quality of life, time with family and friends, etc. to material goods and services. Companies provide more flexible work packages, allowing time out, community-volunteering, etc.
Change in perceptions & beliefs	Individual choice remains dominant; strong confidence in science and technology to find solutions to emergent problems. Equality of opportunity.	Family and community-oriented values see an upsurge. Environmental beliefs become more widespread; lack of environmental concern becomes less socially acceptable. Equality of outcomes.
Change in leisure and tourism	Increased globalised tourism & leisure, with much more and cheaper aviation. Older and younger population much more mobile. More international migration, hence associated travel.	More localised and UK or near-continent based tourism & leisure. Reduced aviation-based tourism. The idea of 'going on holiday' replaced by 'being on holiday' in your own locality.
Change in commerce	International business and commerce dominate. International financing of science and technology, which drives the global economy.	Move away from global trade to local and regional economic development. Encouragement of SMEs serving local needs. Science and technology become more localised, slowing down pace of change.
Change in industry	'Old manufacturing' declines, whilst high-tech. manufacturing grows; job insecurity rises	Old skills in manufacturing re-activated by need to supply local needs; return to improved job security
Change in transport	More premium-payment transport solutions provided, e.g. high fares upon privately financed transport links. This increases unequal mobility.	Strong emphasis on community-based, low-priced, heavily-subsidised transport solutions, with high charges for private car users and for aviation.
Change in health care	Trend is towards more privately-based and financed health care, e.g. through private insurance measures	Re-invigoration of the public health care sector.
Attitude to environment	Environment to be used to further economic growth. Must be protected if growth is threatened, and it is economically viable to do so. 'Conquer nature'	Environment is valuable for its own sake. Less easily-quantified considerations such as amenity value are taken into account in development decisions. 'Work with nature'
Change in arts & media	Media consolidates further at the global scale, with more concentration in fewer hands; rapid expansion in 'pay as you go' multi-media options, e.g. cable, satellite, mobile communications	Prevention of excessive concentration of the media. Encouragement of local to regional media and community-based multi-media.

Variable	Global Markets	Regional Sustainability
Change in Communities	Greater number of individual households. Generally increased fragmentation of spatially-based communities. People's social relations defined more through workplace, internet, leisure activities, etc.	Move towards community-focused living. Reverse of trend towards single-occupancy households. 'Extended families' start living closer to each other once again across society. More time and opportunities available to facilitate social interaction in neighbourhoods.
Change in policing & community safety	High-technology, remote-sensing policing in which a highly trained, relatively small police force controls London via CCTV and associated, more powerful, future technologies.	More community control over policing. CCTV and remote-surveillance technologies are phased out.

Source: authors and drawing upon UKCIP (2001), IPCC (2000)

In our workshop application of the GM and RS scenarios (see Appendix B: Study Methodology), we found a proclivity to brand GM as 'bad' and RS as 'good'. We suspect that this is because GM is a more familiar prospect to the participants, representing more closely the present situation. Hence the 'bad' side of the scenario are more immediately evident, whereas the 'bad' aspects of the RS scenario are less apparent. The RS scenario does, however, entail a major shift away from the global financial and business service role that London currently depends upon for much of its economic wellbeing. A decline in this could have major and far-reaching economic ramifications for the city and, to be accepted, might require a quite radical change in values away from economic and financial incentives and current indicators. If there was widespread acceptance that time with family and friends or engagement in community activities that required little if any expenditure, were much more important than financial or work achievements, then the RS scenario would be achievable. This, however, is a very significant social and value-shift and there is very mixed evidence of it occurring in practice. (We are not suggesting that many people do not already make this decision; the important aspect we allude to in RS is the change or shift in lifestyles from the present, so that emphasis on community becomes the norm).

There is also uncertainty about what an RS world would actually be like to live and work in and a risk that it would not be economically sustainable or that it would be considered widely undesirable, given the cultural shift towards individualism in the western world. However, that is not to say that society in the future would not choose such a path. A further limitation of the RS scenario with respect to its implied carbon emissions (hence low level of climate change) is that it assumes that regional sustainability occurs through out the world in an analogous way to what occurs in London. If that is not the case, then carbon emissions might be very high in other parts of the world because of the occurrence of rapid economic growth. In that case, carbon emissions and global climate change rates would be higher and London would have to face an RS world in a context of high climate change. We will allude to the particular problems this anomaly could create throughout the document. (The analogous case, where a GM world is combined with a lower level of climate change, should not produce any problems not already faced by a GM/high climate change world: indeed the impacts of climate change would generally be alleviated).

Finally, we fully acknowledge the limitations of utilising only two socio-economic scenarios here. Inevitably, we cannot capture the full complexity of socio-economic and political dynamics and some futures are less readily expressed in the current structure than others. For instance, approaches for sustainable development which rely heavily upon market mechanisms (natural and socially-responsible capitalism) are less readily accommodated in the scenarios framework. Development of desirable 'end-point' scenarios by the London Climate Change Partnership itself might be a useful step in future work on adaptation.

6.3 The Draft London Plan: A Hybrid Scenario?

The draft London Plan in effect presents its own scenario for London, but on the much shorter time scale of the next 15 years. How, then, does the draft London Plan scenario relate to the Global Markets and Regional Sustainability scenarios? We could perhaps identify the draft London Plan as a hybrid scenario containing elements of GM and RS. There is undeniably an emphasis on preserving, and if possible enhancing, London's global role as a financial and business services centre. The influx of new inhabitants is welcomed as a way of satisfying the labour shortages, with 600,000 new jobs anticipated. The view is taken that the choice that will be made by global companies is not 'London versus other British cities', but 'London versus New York, Tokyo, Paris or Berlin'. This identification of London as the jewel in the crown of the UK economy, is very much a continuation of its traditional role in the UK, hence 'dynamics as usual'. At the same time, the Plan recognises the considerable social and economic disparities within the city and the need for more sustainable approaches. Hence, there is a strong emphasis upon community development and policing, better health care and education, more effective and equitable transport, a solution to the problem of overly-priced housing, more attention to the problem of over-crowding in houses in certain sections of society due to house prices, more sustainable building design, reduction of waste and more sustainable use of energy and enhancement of open and green spaces. These strategies and policies tend much more towards sustainability, with its focus on equity, balance between economic and social development, and limiting environmental impacts.

The draft London Plan scenario is in some respects similar to GM for some issues (e.g. economic growth, population change, new jobs), and similar to RS (or a global sustainability scenario) in others (e.g. sustainable design & construction, community development, policing, affordable housing, etc.). It is important to stress that the underlying basis for the draft London Plan scenario and the GM and RS scenarios is different in several important respects. Firstly, the draft London Plan projections to 2016 are based upon established forecasting methods, such as econometric models. The GM and RS refer to 50 years hence, and there is no known forecasting method or model able to reliably capture socio-economic, political or cultural change on such long timescales. Hence, our scenarios are deliberately qualitative, to avoid the false impression that they are anything other than indicative.

Secondly, the draft London Plan is a critical document to assist in detailed planning and policy decisions which have to be taken now and in the next several years. By contrast, the climate and socio-economic scenarios we use, operate at a much less refined level of detail and sophistication. To use an analogy, the draft London Plan is equivalent to planning your holiday in, say, 3 months times. Attempting to use the climate change and socio-economic scenarios in this way would be like trying to plan in detail a holiday to be held in 10 years time: what day you intend to leave, where you will stay over, which travel mode and firm you will use, and so on. The appropriate way of using the climate change and socio-economic scenarios is instead to obtain a broad-brush evaluation and assessment of policies and commitments being entered into in the near term. They can be seen as a 'check list' against which policies can be passed to explore how 'climate change (un)friendly' they are.

6.4 Need for a Comparative Approach

The consequences of climate change in any one place are inextricably linked-up with climate change impacts elsewhere. This is because of the interconnectedness of the flows of people, money, resources, goods and services between different places. Hence, the potential impacts of climate change in London are intertwined to some extent with the possible impacts in other cities and regions. A comparative approach also has the advantage that it allows us an insight into what the future climate change of London might be like in tangible terms, i.e. compared to other present-day cities. Hence, by the 2050s London's summer extreme would perhaps be comparable with present-day Paris or Berlin, and to New York or Madrid by the 2080s. A further use of such comparisons is that they help to identify potential adaptation strategies, given that cities such as Madrid and New York already cope with temperatures anticipated to occur in London in the 2050s to 2080s.

As the draft London Plan makes clear, the particular bundle of skills, services and activities in the capital render it in many senses unique within the UK, so that the most appropriate comparison is not with other UK cities, but instead other global cities which provide competing services, in particular Tokyo and New York. Because Tokyo and New York are (to some extent at least) serving needs in Asia and America, we should caution against assuming that trade can readily be transferred between these cities. It might, therefore, be as useful to compare London to, say, Paris, Berlin, Frankfurt and Brussels. Furthermore, we know that business often depends upon long-established reputations and networks of knowledge and trust, and hence business is generally not quite as footloose as might be imagined, particularly high-value added work, where much of the skill is 'intangible' and hence not easily transferred.

A scenario approach also leads us to question the assumption that London would not face competition from other cities in the UK. If, for instance, there is a strong shift towards regional governance and devolution, then there could conceivably be a greater distribution of the finance, business services, media, arts and culture activities, etc., currently concentrated in London. The model for this is, perhaps, Germany, where Hamburg is lead city for media and publishing, Frankfurt for finance, Berlin for administration, arts and culture, Munich for the automobile industry, and so on. Germany shows that it is not impossible for such regional distinctions which are globally competitive to emerge within a single nation. Even if we do not accept the importance of the devolution and regionalisation agenda for London, a scenario approach is still very helpful in providing a wider range of possible medium- and long-term futures.

The growth projections in the draft London Plan appear to be based on the very high growth rates that London experienced in the 1990s. Assumptions about continued high economic growth are also not at all guaranteed, merely because in the long-term past such growth has always happened. As global inter-connectedness increases, the systems created to run our countries and economies become ever more complicated. They may appear to become more 'solid' as they become more widespread and more sophisticated. According to theorists such as Perrow and Beck (1992), however, such complex globally interconnected systems may actually be more vulnerable to small disruptions at key points, because of their large knock-on effects, than would be the case in a world with more localised self-sufficiency.

Table 6.2 provides some basic data to allow a comparison between London and the other cities (Wright, 2002).

Table 6.2 Summer and winter extreme temperatures for London and 'competitor' cities

Station	Latitude	Longitude	Elevation (metres)	Annual max Temp. (°C)	Annual min Temp. (°C)
London (Heathrow Airport)	51.48N	0.45W	24	30.5	-6.3
Toronto	43.67	79.63W	173	33.1	-24.0
Paris (Orly Airport)	48.73N	2.40E	96	33.4	-8.2
Berlin	52.47N	13.40E	49	33.8	-12.2
Rome	41.80N	12.23E	3	34.4	-3.2
Tokyo	35.55N	139.78E	8	34.4	-2.6
New York (JFK Airport)*	40.65N	73.78W	7	35.3	-14.7
Madrid	40.45N	3.55W	582	38.9	-6.8

* John F Kennedy Airport is within the urban area, but adjacent to the sea so likely to be cooler than central New York.

Most of the competitor cities to London have a higher temperature baseline than London, and are likely to remain hotter than London in the future due to climate change, though not necessarily by the same difference as currently. As shown in Table 6.2, London has the coolest summers of all the cities. Its winters are colder than Rome and Tokyo, though not as cold as Madrid despite London's much more northerly location. Toronto is the closest to London in summer extremes, both cities being slightly cooler than Paris. Toronto has much more extreme winters than London, however, whilst Paris is only marginally colder than London.

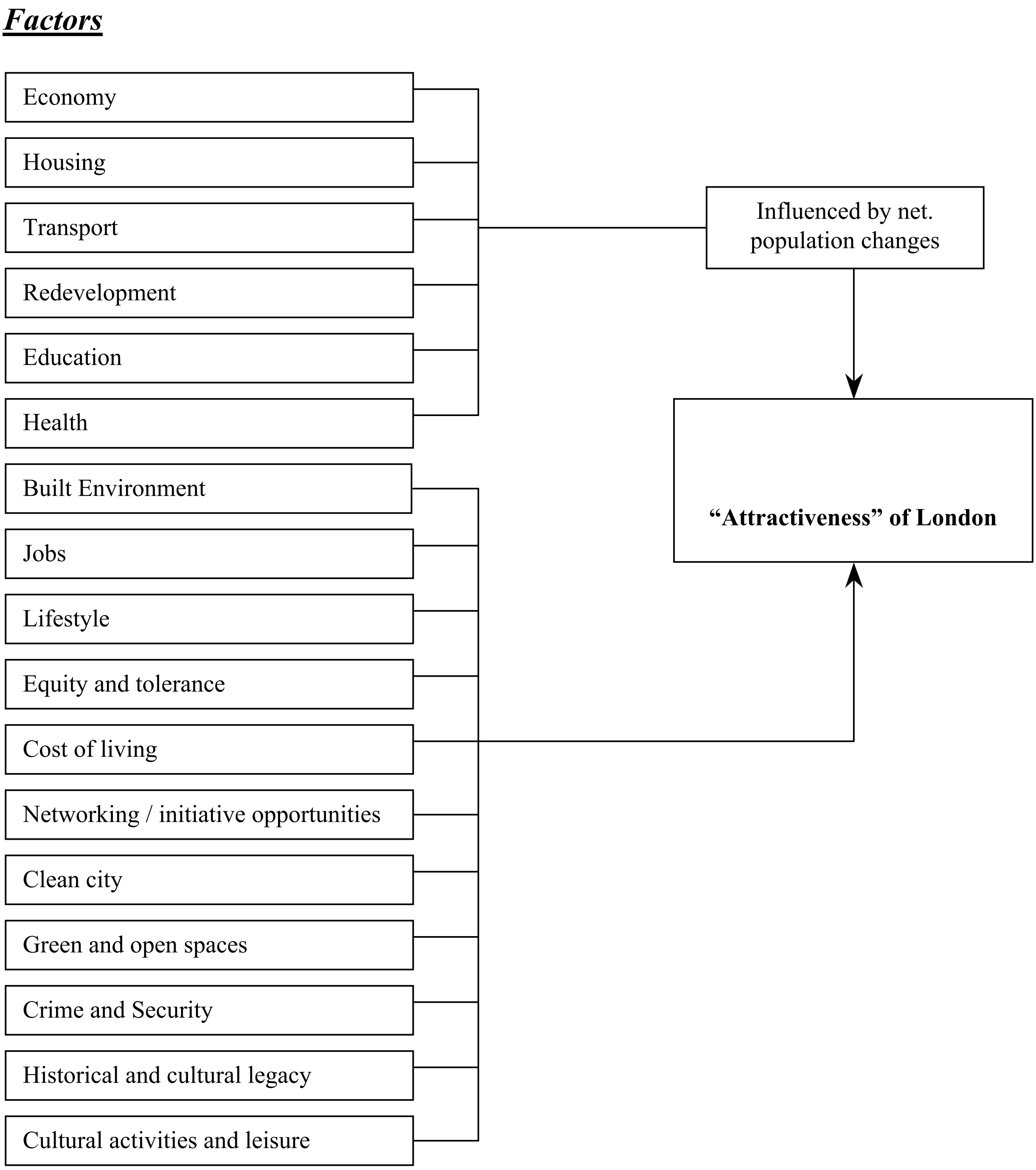
Tokyo and New York are noticeably hotter and more humid than London already. Both cities are coastally-located and therefore vulnerable to sea-level rise. As the Metro East study covering New York City expresses it: "*Many of the region's most significant infrastructural facilities will be at increased risk to damage resulting from augmented storm surges*" (Rosenzweig & Solecki 2001a:7). It is difficult to compare the UKCIP02 scenarios with existing studies of climate change in New York and Japan because different climate models and specifications have been employed. Nevertheless, the range of temperature changes for Japan (0.7 to 3°C for a doubling of pre-industrial CO_2 concentration which will occur before 2050, Nishioka & Harasawa 1998) and for New York (1.4 to 3.6°C by the 2050s and 2.4 to 5.7°C by the 2080s) (Rosenzweig & Solecki 2001), are reasonably similar to those suggested for London. Rainfall changes are more difficult to compare, and for New York at least, they vary significantly with respect to the different climate models used. As for extreme events, New York experienced major heat waves in the summer of 1999 and in September 1999, Tropical Storm Floyd brought large-scale flooding in northern New Jersey and southern New York State (Rosenzweig & Solecki 2001).

6.5 Attractiveness

We propose here to analyse the potential social impacts of climate change upon London by employing the notion of *'attractiveness'*. Attractiveness is made up of a combination of factors: economic, lifestyle, socio-cultural, opportunities, cost of living, land availability, and so on.

Figure 6.2 aims to illustrate this idea. ‘Attractiveness’ is an inherently subjective concept: whilst some people love heat waves, others find them oppressive; whilst some would welcome a more outdoors lifestyle, there are others who regard the associated noise and visibility of others to be intrusive. There are, however, some changes whose effects upon attractiveness we can be a bit clearer about: few if any would welcome a hotter journey on the tube, or parched, dusty parks and gardens, or hosepipe bans, for example. In the following we have provided judgements on attractiveness which are based upon expert and stakeholder discussions, infused with our own judgements based on past work on regional climate change impacts and a review of the literature. (Note that some dimensions of attractiveness are discussed more completely in Section 7, e.g. transport and tourism). A summary diagram of the changes in attractiveness due to climate change is given in the Summary and Conclusion to this section.

Figure 6.2 Factors Contributing towards the 'Attractiveness' of London as a city



London's attractiveness emerges from its role within the UK as centre of government, commerce, finance, other business services, the media, creative arts, etc. The sheer concentration of these activities and associated resources generates its own momentum and accelerates further concentration. London becomes a 'magnet' for many seeking their professional development, family and friends, likeminded people, involvement in national-scale organisations, networks, events and activities and so on. The 'pull' of London is therefore an upward spiral – the more people are attracted because of these reasons, the more reasons there are to attract others. The risk is that some set of circumstances might trigger a reversal of this process, resulting in a negative spiral (as witnessed in the past several decades in many towns and cities in the north of England). House prices, pollution, poor infrastructure, lack of health care, crime and so on, could all contribute to such a reversal, though the underlying economic conditions are likely to be the most important factors.

MORI's survey work for the GLA over the past two years provides evidence of the attractiveness of London. More people agreed that London had a positive rather than a negative record for culture and leisure, tolerance, parks and open spaces, easy accessibility, good relations between sections of the community, less discrimination than in the past, good schools and accessibility for people with disabilities (GLA 2002). Only on three issues did London score a more negative than positive record: availability of good quality health services, being a 'green city' and 'clean' city. The fact that 75% of respondents thought that London is *not* a clean city is highly significant to this study.

About a quarter of MORI's respondents were 'very satisfied' with London as a place to live and another half were 'satisfied', only one in ten said they were dissatisfied. It is interesting to note that a larger number of people are 'very satisfied' (about a 1/3rd of respondents) with their neighbourhood rather than with London as a whole. That could indicate the negative aspects of being part of Greater London which are not necessarily so evident locally, or which are more readily adapted to locally through familiarity and experience. On the negative side, when asked whether their neighbourhood is getting better or worse, 38% of people said it was getting worse, compared to 24% who thought it was improving (GLA 2001). The corresponding figures for London as a whole were 47 and 19% respectively.

The perception of negative costs associated with living in Greater London (as opposed to the respondents' own neighbourhood) appears to be becoming more pronounced. Judging by the responses elsewhere in the MORI survey, these negative costs appear to be crime and security, cost of living, traffic congestion, lack of public transport and problems with public services (health and education). Slightly more than 1/3rd of respondents said that they would tend to agree or strongly agreed that they would move out of London 'if they could'. This is higher than the 20% of respondents who, in a separately posed question, thought that they were certain, very likely or fairly likely to move out of London. One interpretation of this is that 10% or so of the respondents do not feel able to move but would quite like to if they could.

We should note that a major limitation of the use of MORI data here is that we do not have a comparator data-set for other cities in the UK, EU and further afield. If we had had such data, we would have been able to get a much better understanding of the relative attractiveness of different cities, against which the impacts of climate change could have been evaluated. Unfortunately, such detailed survey data is only available for London as far as we have been able to ascertain. There are perhaps fewer incentives for those in London to leave the city than residents of other parts of the UK because opportunities are generally higher in the capital than elsewhere. By contrast, there is a shift of population from the north to the south east of England because of declining opportunities in the north.

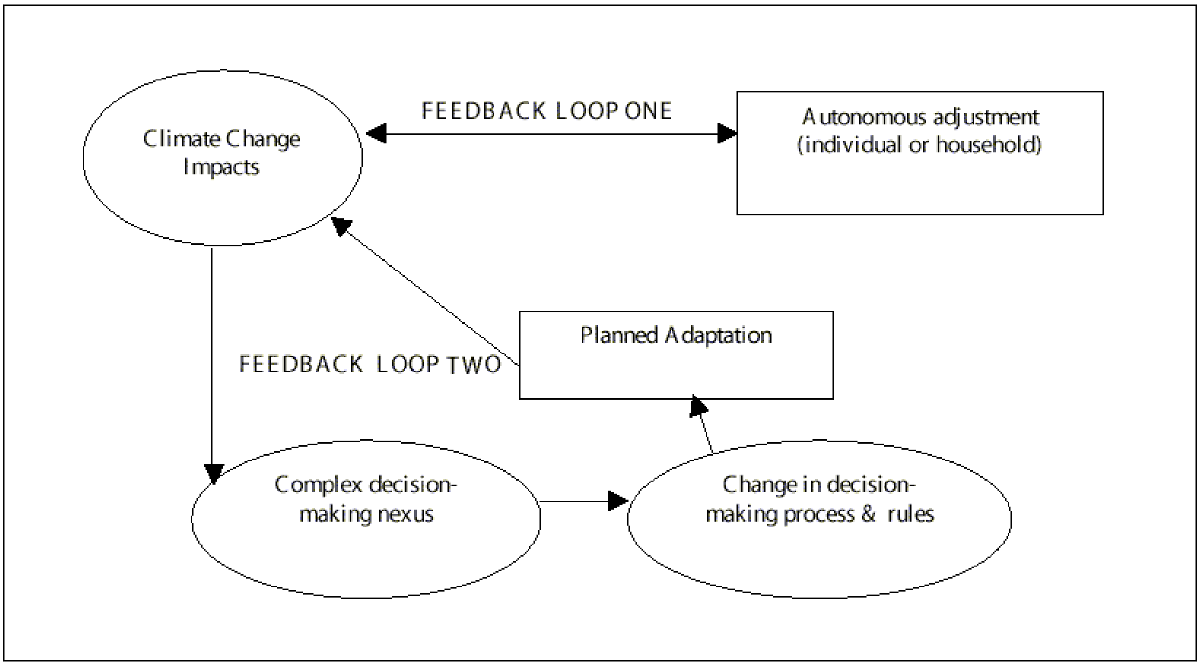
Social mobility is less pronounced in less affluent parts of society and many people stay in one place for social, family and cultural reasons. This creates a certain 'inertia' in demographic trends and patterns, which means that only a proportion of the population will respond to perceived changes in 'attractiveness', at least in the short-term. Evidence for such inertia can be found in the response of populations in the north of England to sustained economic decline in the past 30 years. Whilst there has been some net outward migration, it has not been anywhere near the level that would be implied by the relative difference in fortunes between South East and London and the north in terms of economic growth and job opportunities. (Part of London's workforce would, however, be likely to have more transferable and desirable skills than those in what was a largely manufacturing-based economy). The cultural, family and 'familiarity' ties which keep people in the area they grew-up in or have lived in for a considerable time, are strong and enduring. This does not detract from the value of the concept of 'attractiveness' since a less mobile individual, household or organisation may still wish to know what, on balance, the impacts of climate change might be (hence how to respond, if at all).

How, then, might climate change affect London's attractiveness - the strength of the magnet which is the capital? And what are the potential consequences of such change?

6.6 Autonomous Adjustment and Planned Adaptation

We now present the potential direct and indirect impacts of climate change upon the factors which contribute to, or detract from, the attractiveness of London, as identified in Figure 6.2 above. As pointed out in one of the workshops, human systems are inherently adaptive and responsive to change in conditions. A useful distinction suggested in the workshop and in the literature is that between what has been termed '**autonomous adjustment**' and '**planned adaptation**'. Autonomous adjustment whereby individuals respond to change through minor adjustments in their lifestyle, practices and behaviours. If hotter drier summers occur, then it is likely that lifestyle changes would follow on the part of millions of Londoners. Many people would probably spend more time outdoors, dress differently, eat different foods, spend their leisure time differently, grow different plants in the garden, and so on. Such changes are not 'planned-for' as such by organisations: usually they are decisions taken at the individual or household scale. (Though planning might encourage and facilitate change to occur in one direction rather than another: your local garden centre might not stock 'drought resistant' plants for example). It is assumed that the relevant actors would have access to resources to enable autonomous adjustment to take place. On the other hand, **'planned adaptation**' involves multiple-actors, change in organisations and policy making and decision-making rules and processes. Protecting development from the consequences of flooding is a good example here; once a particular development has been designed and constructed in a specific location, there are built-in vulnerabilities, which are to some extent irrespective of how individuals might respond to a flood event.

Figure 6.3 Autonomous Adjustment and Planned Adaptation [*source: Simon Shackley*]



It is not really possible (or sensible) to separate autonomous adjustments from the impacts of climate change, because it is a closely coupled system (Feedback Loop One in Figure 6.3). On the other hand, planned adaptation requires significant choices to be made in how the potential or perceived impacts of climate change are in reality responded to. Hence, for these types of issues, it makes sense to distinguish more clearly between impacts and responses.

Inevitably, in a report of this nature, there are some overlaps with the economic impacts section, and therefore, to avoid repetition, where appropriate certain social impacts have been combined with the economic impacts section. The opposite has also been applied with the economic impacts section.

For consistency, each section of the social and economic impact section is subdivided up according to the impacts of different climatic variables. Relevant discussion and case studies are included in each section as appropriate.

6.7 Built Environment

6.7.1 Context

There are currently 26.7 million square meters of office space in London. About three-quarters of this is in the central sub-region or in the eastern sub-region close to the centre. The amount of new office space required in the next 15 years is set out in the draft London Plan (GLA 2002a). This shows the need for significant new capacity (0.5 to 0.7 million square meters per year over the plan period, significantly more than was being added in the 1990s) (ibid.). Most (80%) of this new office space will be required in the central and eastern sub-regions.

In this section we consider the implications of a changed climate upon the built environment. We start by summarising the change in the urban winter and summer air temperatures arising from changes in greenhouse gas emissions and the urban heat island effect. The bulk of the section assesses the effects of these changes upon the heating and cooling requirements of commercial buildings (the domestic building stock being dealt with in the next section). Much of the analysis was done specifically for this project, and more details can be found in Wright (2002). We also cover the potential impacts of a change in rainfall patterns.

The Changing Climate

In the future (Wright, 2002; Wilby [This document, Section 5]):

- *Warmer winters are expected in London*, which will reduce heating requirements. The number of heating degree days (roughly proportional to the space-heating requirements in a well-heated building) will fall by between about 20 and 40% depending on emissions scenario, by the 2080s.
- *Trend in the magnitude of the central London heat island:* All seasons *except winter* show the difference between rural and urban temperatures increases over the 21st century. Over the heating season (October – April) it remains approximately constant. This means that the *difference* between heating requirements around the centre of London, and the suburbs, will not change.
- *Summers in London are expected to become warmer and drier*. The heat island effect also increases in summer. However, the regional rise in temperature is much more important (of the order of 1 to 3°C) than the *increase* in heat island effect (of the order of 0 to 0.5°C).
- *Summer evenings will be warmer*. Each 1°C warming on summer nights equates on average to more than an hour shift in the diurnal cycle; temperatures currently experienced at 7pm would be experienced well after 8pm.
- *The frequency and intensity of summer hot spells will increase.* The temperature exceeded on average on one in 10 summer days will increase by between 4 and 7°C under climate change, depending on emissions scenario. This is approximately double the increase in seasonal mean temperatures. Assuming the annual extreme maximum temperature changes by a similar amount, from Table 6.2, London's summer extreme would be about 33.5ºC by the 2050s in the two Medium Emissions scenarios, comparable with present-day Paris or Berlin. In the 2080s this rises to 35ºC under the Medium-Low Emissions scenario, similar to present-day Tokyo and New York. Note this is also hotter than all the present-day European cities at a similar latitude.
- However, since New York is about 11º latitude further south than London, it experiences much stronger sunshine – sun strength on clear days is largely determined by solar geometry and hence unaffected by climate change. Therefore, although temperatures may be similar, the weather would never feel quite like present-day New York. Cloud cover does decrease however in summer, by between 8 and 17%, depending on scenario, by the 2080s so there will be more sunshine on average. Note, however, that the level of confidence on changes in cloudiness is given as 'low' in the UKCIP02 scenarios. This compares with high

levels of confidence for general temperature increase. [See UKCIP (2002) for details of confidence levels].

- *London will not often suffer the very high humidity and high temperatures typical of cities like Toronto and New York.* By the 2080s the reduction in relative humidity ranges from about -7% under the Low Emissions scenario to about –14% for the High Emissions, compared to typical summer values around 60-70%. Therefore higher temperatures will to some extent be counteracted by reduced humidity.

So, under the two Medium emissions scenarios, around the second half of the century:

- Average summer temperatures outside London would be similar to those in the present-day city centre, though with a different diurnal pattern;
- If the urban heat island effect could be eliminated through dramatic changes to the cityscape, city centre temperatures would be similar to now, though again with a different diurnal pattern.

Climate change and the urban heat island already occurs in competitor cities of course. Comparison of the temperatures in Tokyo now and in the 1830s shows that they are on average about 4°C higher today (Tanaka, pers.com.) and 2.9°C higher over the past century (Reuters 2002). The number of nights during which temperatures stay above 25°C has doubled over the past 30 years (Reuters 2002). On one hot day in July 1995, there was a 7°C difference between the outskirts and centre of Tokyo (which nearly reached 39°C). The urban heat island intensity in Tokyo has been increasing in a linear fashion through out the 1990s, probably due to increased demand for summer cooling, higher traffic levels and greater use of computers (Tanaka, pers.com.).

6.7.2 Flooding and Rainfall Intensity Impacts

The building industry will benefit from an increased number of available construction days; in summer due to fewer rain days and in winter due to fewer frosts (although possible risk of increased waterlogging). If higher winds were to occur, there would be implications for the safe use of construction equipment, such as cranes and scaffolding.

The rise in groundwater levels in London due to changes in abstraction could be accelerated by increased winter rainfall although this is uncertain. One of the concerns of this is that the rising groundwater may build-up pressure beneath the clay layer which sits above the water containing chalk (the aquifer), thereby slowly increasing the saturation of the clay. This could affect the stability of certain foundations, in particular of tall buildings, and also of tunnels, which are drilled through the clay, resulting in subsidence and heave problems (ABI 2002). Plans to use some of this groundwater to alleviate the emerging supply-demand imbalance would clearly limit the problem (indeed, this issue is being addressed by The General Aquifer Research Development and Investigation Team or GARDIT, an informal group of interested parties derived from its three original members, Thames Water, London Underground Ltd and the Environment Agency set up to address the rising groundwater problem). On the other hand increased summer dry periods could lead to building subsidence due to drying out of clay soils, which is the dominant soil type in London.

Building design also needs to take full account of future potential water constraints, through use of ‘grey water’ recycling and other water conservation practices. Could new buildings in

London benefit from the rising ground water levels by using such water for flushing toilets, etc.? Could such ground water use also assist in the cooling of buildings in the summer, given that it will be significantly cooler than the air temperature?

6.7.3 Temperature Change Impacts

Effects on Heating

Non-domestic buildings and dwellings of those not in fuel poverty, are generally well heated, i.e. to a constant temperature during occupied hours. For these, the future reduction in heating degree days should be reflected approximately *pro rata*. Many non-domestic buildings such as offices and shops have high internal heat gains and therefore require cooling in all except cold winter weather. Increases in winter temperatures, and even larger increases in spring and autumn temperatures, will significantly increase the cooling loads in such buildings and bring more buildings into this type of regime.

Impacts on Air Conditioned Commercial Buildings

Analysis has been carried out on the effects of the urban heat island on cooling for a typical air conditioned office building in London, with no particular efforts made to reduce cooling demand such as solar shading. Using a derived relationship between cooling energy and average summer temperature, the percentage change in cooling energy was estimated (See Table 6.3). Increases are over 10% by the 2050s and around 20% in the 2080s. Cooling loads in many buildings increase greatly in sunshine where shading is poor; since cloud cover will reduce in future decades, this is likely to increase loads above those given. These increases are likely to be compounded further by a large increase in the number of buildings with cooling, in the absence of restraining factors.

Table 6.3 Increase in cooling energy compared to 1961-2000 for standard air conditioned building, by simulation

Emissions Scenario	Increase in cooling demand (%)		
	2020s	2050s	2080s
Medium-Low	7	12	18
Medium-High	7	15	26

Impacts on Non Air Conditioned Commercial Buildings

Building simulations for the 2050s conducted by the Tyndall Centre under a Medium-high UKCIP98 climate scenario, have explored the impact of future temperatures upon a smallish commercial property in London (Connor, 2002). Working conditions would be outside established ‘comfort levels’ for 451 hours or 23% of working hours. The use of best-practice natural ventilation and green design could reduce this to 169 hours or 8% of working hours, still a significant amount of time and outside the annual ‘comfort’ criterion. It is worth noting that the ‘established comfort level’ remains controversial and certainly not a mandatory standard, with some arguing that it should be relaxed or scrapped in favour of individual client/designer arrangements.

These results are in line with other work which has shown that in order to meet the comfort criterion even outside the centre of London for a present-day ‘hot’ summer, several features have to be included in the building design to lower indoor temperatures. Examples are high thermal mass, solar shading and natural (windows open) or mechanical (fans) night-time ventilation. Most of these features are lacking in existing buildings, and are expensive, difficult or impossible to retrofit. Night ventilation is one measure which is very effective outside London and often feasible to retrofit (though window opening must be designed to avoid a security risk). But since the urban heat island effect is at its greatest at night in summer, already raising the city temperature by about 3°C overnight and slightly more in the future, the effectiveness of night ventilation will be considerably reduced compared to non-urban areas. Also, summer cooling relies on high ventilation rates largely or totally provided by open windows. With high noise levels from traffic and pedestrians in much of London, this may not be a practical option.

The inevitable conclusion is that much of the existing commercial building stock is likely to be often uncomfortably warm later this century. This includes many existing buildings currently without air conditioning, and new buildings which have not been designed for summer conditions. Many clients and designers are therefore likely to go down the higher energy air conditioning route with more predictable internal conditions. One compromise approach which can result in a low-energy but comfortable building is the use of ‘mixed-mode’ operation. Here, the building is designed to be cool in summer with natural ventilation most of the time, but a limited amount of cooling is provided during the hottest periods to limit internal temperatures to (say) 25ºC, thus automatically satisfying the comfort criterion. The mixed-mode approach has been used successfully in many recent buildings, but is not standard practice. Buildings could be designed to minimise internal gains and take full advantage of natural ventilation, whilst leaving open the possibility of incorporating AC at a later stage should this prove to be necessary. One could, for example, put in high ceilings to leave space for chilled beams or ductwork, though there would be a higher initial construction cost. Such inherently flexible approaches could be a useful response to the uncertainty inherent in climate change because under a low climate change scenario, natural ventilation may be sufficient. Use of natural ventilation wherever possible within a mixed-mode operation reduces the AC load, thereby limiting the energy use and running costs.

There is also the possibility for significant innovation into more sustainable forms of cooling buildings. For example, chilled water could be provided by district Combined Heat and Power, perhaps powered with fuel cells (as adopted by Woking Borough Council). Borehole water could be utilised for cooling, with fuel-cell driven pumps, where it can be abstracted sustainably. Photovoltaics could be used in place of expensive cladding on prestigious buildings to provide electricity for air conditioning: the supply of PV electricity coinciding with high cooling demand.

Building specifications in the commercial sector in the UK, and London in particular, have frequently been driven by the perceived need on the part of property developers to provide a high quality development, thereby increasing the range of potential occupants, but not really taking full account of the client’s energy costs (Guy & Shove 2000). Changing current practices, such that a sustainable response to climate change is feasible, may therefore involve a different approach to how building specifications are made.

Even if a building is air conditioned, such cooling is usually set to go on and off during conventional office hours. Hence, those who wish to stay late or start early might find that they are having to put up with higher than desirable or acceptable office temperatures, with knock-on effects for health and productivity. So, climate change could indirectly limit flexible working patterns, even though the latter have some advantages in reducing traffic congestion, since they spread the traffic load through out a wider range of hours than just the rush-hours.

6.7.4 Socio-Economic Scenario Differences

Under GM there would be continued pressure to install AC in all new buildings, whilst under RS there would be strong pressure (possibly through the planning system) for architects and developers to use natural ventilation or at least mixed mode. The use of buildings would also vary significantly between these different scenarios. In GM, there would be stronger demand for, and a faster turn-around in, commercial and domestic rentals. This would put the developers in a stronger position vis-à-vis building users, and might increase the pressure for the routine installation of AC (because developers wish to extract greater rents and maximise attractiveness of their buildings to a potential range of occupants, both of which tend to enhance building specifications (Guy & Shove 2000)). In RS, we might well see longer-term use of domestic and commercial buildings, with greater user involvement in design and specification accompanying the longer tenancy agreements. This would put more emphasis upon running costs and hence encourage the uptake of more energy efficient features in buildings.

Under GM, we can envisage new ‘landmark’ buildings, e.g. tall and striking office blocks, grand development of apartment blocks or retail centres, large bridges, and visitor attractions (e.g. emulating the success of the London Eye). Under the lower economic growth rates in the RS scenario, it is unlikely that there would be sufficient resources to support such grand developments, and there would probably be less demand for such buildings. Lower buildings would be preferred, but there would be some different forms of architectural innovation, e.g. for more sustainable designs.

Demand for green spaces would have to compete with demand for land to build upon in the GM scenario. This would tend to restrict extensive outdoor areas and gardens attached to new buildings to the higher end of the market. Under RS, planning would be used to achieve much higher levels of green space development in the urban context. Parks, gardens, open areas, street trees, and so forth, would become a standard element of new development and redevelopment.

6.7.5 Adaptation and Mitigation

Adaptation and mitigation are closely related for the urban environment; many single measures will have effects on both. For example planting trees reduces summer temperatures (adaptation) and cooling loads (mitigation), while installing cooling limits internal temperatures (adaptation) but increases emissions of greenhouse gases (negative impact on mitigation). Climate change should cause few problems in winter vis-à-vis temperature change and heating, hence energy consumption, is reduced. The main problems occur in summer, with higher temperatures and solar gain. Many of the measures to reduce the effects of the urban heat island, as described in Graves et al., 2001 will also have positive mitigation and adaptation climate change effects. In summary (Wright, 2002) these include:

- reducing the H/W ratio, where H is building height and W is spacing (width) between buildings;
- reducing anthropogenic gains, by having low energy buildings and less traffic;
- increasing vegetation and tree planting (several positive effects, and weak negative effects);
- fountains and open water;
- increased albedo – overall reflectiveness – with light-coloured building and street surfaces;
- solar shading on buildings;
- natural ventilation, mixed-mode operation and low energy air conditioning (in order of preference).

Much can be learnt from traditional approaches in hotter cities with high solar gain. In these, light coloured, heavy buildings, careful natural ventilation design, small shaded windows, garden courtyards with fountains, tree-lined avenues, etc., have over many centuries provided pleasant environments without any mechanical cooling systems. One could envisage future planning requirements for tree planting, or minimum reflectivities for building and street surfaces.

6.8 The Domestic Sector

6.8.1 Context

There are 3.1 million dwellings in London. 60% of these are owner-occupied and nearly a half are flats, a much higher proportion than for the UK as a whole (where flats comprise 20% of dwellings). In inner London, about three quarters of dwellings are flats. The latest housing survey showed that 7.7% of London's housing (237,000 properties) is classified as 'unfit' a slight drop from the previous survey (LHC 2002). The proportion is higher (13.2%) in the 'older' London Boroughs, with the greatest difference between Haringey and Sutton (an eight-fold difference) (LHC 2002).

The average London property now costs £205,850, the price having risen by 115% since 1995 (GLA 2002a). To purchase such a property would require a wage of at least £55,000. The average London wage is £34,777, however (GLA 2002a). Given such high house prices and high levels of poverty in sections of the community, it is not surprising that there are 52,000 households in temporary accommodation in London, 8000 of which are in Bed and Breakfast accommodation. Over-crowding is also common, and six times the UK average. The over-crowding problem is especially apparent in the Bangladeshi community (LHC 2002). Much has been written about the number of new dwellings required in London, discussed and reviewed in the draft London Plan, which concludes that there is a need for 31,900 new dwellings each year for the next 15 years (including rehousing requirements).

Four out of five respondents (77%) in the 2001 MORI survey (commissioned by the GLA) on living in London mentioned affordable housing as a problem and half of the respondents thought that making housing affordable is a top priority to improve living in the city. London is set to build nearly 500,000 new houses over the next fifteen years. The draft London Plan has proposed that a half of these should be 'affordable' housing. These houses will have to be designed and constructed with climate change in mind; existing housing stock may also have to be adapted to cope with increased summer temperatures, more winter rainfall and, arguably, more extreme weather events. Already we are seeing air conditioning being used in the domestic sector, and this trend is likely to continue given projections of climate change.

6.8.2 Changes in rainfall and water resources

Water shortages in the summer could result in more frequent non-essential use water restrictions which would affect households which have got used to abundant water supplies. It might be supposed that London would have a lower per capita water consumption than the UK average, because gardens in London are probably smaller. Somewhat surprisingly, however, the per capita consumption of water in London is actually higher than the UK average (155 litres per head per day compared to the national average of 146 litres per day). The reasons for this appear to be two-fold:

- Greater affluence in London leads to higher levels of ownership of water consuming devices (washing machines, dishwashers, power showers, etc.)
- The lower household size in London relative to the UK as a whole (as occupancy levels decrease, per capita water consumption increases). (Tattersall, Thames Water, pers.com.).

Without behavioural change, household demand for water in a hotter climate would increase due to more clothes washing, more showers, more water for gardens and so on. Lack of water for irrigation of parks and gardens, and for street cleaning would have an adverse effect upon the image of London, especially for visitors. It is likely that that non essential use restrictions would be imposed to manage a drought situation, with the introduction of rota cuts and standpipes being a last resort measure with a range of demand management measures being introduced between these two extremes.

The five Water Companies that supply London are Thames Water, Three Valleys, North Surrey, Essex and Suffolk and Sutton and East Surrey Water. Thames Water is the largest supplier of water and has a well distributed groundwater resources and the major surface water resources, all of which is managed as an integrated system (ibid.). Groundwater storage is used to compensate in part for the lack of rainfall over a number of seasons. Thames Water also has the advantage that it is abstracting water for London close to the tidal interface, which means that it can extract more water for public supplies (DeGaris, pers.com.). However the utilisation of this source has a number of issues including navigation, tideway water quality and ecology. Three Valleys relies largely on groundwater sources though does have surface water source from the Thames near Iver. They also import water from Grafham reservoir in Anglian Region. Thames Water is the only water supplier with large reservoir storage facilities within Thames Valley basin. These reservoirs allow greater resilience and there were no drought orders in the Thames Region in 1995. Reservoir storage was, however, falling at 1% per day in the 1995 drought, so it cannot be claimed that London's water supply system is 100% robust in a single year drought event (ibid.). Resource stress would, therefore, only be apparent over a longer period of low rainfall, e.g. extending over at least two winters (March, pers.com.). Water stress might also increase as a result of increasing demand for water from the environment. The benefits of groundwater storage could be reduced in this way, moving the system towards single year criticality (ibid.).

Adjusting to climate change requires a fully balanced and twin track strategy with actions to manage demand, reduce leakage and provide additional sustainable resources. Adjustments to water shortages at the household level might involve water conservation measures (such as installation of devices in toilet cisterns), use of water butts in garden, metering and tariff development, re-use (rainwater or grey water). In the commercial sector recycling of water in appropriately scaled commercial developments and pressure and flow management for taps in commercial premises. A more radical response could be the installation of water storage tanks in properties, though this would obviously carry with it high costs in terms of installation and redesign of properties which have been built without water tanks.

When considering flooding, the vulnerability of housing to floods is partly a function of its design and the materials used. Modern housing is more vulnerable to flood damage because of the greater use of chipboard floors, dry wall plasterboard, cavity insulation and so on, and design features such as lower thresholds to improve access (ABI 2002).

A pertinent question from the social impacts workshop for this study was just how many times households and individuals would need to be subjected to water shortages or to flood events before they would respond by, for example, installing water conservation measures, water tanks, or making the design of their homes more flood-proof. It was asked whether there is any empirical evidence of behavioural change at the household level in response to floods. We have not been able to find any empirical evidence on this question, though the Environment Agency is engaged in a research project on public perceptions of flooding and risk communication which may provide such information in due course.

Another interesting stakeholder point raised in the social impacts workshop was the provision of information on flood risk and subsidence risk to home owners and residents. It was pointed out some communities would be better at finding out information on flood risk than others. The agencies involved in house conveyancy would probably not bring issues such as flood risk to the attention of potential buyers, and hence some pro-active investigation and questioning by the buyer would be needed. Such a system suits the more affluent white-collar professionals than it does the socially excluded. Hence, the institutional mechanism for providing information can itself contribute to social inequity. A further twist here, however, is that those agencies who provide information on flood risk may find themselves liable to legal challenge on the basis that such uncertain information is affecting house prices.

6.8.3 Temperature Change Impacts

London contains a wider range of housing types than most UK cities, reflecting the greater disparity of incomes. While some live in fuel poverty (generally defined as spending more than 10% of income on fuel), for others fuel bills are of no consequence. Future changes in London's climate will affect different dwelling types in different ways, and have varying economic impacts on households. This section considers some of these impacts, firstly for heating which all homes need, and secondly for cooling which is at present used in only a small minority of homes.

For poorly heated buildings, including dwellings of those in fuel poverty, much of the reduction in heating demand will be taken in increased comfort; cold bedrooms will be less cold, living areas will be warmer. The heating season will also become shorter, with people turning heating on later in warmer autumns, and switching it off earlier in the spring. There will therefore be a very positive effect on winter comfort and heating costs.

Cooling in Domestic Buildings

Until a few years ago, air cooling was only found in a few luxury cars; now it is standard in many ordinary models. This is not the result of climate change, but an interaction between manufacturers and consumers generating a new market. Similarly, most large London hotels now have air conditioned rooms. At present, the UK space cooling market for housing is very small, but it is growing rapidly and concentrated in the south east and London where summers are hotter and wealth greater. Typical installations include luxury flats and housing, particularly in the London area. A recent example is the Kings Chelsea development, a conversion of a former nurses' home into 287 luxury apartments and 12 houses. All of these have electric heating and air conditioning, with prices starting at £350,000 (BSJ, April 2002).

A number of factors could create a rapid increase in domestic space cooling in London:

- Generally higher summer and autumn temperatures;
- More frequent very hot summers, triggering purchasing decisions;
- More cooling in cars and non-domestic buildings;
- More products (portable systems are already on sale in DIY stores);
- Strong marketing by house builders and manufacturers of cooling as 'added value';
- Encouragement by electricity suppliers to increase low summer demand.

Apart from small portable units, the most likely type of fixed system would use an air-cooled condenser on the outside of the building or fitted into a window, as already seen on smaller commercial buildings in London. These are cheap and simple to install, but relatively inefficient with high running costs, becoming less efficient at higher temperatures. They are also visually intrusive, and since they use fans can be noisy both on the inside and outside.

More insulation in older properties is a good adaptation response, since it not only keeps the heat out, but keeps the warmth in during winter. Alternatives such as ground-source or water-source cooling exist; the capital costs are higher but running costs lower due to greater efficiency, and with no equipment or noise outside the building. There are strong arguments against more domestic cooling:

- more electricity use and hence greenhouse gas emissions;
- higher energy costs for households;
- possible replacement of winter electricity peak with summer peak, straining networks;
- visual intrusion;
- noise pollution.

In Tokyo, only the poorer suburbs do not incorporate AC in domestic properties. There is encouragement of energy efficient appliances, computers, fridges, TVs, etc., in order to limit energy consumption, hence reduce waste heat production. Other innovative approaches being explored in Tokyo include 'green roofs', i.e. using vegetation grown on roof tops to limit heat gain and to increase heat loss by evapotranspiration from the roots of the trees and shrubs. Such green roofs do appear to have had some success in temperature moderation within buildings, but one downside is that they increase the humidity of the air in the immediate vicinity of the building. Chicago also has a programme of encouraging green roofs (www.cityofchicago.org/Environment/Airpollution). The Japanese Construction Ministry is also investigating constructing a large heat exchange system covering some 123 hectares in the centre of Tokyo, including the Marunouchi business district and Ginza shopping area (Reuters 2002). Water would be pumped in buried pipes and would collect waste heat from air conditioning systems before being sent to a heat exchange system on the Tokyo waterfront, where cooler sea water would be used to absorb the heat. The cooler water would then be pumped back to collect more waste heat from the city, cooling the local air temperature by between 0.4 and 2.5°C. The scheme is currently only an idea and would be expensive, costing about $350 million dollars (pay back time of 30 years due to lower air conditioning costs) (Reuters 2002).

Social Responses to Warmer Domestic Properties

A larger proportion of Londoners live in flats and apartments and in multiple occupancy dwellings than elsewhere in the UK. This limits the responses which can be undertaken to some extent, since you cannot simply 'go into the garden/backyard' to cool down. Very few of the flats being built in London have balconies, but this is a well established method for coping with high summer temperatures used in buildings on the continent. In the social impacts workshop conducted during this study, there was a joke about 'Affordable Balconies' for London, but more seriously it was proposed that building guidelines might explore whether outside space could be enhanced for all new domestic and commercial property.

Another obvious adjustment to hotter weather is to open windows and doors to let cooler air replace hotter inside air. This is not always feasible, however, due to the greater risk of crime arising from open doors and windows, as well as traffic noise and traffic-related pollution. One finding from the heat wave in Chicago in the mid-1990s was that poorer households felt less able to open doors and windows because they felt more vulnerable to crime (stakeholder input to workshop, May 2002). Given that security and crime consistently emerge as prime concerns of Londoners, and as the top priority for action to improve London as a place to live (MORI 2002), the reluctance to opening doors and windows could easily be as real a phenomenon in London as it is in cities such as Chicago. This would affect less affluent neighbourhoods disproportionately and hence increase social inequity.

A further adjustment to hotter weather is be outside more often. This would require dwellers of flats and apartments without balconies to utilise communal space, or public spaces such as parks and gardens, so increasing pressure upon these. Whether local parks would be sufficient to cope with a greater demand for more outdoor spaces is not known and depends upon behavioural change which is impossible to predict. There might well be 'improvisation' in such a situation, utilising street corners, areas outside shops, or outdoor facilities in pubs and cafes. Access to such areas would not be even, however, since they may not be designed to cope with those with disabilities for example. Also, such impromptu congregations are unlikely to be welcomed by all local residents, some of who would perhaps complain about noise and disruption, feel threatened, etc. An interesting question is whether newly-built housing today should incorporate design aspects that take account of the likely greater demand in future for more outdoors living. This might be at the individual dwelling level or communally, e.g. shared areas of barbecues, outdoor get togethers and entertaining, etc. In Australia, for instance, public

BBQs facilities are provided, at which individuals bring their own food to cook on payment of a small fee.

One indirect effect of more outdoors living could be greater noise pollution, exacerbated by open windows. This could result in disagreement and conflict between neighbours as an individual or household or community perceives itself to be adversely impacted by the noise of the other. It is not unreasonable to suppose that people would adjust to any adverse social repercussions of more outdoor lifestyles and find ways of coping; this does, after all, happen in many other countries in hotter climates (Spanish, Italian and French cities for example, though none are strictly comparable with London).

Benefits
Warmer winters should reduce winter fuel bills, which will save householders money. Warmer winters will also mean fewer cold-related deaths which, at the national scale, is a larger effect than increases in deaths from heat stress.

6.8.4 Socio-Economic Scenario Differences

Flood Risk and Water Resources
An important finding of research on the impacts of flooding is that much of the increased costs associated with flood events in the USA are accounted for by the increased exposure of households due to: a) development in floodplains and flood risk areas; b) greater affluence meaning greater damage costs (Pielke 1999, 2000). Put simply, the exposure risk is higher and people now own more possessions which are liable to be damaged when flooding happens. Hence, evidence of the increased costs of flood events over time cannot be used to argue that there has been an increase in serious flood events *per se*. A similar argument can be applied to the UK, where most households have accumulated more expensive electronic and electrical goods, furniture and furnishings, etc.

Under the GM scenario this trend towards more goods is likely to continue, whilst under RS it is more likely that there is a slow down in the accumulation of material goods, hence the costs of flooding would increase more slowly. Under GM, building in flood risk areas is perhaps more likely than under RS. High-quality development in GM would be likely to be associated with high levels of flood resistance and mitigation measures and associated reduced insurance premiums. For instance, private developers along the Thames would include suitable private flood risk measures (as occurs along stretches of the US coastline). Low-quality development, however, would presumably not be so well designed or protected through private-sector schemes, and hence it would suffer from insurance-led property blight if flooding were to occur.

As for water resources, under GM there would be a continued upward trend in the per capita water consumption arising from greater ownership of water using appliances and continued move towards single occupancy. Under RS, the per capita consumption would reduce due to a reversal in the trend towards lower household numbers and an emphasis on water use efficiency and conservation. Hence, pressures upon water supplies will be exacerbated under GM with high climate change, though the supply-demand balance would depend on what increases in water supply are planned-for.

Temperature Change
Under GM, we would envisage more individualistic lifestyles. More 'private' and individual solutions to hotter buildings would be sought. Hence, the richer households would simply install AC systems, and the waste heat from these would be distributed locally, increasing the problem of over heating for those (presumably less well off) without AC. Climate change would, therefore, indirectly increase inequality between the better- and worse-off. The high economic growth rate would ensure that AC is provided as standard in many new properties. It would also mean that AC could be retrofitted into much of the existing building stock. However, there would still be much cheaper property where AC is not installed for financial reasons, with potential increases in inequality.

More privately-owned open spaces would also be fenced-off and protected to prevent use by others. There would be an increasing tendency for private purchasing of parks and gardens in squares or other local areas, for example; these would then be closed-off to members of the public and only available to members with property rights or who are prepared to pay fees. Disputes over noise pollution might be heightened under GM and there would be more recourse to 'private' mechanisms for dealing with social conflict, e.g. use of the legal system for the wealthier members of society.

Under RS, by contrast, there would be a stronger tradition of communal living and a greater willingness to engage in outdoor social activities with neighbours. Also, the risks of crime would be reduced through neighbourhood watch schemes, etc. On the other hand, under RS there would be less resource available for the retrofit design of older properties, due to generally lower wealth and less disposable income in this scenario. There would be a preference for using natural ventilation for cooling of domestic and less prestigious commercial buildings, not only because it is deemed to be more sustainable, but also because of the extra costs imposed by AC, which are less readily absorbed in RS.

There is likely to be a greater demand for new housing under GM than RS, because of more single-occupancy (a consequence of the continued trend towards individualistic lifestyles) and more inward migration. Hence, the overall density of development would increase and potential problems of urban heat islands would become more severe. Under RS, however, more of the new build would probably be communal and there would be a preference for higher urban density in order to free-up more land for green spaces. The thermal mass of such development could, potentially, increase the heat discomfort experienced. Inclusion of natural ventilation in the design would assist the alleviation of high temperatures. It is not known (with out more detailed modelling) whether such approaches would work adequately with a lower level of climate change. Natural ventilation approaches would probably not be sufficient in an RS scenario for London with high climate change.

6.9 Education

6.9.1 Context

Educational performance varies considerably across London, with lowest performance in the inner city boroughs of Islington and Haringey, and the highest performance in the boroughs of Sutton, Kingston and Redbridge (LHC 2002).

6.9.2 Flooding and Rainfall Intensity Impacts

There is anecdotal evidence that flooding can be highly stressful to children, some of whom see any subsequent rainfall event as threatening (Shackley et al. 2001). Such behavioural and emotional impacts are likely to affect children's educational performance.

6.9.3 Other Climate Change Impacts

Higher temperatures may affect the ability of children in schools to concentrate. A change in the scheduling of the school day is one possible response, e.g. with an earlier start and earlier finish, as in French schools. This change could, however, have serious repercussions for the parent(s), as they might then not be able to collect children from schools, or be at home for them in the afternoons. A different type of response would be for the school day to change, e.g. with more time spent outdoors in the hottest parts of the day. The ability to change the school day in this way would, however, depend upon availability of outdoor areas, with appropriate shade. Redesign of school buildings and lay-out would be one planned adaptation to temperature change. Change in extreme weather could potentially have some unexpected impacts on children. Teachers have reported anecdotally that some children become more excitable and 'hyper-active' in periods of high winds. Direct behavioural impacts of extreme weather could contribute to enhanced feelings of vulnerability.

If climate change were to influence the demography of London, this would have a knock-on effect on the number of children requiring education. Impacts of climate change upon transport would effect the ability of children to get to and from school.

6.9.4 Socio-Economic Scenario Differences

Under Global Markets (GM), we would have more private-funding of education, and more parental choice of school and, possibly, more choice concerning the educational approach, learning style and assessment method. One could perhaps envisage more and earlier differentiation of pupils, based on evaluation of their particular and specific abilities. This could exacerbate differences between the 'haves' and the 'have nots'. Under GM there might also be more children in London needing to be educated (depending on the deficit in population replacement elsewhere in society). Hence, any impacts of climate change would be more keenly felt under GM than under RS. The response to higher temperatures in GM would be more air conditioning in wealthier schools, increasing energy bills.

6.10 Redevelopment and Movement of Population

6.10.1 Context

Large-scale development is planned to occur across Greater London. For the purposes of this study the most significant is the Thames Gateway, which is the largest regeneration project in the UK. Whilst we will focus upon the Thames Gateway in the following section, we should make it clear that similar issues will also apply to all new building which occurs in the flood plain, not just of the River Thames, but also of its tributaries. With the Channel Tunnel Rail Link (CTRL) now agreed, the regeneration is also of national and EU importance (TGLP, 2001). The overall aim is for the East of England and South East Economic Development Agencies (EEDA & SEEDA) to work alongside the Greater London Authority, the London Development Agency (LDA) and Transport for London (TfL) in focusing sustainable development on brownfield sites, in order to achieve wealth creation and social inclusion. The Mayor of London, Ken Livingstone, has articulated this vision as follows:

> *"All my life activity has been in the west. Now it is the turn of the East. Almost all the growth and economic dynamism has been in the sector to the west of London. East London has been neglected for so long but it will be a major engine for growth". (TGLP 2001:3).*

The London Development Agency has stated that:

> *"The Thames Gateway is one of the key locations best placed to deliver large scale sources of new employment to London's major concentrations of deprived communities in inner east London" (LDA, 2001).*

The draft London Plan (GLA 2002a) outlines the drivers which are likely to shift development from the west to the east, both north and south of the river. These include:

- The high cost of offices and housing in central, north and west London;
- The support by government for the Thames Gateway and the existence of well-established partnership mechanisms;
- The existence of 10 square kilometres of development land adjacent to the greatest concentrations of deprivation in London;
- Opportunities in adjacent North Kent and South Essex;
- Radically improved public transport networks, including phase 2 of the CTRL and new rail and river crossings.

The existence of good examples of success such as Canary Wharf, where investment and infrastructure (especially transport) has led to high quality business accommodation which supports, and builds upon, the success of the adjacent City.

The London boroughs of Lambeth, Southwark, Greenwich and Lewisham - all of which are adjacent to the River Thames - thus have a combined target of providing accommodation for approximately 93,000 households in the next 15 years. Similarly, the demand for office space in the East sub-region of Greater London is estimated to increase from 8.1 million square metres to 12 million square metres, accompanying a continuing shift away from manufacturing and towards service industries.

6.10.2 Flooding and Rainfall Intensity Impacts

The proposed Thames Gateway development occurs upstream (Canary Wharf, Isle of Dogs, Stratford, Leaside, Royals, Greenwich Peninsula, Lewisham, Deptford, Greenwich) and downstream (Barking, Havering Riverside, Woolwich, Belvedere and Erith) of the Thames Barrier (TGLP 2001, MCA 2001). The flood defences of the river downstream of the Thames Barrier include the Barking and Dartford Barriers, which operate at the mouth of tributaries into the Thames, privately operated smaller barriers, and refurbished sea walls and embankments. In the 1980s the sea walls along the Thames Estuary were rebuilt and the crest levels were raised by 2.5m. The Thames Barrier and the defences which are located downstream of the Barrier were designed to provide protection from flooding of a 0.1% risk in the year 2030.

As a consequence:

> *"the flood defence standard is about 1:2000 years or 0.05% risk of flooding. With sea level rise this will gradually decline, as planned, to a 1:1000 year or 0.1% risk of flooding by the year 2030. Thereafter, if improvements are not made the defence standard will continue to fall. Preliminary estimates of the cost of providing 0.1% standard to the year 2100 show that a major investment in the flood defences infrastructure of the order of £4bn may be required within the next 40 years" (Environment Agency 2002).*

The standard of flood protection of the Thames in London is high. Low-lying areas targeted by development plans for the Thames Gateway (Barking, Havering, Erith, etc.) are currently well-protected against the risk of flooding; nevertheless the risk does need to be recognised. Clearly, a 0.05% risk is relatively low and a higher standard of protection is applied to the Thames than that which is usually applied to riverine (1%) or estuarine & coastal (0.5%) flood protection in the UK. The residual risk of an extremely serious flood event overtopping or breaching the defences of course remains. Much of the development land in the Thames Gateway will consist of brownfield sites, and such land is frequently to be found in the flood plain. Many brownfield sites have been used for industrial purposes. The ABI notes that the vulnerability of housing and retail property to flood damage may be far greater than for many industrial uses because of the greater value of the assets exposed (ABI 2002).

It should be noted, nevertheless, that the economic and social costs of a 1 in 2000 year event (the level of protection which existing flood defences are currently estimated to provide) are likely to be highly significant for the local, national and international economies. The most significant of these costs are thought to be:

- Repair to private property – to be met by the household/business and/or insurance agents;
- Repair to public property – to be met by local and/or national taxpayer;
- Relocation costs of household, business and public administration;
- Preventative expenditures associated with building design that reduce flood risk further – to be met by developer/occupier (private property) or taxpayer (local authority-owned);
- Disruption to transport infrastructure and subsequent repairs.

There may also be an impact on the attractiveness of the London property market to overseas investors, and more generally, the attractiveness of the city as a place to conduct business of all sorts. These potential indirect effects have not been quantified but are clearly likely to be a major factor in the economic appraisal of future investments in flood prevention measures.

Related to this, a greater perceived flood risk along the Thames corridor may result in reluctance of businesses and households to live and work in at-risk areas. This type of economic blight may cause those who can afford to relocate to move to other areas of London or outside of London. These effects will cause land prices to rise in other parts of London and result in occupation of the blighted areas only by low-income groups.

A further important issue relating to the nature of economic development in London is the knock-on impacts of riverside development in East London in the next decade upon the requirement for future flood protection. Once major new infrastructure is constructed, then there is a large new asset base which needs to be protected and this in some senses limits (or renders less attractive) other options, such as using land for green areas which can serve a role in flood water storage. The issue is, in part, one of how long a time scale is adopted in analysing urban development and regeneration plans. If one were to adopt a timeframe of 15-20 years ahead (as used in traditional planning), then flood risk would probably not feature as an impediment to riverside development. Over a 50-100 year timeframe, the evaluation process would have to change because of the need to take account of the change in level of flood protection provided by the Thames tidal defences beyond 2030 (hence requiring use of a scenario planning approach).

An even longer timeframe, i.e. beyond 2100, would require yet another assessment, because of the accumulated effects of sea-level rise. Depending upon global greenhouse gas emissions and the uncertain response of the oceans and ice-caps, etc., sea-level rise over the next several hundred years could challenge the technical capacity to provide adequate levels of flood protection in parts of London. No thorough assessments of the risks of sea-level rise and extreme rainfall affecting the river level on these longer time-scales have yet been conducted.

Another issue for the Thames is the potential need to store large amounts of water up and down-stream of the Barrier depending on whether the issue is increased rainfall (up-stream) or higher sea-levels plus surge events (down-stream), or perhaps both. Re-channelling water out of the Thames upstream, and into other waterways is one option for coping with large amounts of accumulating river water. Down-stream water storage is required when the barrier is closed and this could, potentially, have an adverse impact upon fisheries and cockle beds, which are protected by EU legislation. Using the river and estuary for water storage purposes to avert flood risk could, therefore, collide with its natural ecosystem role and functions (Naylor, pers.com. 2002).

Several of the Strategic Zones of Change which have been identified within the Thames Gateway for London have included nature reserves, country parks and visitor centres, e.g. Havering Riverside and Rainham Marshes (a 1,400 ha reserve is proposed, with capacity for a quarter of a million visitors per year) (MCA 2001). There is clearly a good opportunity here for such set-aside land for biodiversity to double-up as land for flood water storage. The future of Rainham Marshes as London's biodiversity 'jewel in the crown', and one of the few remaining remnants of the marshes that once fringed the River Thames, now seems more certain, with the London Borough of Havering agreeing that the marshes should be protected (FoE 2002). In 1998, considerable concerns had been expressed when English Partnerships applied to Havering to build on 50 hectares of the area (FoE 1998). Interestingly, the lack of proper management of the site in the past had led the opinion to be expressed at that time that the Marshes were 'not worth protecting'.

The 142,000 new houses and 255,000 new jobs planned for the Thames Gateway (TGLP 2001) have huge knock-on implications for the provision of water resource and suitable sewerage treatment facilities, as identified by stakeholders in the course of the study. The design of the sewerage system clearly needs to avoid the prospect of overflow at times of high rainfall directly into the Thames. This high level of development also implies a quite massive urban development, which could increase water run-off. Potential solutions to this are greater use of sustainable drainage systems, permeable 'soakaways', and so on, though such methods are far from having been fully proven in a range of situations.

The Environment Agency (2002) and Thames Estuary Partnership are currently undertaking a comprehensive assessment of flood protection of the Thames Estuary, and it is proposed that this should extend its timeframe for assessment beyond 2100. The EA assessment will not be completed until at least 2006, however. Some of the development decisions in respect of Thames Gateway may be made in a shorter timeframe than that, e.g. purchase of land for redevelopment, provision of guidance, planning permissions, etc.

6.10.3 Temperature Change Impacts

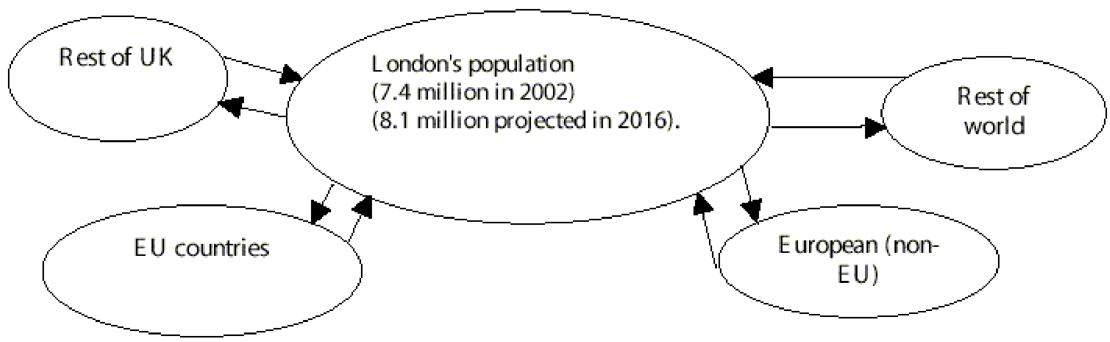
Major new development such as the Thames Gateway presents opportunities for innovative solutions to the problem of over-heating within domestic and commercial buildings. As well as natural ventilation and mixed-mode approaches, which can take advantage of the flow of cooler air up the river Thames, there is the potential to use heat exchanges with ground water and/or with the River Thames and its tributaries. Groundwater heat pumps could utilise the cooler underground waters for cooling of buildings, whilst heat exchangers extending into the river Thames would moderate temperatures in summer, also providing some warmth in the winter. The costs of such heat exchange systems are usually prohibitive, though in the case of a new development the costs would be relatively more contained. The new GLA City Hall building is showing a lead by having a borehole ground water cooling system.

6.10.4 Indirect Effects due to Demographic Changes

The demand for housing and associated infrastructure (work places, schools, hospitals, transport, etc.) depends on the net population in London, represented by Figure 6.4 below. The workshop discussed the possible impacts of climate change upon these population flows. It was thought that high climate change might increase the flow of people out of London, since these would mainly be retired and older people, who would be more attracted to a rural or suburban residence outside of London because of heat waves and heat discomfort. An additional outflow might be more seasonal, with wealthier inhabitants decamping in other cooler and cleaner locations in the UK or elsewhere.

There is currently a net outflow of UK citizens from London. In 1999, 163,000 people moved into London from elsewhere, whilst 197,000 moved out (ONS 2001). Birth rates per 1000 people in London is significantly higher (by 23%) than the UK average, reflecting the younger than average population of London compared to the UK average (ONS 2001). The flow of people into London from elsewhere in the UK would *not* be sensitive to climate change, it was felt, because the strong pull of the capital is for jobs and the other elements of attractiveness identified in Figure 6.2. Also, many of these inward UK migrants are younger and less likely to be put-off the city by the weather conditions. A proviso to this assessment, however, is if the ‘magnet effect’ of London is diminished by a reduction in its attractiveness (perhaps in a part because of climate change). In that case, more offices and HQs would be based outside of London, and the attractiveness of those other locations would increase relative to the capital. A further proviso is that if sea-level rise threatens coastal habitation in the south east and east of England (or indeed elsewhere in the UK) there could be an inward migration to London, either from abandonment of settlements or property blight due to cost or lack of availability of insurance protection.

Figure 6.4 Flows of People into and out of London



As for the flow of EU residents into London it was not felt that this would substantially change as a result of climate change. Other major European cities would be affected by climate change, but it is not obvious that there would a major exodus from these to London. If a 'critical threshold' were exceeded, e.g. for water supplies, then it is conceivable that some southern European cities would have to 'down-scale', though no evidence of such thresholds is presently available. Furthermore, the other major financial and business service centres (Paris, Berlin, Frankfurt, etc.) are located in northerly parts of Europe and inland, and much less likely to be subject to such critical climate-related thresholds (though there might be problems arising from summer temperature extremes). In the worst-case scenario, there would be very high climate changes and associated impacts in southern Europe, which would contribute towards a general northerly shift in the EU's population. The level of climate change and impacts would have to be rather extreme for this to happen, however. Many people in Europe appear to be more than content to live in their hotter southerly climates, however, and indeed they are joined by many thousands on holiday, or permanently to live, from the north of Europe. It appears that many citizens of the EU are not yet near the higher end of their 'preferred' temperature regime!

As for flows of *non*-EU residents into London, this might be more sensitive to the impacts of climate change in the areas where people are coming from. It was felt quite strongly, however, that by far the most powerful driver is the lack of economic opportunity in the host country. Climate change could reduce the economic fortunes of that country even more, though it could also have the converse effect, if there are agricultural benefits (relative to other countries). Hence, it was felt that too much importance should not be attached to climate change in understanding migration. The exception was where a major climate-related disaster or catastrophe struck (a drought, flood, storm, extended problems over water supply, etc.): in this case then there could be large-scale movements of people, 'environmental refugees' as they have been termed, though the UN does not currently recognise such refugees. Experts in refugee studies have stressed that environmental events by themselves rarely, if ever, produce 'refugees' (Barnett 2001). It is, instead, the accumulation of economic and social hardships, wars and (in some cases) environmental events, which produces refugees. This is not to say, however, that climate-related environmental threats might not become more of a problem in the future, as there is an acceleration of global environmental change. The political pressure generated by many more refugees would be significant.

To summarise, the workshop concluded that climate change would not substantially effect the net migration into and out of London. It could, however, accentuate the *existing* trends of outward migration and, to a lesser extent, inward migration, though to what extent is very difficult to assess, and possible effects are discussed in relation to the supply of labour for some industries, in the Economic Impacts section below. If climate change did influence the overall attractiveness of London as a global economic centre, then this could also influence net-migration.

6.10.5 Socio-Economic Scenario Differences

Under a GM world, the role of strategic planning and oversight of the development of land in east London would be fairly limited. It would be more or less the prerogative of private developers to decide on their own development strategies and priorities, within broadly construed, but not overly prescriptive, guidance. Under the RS scenario, planning would become much more important and there would be greater use of regulation and guidance, with an emphasis on 'appropriate development' given flood risk and urban redevelopment priorities. RS would favour 'green corridor' approaches (though in addition to, not at the expense of, green belt) with some managed retreat of the existing defences in selected locations.

6.10.6 Adaptation Options

There is some discussion within the Thames Gateway partners and London planning community of whether a green corridor alongside the south and north banks of the Thames could be included as an integral part of the Thames Gateway. This would, inevitably, limit the area of land available for redevelopment. Hence, there may be a need for more land to be made available elsewhere within the target development area. One idea that has been mooted, is to relax the Green Belt on the north easterly and easterly fringe of Greater London in certain locations, but then to compensate for the loss of green land by the creation of 'green corridors' that radiate from the outskirts into the inner city. Such green corridors would follow river valleys where possible (e.g. River Lee) and would have other social and environmental benefits (e.g. recreational and leisure use).

A more radical way to allow high levels of urban development in areas at risk from flooding might be to restrict the time span over which planning permission is granted. This would retain the flexibility over future policy options which is desired by the Environment Agency, whilst facilitating development which clearly has multiple economic and social benefits. Planning permission in a new development could be permitted, but only for, say, 50 years into the future. The construction and infrastructure would need to take full account of the limited time-span. In practice, however, it is very difficult to imagine whether the population of an area would ever accept the need to 'move on' and find somewhere else to live, especially since most of them would not be the same individuals who invested in the area originally. The financial prospects of investing in an area with a limited timespan is also doubtful, unless demand was extremely high and no other credible alternatives existed. Why, in the last analysis, would any one wish to buy or invest in a property in such an area, especially with elapse of time? Limiting the flood defence protection available to the area (to reduce the expectation that flood protection would be provided beyond the planning time horizon) would simply exacerbate the problem of 'property blight'.

6.11 Lifestyles and Consumption

6.11.1 Context

Lifestyles are highly diverse and changeable. Climate change could be significant in so much as it accentuates, facilitates or inhibits certain existing and on-going changes in lifestyle. The predominant drivers for lifestyle changes are, however, a complex mixture of social, cultural and economic factors and only tangentially related to environmental concerns for the majority of individuals and households. This might change in the future, of course, due to value-shifts (e.g. a shift to 'post-materialism'), or it might change because of adverse environmental impacts, such as droughts, heat-waves, floods, and so on.

6.11.2 Temperature Change Impacts

Climate change might accelerate a move towards more active, outdoor lifestyles and all-year around tourism. This trend is already in place, driven by greater affluence, earlier retirement, better health and a cultural shift away from the idea that older people cannot have an active lifestyle. Better weather can only accentuate the growing popularity of 'out of season' tourism, and would encourage more outdoors activities in general. Lifestyles become more outdoors oriented, increasing pressure upon open-spaces, and possibly increasing the demand to travel out of urban locations. Different populations have varying potential to adopt more outdoors lifestyles due to income, location of residence, dependants, and cultural issues. There are also implications for the design and styling of clothing, fashion, buildings, cars, and so on. This creates opportunities for designers who are looking to provide the market with – literally - 'cool' goods and brands. We have already seen the brewing industry using advertising that emphasises the cooling quality of their products, and even relating this to global warming. Such marketing (whether serious, ironic or playful) is likely to become more common in future.

6.11.3 Impacts due to Global Climate Change

There are also certain threats to the provision of taken-for-granted goods and services that might arise from disruption to production, manufacturing, distribution, storage and delivery caused by climate change (see also Section 7.7 on manufacturing). Yet, climate change might well increase the demand for fresh fruit and vegetables, cold water, ice creams, etc., including fresh foods and goods sourced from around the world. Given the highly international nature of food sourcing in UK supermarkets, what happens in Spain, France, Italy, Greece, Israel, North Africa, and so on, will influence availability and cost to UK retailers. Assessing the impacts of climate change upon food supplies in those countries is by no means straightforward, however. This is not only because of the scientific uncertainties but also because of the potential role of adaptation in moderating the impacts. It is also a consequence of the potential opportunities for new agricultural developments in other countries (e.g. in Eastern Europe), and in the UK itself, which could emerge through climate change plus socio-economic development.

6.11.4 Socio-Economic Scenario Differences

Under an optimistic GM scenario, new supplies of goods and services desired by consumers would be forthcoming. The assumption here is that climate change will bring opportunities for some producers, at the same time as others suffer. Entrepreneurial retailers will always be able to exploit these new opportunities. The GM scenario would also see greater affluence and greater longevity as health care improves for the well-off, who would therefore be even better predisposed to take advantage of new opportunities for tourism and leisure. The less well-off would, clearly, not share these opportunities to the same extent. Under the RS scenario, there would be a ratcheting-down of expectations concerning the availability of goods and services from around the world. There would be a greater focus on local production, and the low level of climate change could allow a wider range of food produce to be grown locally, with benefits for the local and UK economy.

High levels of climate change could, conceivably, accelerate the incidence of natural weather-related disasters. Accumulation of disasters and widespread social, economic and environmental impacts might encourage a shift in values, so moving away from the GM scenario. Under the RS scenario, a pattern of natural disasters would provide more evidence of the need for limiting the use of resources.

6.12 Health

6.12.1 Context

Health is regarded by most experts as being strongly related to socio-economic circumstances such as housing, employment, education and lifestyle (LHC 2002). The high levels of inequality in London mean that many of the additional impacts from climate change will be felt most acutely and with greatest consequence by the underprivileged. These would include those who are less well off, live in unfit and overcrowded housing, do not have fresh food readily available, suffer from higher unemployment, are less able to pay for suitable adjustment, and so on. One way to reduce the vulnerability of the population to climate change related health-impacts is therefore to reduce present-day inequalities.

6.12.2 Flooding and Rainfall Intensity Impacts

Flooding results in health impacts which have been investigated in several studies for the Environment Agency (e.g. by the Flood Hazard Research Centre, Middlesex University). Long-term effects upon stress and depression levels have also been studied (e.g. from the Northampton floods of 1998). It was pointed out by Sari Kovats of the London School of Hygiene and Tropical Medicine in one of the workshops, however, that there are significant methodological obstacles to measuring change in stress and depression levels following flooding. How does one know with any certainty what the baseline level of stress and depression was prior to the flood event?

6.12.3 Temperature Change Impacts

Warmer Winters

Of the roughly 70,000 deaths in London every year, about 6,000 more occur during the winter than would be expected from the rate during the rest of year. There is some evidence to link this to cold homes and age. Countries with much colder winter climates, but higher standards of heating and insulation (e.g. Sweden) have much lower excess winter death rates. While improved insulation and heating is far more important than changes in winter weather, a reduction in very cold spells is likely to reduce excess winter deaths over and above the effects of dwelling improvements. The Department of Health suggest that up to 20,000 fewer deaths might occur in the UK as a whole as a consequence of medium-high climate change by the

2050s (DoH 2002). Although winter precipitation is predicted to rise by around 10-20% in the London area, snowfall is expected to decrease by between 60% (Low Emissions scenario) and about 95% (High Emissions scenario) by the 2080s, indicative of far less frequent wintry spells.

Effects on humidity and related health effects are less certain. External relative humidity falls by 2-3% percent in winter under all scenarios and timescales, but absolute humidity rises since warmer air can hold more water. Since absolute humidity determines internal relative humidity in heated buildings, internal relative humidity could rise slightly. This, combined with higher internal temperatures, could increase asthma, since both tend to increase asthma rates. However, there will probably be less internal condensation and mould growth, because internal surfaces on external walls and windows will be less cold and this is likely to be a stronger effect than the slight rise in absolute humidity, with small beneficial effects on health. Predictions for wind remain very uncertain; wind speeds are expected to stay about the same, possibly increasingly slightly in winter, but the effects on infiltration rates and hence internal humidity are likely to be commensurately small.

Hotter Summers

Projected climate change will be accompanied by an increase in hot spells, often exacerbated by urban air pollution on still, hot days, which would cause an increase in heat related deaths and illness episodes (see Section 5.3). The evidence indicates that the impact would be greatest in urban populations, affecting particularly the elderly, sick and those without access to air conditioning. The Department of Health's recent review of the impacts of climate change suggests that approximately 2000 extra deaths might result from higher summer temperatures in the UK as a whole (DoH 2002).

Populations do, however, adapt to continued higher temperatures through behavioural change and through autonomous physiological change. For this reason, populations are most often vulnerable to unusually hot or cold weather, relative to what they are acclimatised to, rather than hot or cold *per se*. Studies have shown, for instance, that the people of Athens suffer more from a cold weather spell than people in Stockholm do to an equivalent cold spell. On the other hand, the residents of Stockholm are more affected by a heat wave than those in Athens (Martens 1996, Gawith et al. 1999). If climate change results in greater variability and more extreme events, then populations will, conceivably, become more vulnerable. Whether populations adjust to a more variable pattern of weather from month to month, or from year to year, is an interesting question. Adjustment to a certain level of variability is feasible, though thresholds may occur in the adaptive capacity. A further impact of hotter weather is the greater risk of skin cancer, especially for children who not only spend more time outside but are also the most vulnerable. The Department of Health (DoH) suggests that 30,000 additional cases of skin cancer could occur across the UK if ozone-depleting chemicals are emitted at current levels, though full implementation of the Copenhagen Amendment would reduce this number to 5000 (DoH 2002). The DoH review stresses that the additional number of cases of skin cancer depends greatly upon adjustments, such as use of sun creams, avoidance and wearing of wide-brimmed hats, and so on. An increase of up to 2000 more eye cataracts a year is also anticipated by the DoH review.

The outbreak of Legionnaire's disease in Barrow-in-Furness in August 2002 is widely expected to have been related to a faulty or poorly maintained air conditioning unit. As of early August, one man had died from the outbreak, whilst 117 people have been identified as having been infected. This highlights the potential risk that more widespread use of air conditioning could increase the incidence of Legionnaire's, if units are not correctly operated and maintained. In the light of the Barrow outbreak, more research is required on the risks arising from possible spread of infectious agents through use of air conditioning.

Other Health Impacts of Climate Change

Other effects on demand for health services arising from climate change include:

- An increase in instances of food poisoning (estimated at 10% increase, or 10,000 more cases, for the UK as a whole) as increased temperatures facilitate bacterial growth (DoH 2002), though again much depends on behavioural change.
- Those in over-crowded accommodation are more vulnerable to the spread of infectious diseases.
- The pattern of demand for health services might change, with somewhat less demand for treatment of cold-related illness in the winter as temperatures increase, though with the possibility of a slight increase in summer. Increases in severe weather events, particularly storms and flooding, will also intensify temporary demands on resources and require the development of improved emergency planning scenarios.
- Increased blooms of toxin-producing algae in summer bathing water. Such toxins can be very dangerous if ingested: children or pets are especially vulnerable whilst playing around affected water ways.
- Potential increase in exposure to infectious agents. The DoH review has concluded that by the 2050s under medium-high climate change, indigenous strains of malaria will re-establish themselves in the UK, but do not pose a health threat. There could be outbreaks of the more serious strain *Plasmodium vivax*, especially in low-lying salt marshes, and local inhabitants would be advised to avoid mosquito bites. This could, potentially, affect parts of the Thames Estuary. The more serious strain *Plasmodium falciparum* would not become established in the UK, but tourists abroad could be vulnerable. Other countries are more vulnerable to climate-change induced changes in mosquito distribution, including parts of southern Europe and the southern USA.
- The risks of tick-borne diseases (Lyme Disease and encephalitis) are unlikely to increase according to the DoH review (DoH 2002).
- The risks of water-borne diseases such as cholera and typhoid are very unlikely to increase due to stringent levels of water quality treatment and control (DoH 2002).
- Less conducive working conditions due to hot weather and lack of air conditioning (e.g. in factories, in offices where AC cannot be afforded, etc.) can contribute to poor health. Even in those buildings with AC, the contrast between a cool interior and hot outside conditions can put stress upon the body’s physiology and can make people more susceptible to illness.

6.12.4 Indirect Impacts - Air Pollution

The impacts on exposure to air pollution are complex, as indicated below.

Table 6.4 Potential impacts of climate change on exposure to air pollution

Positive	Negative
Reduced exposure to damp conditions indoor due to being outdoors more often	Increased tropospheric (low-level) ozone (DoH 2002)
More circulation of air due to windows and doors being left open for longer	Dust mites survive for longer in drier air > asthma
If more outdoors lifestyles led to a more active lifestyle, then resistance to respiratory illness would probably be enhanced.	More dust raised in dry air > asthma

Note that most rooms have an air change rate of at least once per hour so that, chemically, most indoor environments will be similar to that outdoors plus internal sources (moisture, VOCs from plastics, smoke, etc.). Being outdoors more will not, therefore, contribute to greater exposure to air pollutants. Greater exposure to air pollution would occur at low level along major roads (including inside cars and buses) (e.g. see maps of London Health Commission, 2002). Hence, greater exposure under climate change would be limited to undertaking more journeys along major roads by car, bus, cycling or walking. More windy weather under climate change would, on the other hand, cause fewer air pollution episodes arising from the build-up of NOx, PM_{10}s, VOCs, etc.

People tend to eat more healthily in hotter and drier weather if the evidence of the hot summers of the mid-1990s is anything to go by, i.e. more fruit and vegetables (Palutikof et al. 1997). More active lifestyles on the part of children is to be desired given current trends towards obesity and lack of exercise. If better and hotter weather encouraged this, then there would be a benefit. If better weather was to improve the prospects of children walking or cycling to school more, then there would be the added benefit of alleviating traffic congestion during the 'school run' period. Likewise, if better quality and fresher fruit and vegetables were available under climate change, then benefits would arise, assuming that such foods are accessible. Unfortunately, there are already wide-spread variations in access to fresh foods in London. Whilst lower prices would help to make fresh foods more readily accessible, cultural change is also necessary.

What is more, measures taken to reduce the rate of climate change by reducing greenhouse gas emissions could produce secondary beneficial effects on health e.g. decreased dependence on motor transport could encourage walking and cycling - thus improving health. At the same time, 6.3 in 1000 pedestrians in London are injured in accidents (LHC 2002); over 8,500 pedestrians and 3,500 cyclists in 2000 (ibid.). Clearly, the greater use of bicycles and walking needs to be facilitated by taking steps to reduce the risks of accidents with vehicles. The risk is highest in the inner city boroughs of Westminster, Camden and Islington and least in the outer boroughs. Reducing the combustion of fossil fuels also limits the production of other pollutants such as SOx, NOx and particulates with potentially significant health benefits.

6.12.5 Case Study: Comparison with Other Cities

An intense summer drought in New York may have contributed to the fatal outbreak of the West Nile Virus (Rosenzweig & Solecki 2001a).

> *"Populations in such urban areas as New York City will experience increased exposure to heat stress conditions, greater potential of water-borne or vector-related disease outbreaks, and higher concentrations of secondary air pollutants, resulting in higher frequency of respiratory ailments and attacks (e.g. asthma)" (ibid: 9).*

With nearly a quarter of NYC's population below the official poverty line, the vulnerability of a large proportion of the population to adverse impacts, and inability to pay for air conditioning to relieve heat stress, is evident. Heat stress may increase by 2 to 7 times over the next century as the number of days over 90^{o}F (32°C) increases from 20 days per year to between 27 and 80 days per year during the 2090s. The Metro East Coast study also noted that:

> *"Heat waves will also exacerbate secondary air pollution problems in the region. Peak electricity demand and fossil fuel burning during heat waves will result in increases of primary air pollutants (e.g. nitrogen oxides) and secondary pollutants (e.g. ozone). Increased concentrations of such pollutants in turn will result in higher numbers of respiratory-related attacks and hospitalisations".*

It is not clear that increased peak electricity demand in London would have a comparable effect because most of London's electricity is imported rather than being locally generated. Hence, emissions of NOx and SOx associated with combustion will occur elsewhere, where they might have adverse health impacts. Flows of air into London from continental Europe might bring with it more pollutants, especially ozone, as a result of increased peak electricity due to a greater cooling requirement on the continent.

6.13 Historical and Cultural Legacy

The impacts of climate change on tourism and leisure are discussed with the other economic impacts in Section 9.

6.13.1 Context

London is a city rich in historical assets:

- 3 World Heritage Sites (Maritime Greenwich, Tower of London and Westminster Abbey/Palace of Westminster);
- 9,476 listed buildings;
- 123 historic buildings;
- 33 historic gardens;
- 149 scheduled ancient monuments;
- Large areas of the city are protected by conservation measures.

William Fitzstephen, Cockney-born monk of Canterbury, described Medieval London's "fields for pasture, and a delightful plain of meadow-land, interspersed with flowing streams, on which stand mills, whose clack is very pleasing to the ear. ….There are also around London, on the northern side … excellent springs; the water of which is sweet, clear and salubrious, mid glistening pebbles gliding playfully, amongst which Holywell, Clerkenwell and St. Clement's well are, of most note." (quoted in Fitter, 1945).

The little River Walbrook flowed openly through the City of London in the middle ages, entering the Thames at the dock of Dowgate. The River Fleet (or Holebourne) was large enough in medieval times to be navigable to Holborn Bridge. The Fleet then became notorious as an open sewer (Fitter 1945). These 'lost rivers' are now part of the underground sewerage system. Marshes and fenlands existed throughout London, e.g. Moorfields (site of Finsbury Square today) and much of the West End.

6.13.2 Flooding and Rainfall Intensity Impacts

Such histories are interesting insights into potential futures for London in a world of climate change. Is there opportunity to open-up culverted rivers and streams, or to re-establish wetlands? Do such water ways and wetlands provide clues regarding where future flooding might occur?

In addition to this, more stormy weather poses a threat to the integrity of buildings and may require higher expenditure on repairs and maintenance.

As for archaeological artefacts, the change in the flow patterns of the River Thames has already resulted in the un-covering of more extensive archaeological remnants. This is to be welcomed to the extent that it provides more archaeological evidence which can be used to illuminate the history of the city. On the other hand, however, the uncovering process potentially puts at risk the integrity and stability of the very remains which are so revealed. More resources may be required to protect such uncovered remains until such time as they can be stabilised and/or researched. Continued change in the flow patterns of the River Thames is likely due to sea-level rise, change in rainfall patterns and adaptation to such changes, e.g. operation of the Thames Barrier.

6.13.3 Temperature Change Impacts

More resources will probably be required to maintain the integrity of London's historic buildings and the materials contained therein. For example, internal temperature control will be an important requirement to protect delicate fabrics, furniture and furnishings.

Soil subsidence from drying out of clay soils could threaten the structural stability of older buildings. Historical buildings are much less readily adapted to climate change and there are likely to be planning and regulatory obstacles to any major structural or aesthetic modification. Hence, such buildings may be less adaptable and readily used than they are currently.

6.13.4 Socio-Economic Scenario Differences

Under GM, there is likely to be more building and re-development. This would result in potentially larger areas of historic London being uncovered and requiring investigation (or acceptance that this is not feasible). Under RS, there will be a slower pace of change and probably greater interest in the history of the city.

6.14 Clean City

6.14.1 Context

The MORI survey (2001) for the GLA on public perceptions of living in London revealed that air pollution was regarded as the second most serious problem for London out of a list of 8 environmental issues (63% of respondents regarding it as a problem, and 14% not regarding it as a problem). Furthermore, when asked whether London is a ‘clean city’, nearly three quarters of respondents disagreed, and only 19% agreed. Section 5 has illuminated some of the potential decreases in air quality for London arising from climate change. Given the high starting baseline of air pollution problems, that they may get worse given climate is of huge concern in terms of health and also for the image of London as an attractive place to live, work and visit. Natural ventilation approaches to cooling of buildings will be less attractive if there are higher levels of external air pollution, hence encouraging higher uptake of air conditioning, feeding-back to higher energy consumption and more urban waste heat.

6.14.2 Temperature Change Impacts

Household and commercial rubbish will decay more rapidly as a consequence of higher summer temperatures. This would increase the smell of rubbish, reducing the attractiveness of the city for its inhabitants and visitors. Changes in collection routines, with perhaps more frequent collections, might well be required. Hosing-down of streets is also likely to be required given hotter conditions, especially if there are higher levels of dust in the air, due to construction work or blowing in of dust from land. Yet, more street cleaning means more water consumption, putting greater stress upon limited water resources. The opportunities for utilising recycled waste water for street cleaning are evident.

6.14.3 Socio-Economic Scenario Differences

There could in fact be quite significant differences in air pollution arising between the two scenarios. One optimistic vision of Global Markets would see a transition to fuel cells, which would eventually replace the internal combustion (IC) engine. Fuel cells produce fewer noxious emissions. If hydrogen were the fuel of choice, then the principal by-product would be water vapour (with very limited emissions of other gases). If methane were the fuel used in the fuel cell, the emissions could (depending on the precise system) consist of by-products such as SOx and NOx. The greater efficiency of fuel cells compared to the internal combustion engine means that the actual emissions would be significantly lower than cars running on petrol (at least 50% lower per km). The wide-spread penetration of fuel cells in private cars, buses and even trains could have a significant benefit to the air quality in London, since much of the air pollution is currently related to use of the internal combustion engine. A less optimistic vision of GM, would not envisage replacement of the IC engine because less emphasis would be put on regulation of air pollution, reducing the incentive to develop fuel cell technology and associated infrastructure.

Under Regional Sustainability, we would see increased use of policy instruments at the city-scale to limit use of private cars, e.g. car zoning, charging schemes, availability of parking spaces, etc. There would be increased investment in public transport, especially buses (which are already used more heavily than elsewhere in the UK). One interesting aspect of the RS scenario is that we would not necessarily see a rapid development of fuel cell technology. This is because there would be less corporate investment in R&D internationally, because there would be a slow-down in the availability of capital in global markets.

6.15 Green and Open Spaces

6.15.1 Context

The quality and availability of parks and open spaces in London is well known. Indeed, this was mentioned as the *least* serious environmental problem in London in the MORI poll (2001), with 25% of respondents considering this to be a problem, but 49% respondents *not* considering this to a problem. On the other hand, when asked whether respondents considered London to be a 'green city', 55% disagreed, with another 37% agreeing.

6.15.2 Flooding and Rainfall Intensity Impacts

If open and green spaces such as land alongside the Thames are, in future, increasingly regarded as a potential flood water storage areas, then this multiple use of land would have implications for existing users. Using land as flood plains could also have effects upon the biodiversity value of such land (though these could be positive as well as negative). Access to parks and gardens might also be restricted in order to protect habitats and species which are threatened by climate change.

6.15.3 Wind Storm Impacts

Severe storms can have devastating effects upon trees. Richmond Park lost 10% of its trees in the storms of 1987 and 1990, but was relatively less affected than areas further south. Small stocks of veteran trees, as in Richmond Park, are especially vulnerable to extreme storms (Richards, pers.com.).

6.15.4 Temperature Change Impacts

As noted above (under housing) there would probably be greater demands put upon green and open spaces due to climate change. Any new development might need to ensure that there is explicit inclusion of open spaces. More localised open spaces are probably desirable, not just the large parks. Increased fire hazard would accompany hotter drier weather (especially hot dry springs and early summers). Such events are known, in many cases, to be caused deliberately by humans. Hence, not only are measures to detect fires more rapidly important, but also educational campaigns to dissuade those who might think of starting fires. Clearly, fires would have negative impacts for biodiversity, for access and for the amenity value of open-spaces, and adversely affect air pollution (as witnessed dramatically in Sydney in 2001). To deal with fires involves use of large amounts of water and this would add a further strain upon water resources, especially in hot dry conditions when fires are most likely.

The types of trees and other plants which will grow successfully will likely change in the future because of climate change. Already, the Royal Parks are observing that trees such as beech are not doing as well as they once were, though this may also be due to damage by grey squirrels (Richards, pers.com.). The London Plane tree (*Platanus acerifolia*) is probably rather better adapted to climate change, being a hybrid of the oriental and western plane, which grow in hotter climates, e.g. Mediterranean. The appearance of the Plane is quite different from the beech tree, however. An alternative would be Sweet Chestnut, which would perform equally well under hot and dry conditions, and supports a wider range of other species than Plane (Richards, pers.com.).

6.15.5 Socio-Economic Scenario Differences

Under GM, land use would be determined by the market, and there would be fewer restrictions of land for biodiversity and for amenity value than currently. High climate change impacts upon green spaces and its biodiversity would therefore be attenuated by the reduction in statutory protection and spatial extent of such land. By contrast, under RS there would be greater protection of land and more emphasis placed on enhancing and managing biodiversity. Under RS, the lower level of climate change plus greater protection of green spaces would be more favourable.

6.15.6 Case Study and Comparison with Other Cities

Case study of impacts on 'green spaces' - The Royal Botanic Gardens at Kew

The Botanic Gardens at Kew are famous as both a tourist attraction and a valuable centre for monitoring and conservation of flora and fauna. A former royal possession granted to the nation by Queen Victoria, it is now run as a non-departmental government body overseen by DEFRA. One of its statutory purposes is to conserve native flora and fauna, including species which come to live in the UK as a result of environmental change and conservation practice. Records at Kew have shown that some species (e.g. crocus, bluebells, laburnum and certain cherries) have been blooming earlier over recent years – roughly 1 to 2 weeks earlier since 1952. In 2002 the Crown Imperial Fritillary opened earlier than ever before. No records are kept of autumn leaf fall/turning.

Species such as Marbled White and Gatekeeper butterflies and certain types of rare dragonflies appear to be moving their range northwards, and more of these species are being noted at Kew. It is not clear if any species have yet been lost due to changing climate, but in the future drier summers may cause some plants to disappear. Species such as the meadow saxifrage (spring flowering in damp meadow habitat) and the wild camomile may be most at risk. However, even in the hot dry summers such as that of 1995 species reappeared after prolonged drought.

A warming climate would widen the range of species present, but lower summer rainfall with more evaporation would reduce the numbers. Emergency plans such as using river water or Kew lake water for irrigation are being considered, but there are health and environmental implications arising from such uses. For example, the Kew lakes and ponds are themselves important habitats and river water might need treating before it could be used. The satellite garden at Wakehurst Place, West Sussex (currently wetter and cooler) may be used as a backup.

Kew is on thin poor soil over gravel, with a high water table resulting in shallow root structures. Any raising of the water table from increased winter rain would cause even shallower rooting, paradoxically making plants more vulnerable to dry-out in drier summers. Direct flooding from the river has not been a problem yet, nor is salination of groundwater, but this may occur in the future with more overland flooding.

More visitors in a warmer climate would be welcome – in fact there are currently several initiatives to encourage more visitors such as seasonal festivals. Kew could accommodate a substantially larger number of visitors before it reached capacity. However, it is noted that in the very hottest weather the number of visitors falls, possibly due to the effort needed to get there by tube or car, or due to the relatively greater attractiveness of destinations such as the coast or countryside outside of London.

Comparison with Other Cities

New York City has an extensive amount of freshwater marshes (3000 acres, 2000 of which are on Staten Island) and 4000 acres of tidal wetland (Jamaica Bay). This, however, represents only a quarter of the wetland areas which at one time occurred in the New York city region. These coastal wetlands in New York are especially vulnerable to sea-level rise.

> *"Assuming that limited opportunity has been provided for a retreat inland, the remaining fringe of wetlands in the region would be in clear decline, causing a ripple of other ecological effects, including the loss of critical bird and aquatic habitats.*" *(Rosenzweig & Solecki 2001a:11).*

42% of the waterfront of New York City is city, federal or state parkland, including hundreds of acres of natural or undeveloped land, active recreational areas and narrow strips along highways and railways. There has been a tendency in the past to locate necessary, but locally unwanted, land uses on such marginal land (e.g. transport infrastructure and pipelines), so increasing the vulnerability of such assets to future sea water inundation. Land acquisition by the state government is a well established mechanism for the creation of 'greenways', habitat protection and consolidation of coastal properties. Recent purchases have not been in areas projected to be vulnerable to sea-level rise, but they do provide a model for future purchases as adaptations in areas vulnerable to global climate change.

6.16 Crime and Security

6.16.1 Context

The MORI (2001) survey of public perceptions of living in London found that 51% of respondents indicated that doing something about safety and crime was a top priority for London: this scored more highly than any other priority. London has a higher burglary rate than the UK average (at 9.5 incidents per 1000 people, totalling 70,200 in 2001), but the rate has been declining in line with national trends (though is anticipated to go back up in 2002) (LHC 2002). The burglary rate in Hackney and Lambeth is four times higher than it is in Havering and Sutton.

6.16.2 Flooding and Rainfall Intensity Impacts

Certain impacts of climate change have potentially major implications for the emergency services. The agencies involved include:

- The Environment Agency: which operates a system of flood warning. Following the floods on Autumn 2000 the EA published a report on the lessons learned and is taking forward action to improve responses to flooding;
- Health and medical services may be required to respond to human health impacts of climate e.g. illnesses associated with flooding and lack of clean water in extreme instances, asthma epidemics due to worsening air quality, possible increases in

outbreaks of food poisoning from food spoiling in higher temperatures and heat stress victims due to an intensifying urban heat island;

- The Fire Brigade plays a critical role in responding to flooding, i.e. rescuing people and unblocking and clearing highways, pumping out water, dealing with fires caused by electrical storms and stabilising wind damaged buildings. This is important to allow medical assistance and to allow the fire service to respond effectively to other emergencies in the locality, such as fires. The floods of 2000 in other parts of the UK led to significant over-demand for the fire service, leading to major delays in crews getting to incident sites (Speakman, pers.com.). A severe flood in London on the 7th August 2002 resulted in 1,400 emergency calls to the London Fire Brigade in just 8 hours, one of the highest demands ever;

- Water and electricity utilities, which have a duty to restore services to dwellings as soon as feasible.

An important lesson from the 1998 and 2000 floods is the need for effective and well-orchestrated responses on the part of all the emergency services, including local and national government, the Environment Agency, the fire brigade, the medical services, and so on. It was found that a clear command centre is required at a suitable spatial scale (i.e. relative to the scale of the flooded catchment itself), which liases with lower-down local emergency response centres (Speakman, pers. comm.). A continued increase in weather-related emergencies will necessitate more resources being devoted to the emergency services.

An issue that needs to be addressed is the public's understanding of procedures following weather-related emergencies. This is an issue for emergency planning in general but climate change may contribute to an increased frequency of emergency events. Previously, many people's response to an emergency has been to seek shelter in the underground system. In a flood emergency such as failure of the Thames Barrier this would not be appropriate as the underground system may also be subject to flooding. Therefore there is a need for improved public communication on flooding, its consequences and flood warning. As mentioned above, the EA is carrying out a national scale project on communicating flood risk. A project is also planned on the socio-economic impacts of flooding. It would be helpful if this study examined the issues surrounding the public's response to climate change emergencies.

Previous research suggests that the EA's new categorisation of flood risks communicated via the media is clearer than the previous system, and also that its Floodline telephone service has been generally successful in providing information on request (Scottish Executive 2001). Where communities are well networked, there is likely to be a greater ability to respond to warnings and emergencies such as flooding, than in those communities which are highly fragmented. In general, more affluent communities are better able to respond effectively to emergencies than poorer communities. Better networked communities are more able to look after the interests of those who are relatively worse-off and isolated or who have more dependants, e.g. the elderly, single parents, large families, etc. This difference in the ability of communities to respond to extreme events could also be used in the formulation of emergency service response strategies, through targeting the most vulnerable (i.e. less affluent and more fragmented) communities first (Shackley et al. 2001, Scottish Executive 2001).

An integral part of the Environment Agency's Flood Warning service is to produce a London Flood Warning Plan for fluvial flooding. A workshop is held each year with its professional partners to review this plan and ensure the details provided take account of recent flooding.

Local meetings are held regularly with Emergency Planning Officers from the local authorities to discuss specific issues relating to flood risk areas. Exercises are held each year for those agencies responding to flooding emergencies. These exercises provide the opportunity to review and confirm procedures based on flooding scenarios. A close relationship is maintained between the EA and its professional partners through joint public awareness initiatives, local flooding workshops and regular emergency planning meetings. The last update of the London Flood Warning Plan was two years ago and an updated version is being produced. The Plan is reviewed annually and will be updated as appropriate in future based on the impact of climate change.

The legislation and funding of local emergency planning is currently being reviewed by the Home Office/Cabinet Office, with a view to ensuring that responses to all emergencies, including flooding, are fast and effective. The Office of the Deputy Prime Minister (formerly DTLR) is also reviewing the Bellwin Scheme which is a means for local authorities to obtain financial assistance in clearing up immediately after a local disaster or emergency. Adaptations were made to the system in October 2000 in recognition of the exceptionally high number of flooding incidents requiring activation of the scheme. A review group has been set up to take full account of the operation of the scheme following the autumn 2000 floods. As part of this general review of funding, the GLA and London local authorities should assess the possible impacts of climate related emergencies on funding requirements.

6.16.3 Temperature Change Impacts

Certain impacts of climate change have potentially major implications for the emergency services. The agencies involved include the fire service, police, local authorities, health services and the Environment Agency. An increased risk of fire from drier, hotter conditions may require action by the London Fire Brigade.

In addition to the direct threat to the safety of individuals and their property from floods and extreme winds and so on, there is also the risk that disruption might render some systems more susceptible to crime. (Looting of shops has accompanied natural disasters such as earthquakes in some cities in the USA). The possible increase in crime from more open doors and windows in a hotter climate has already been discussed under housing. There is some evidence of a relationship between hotter weather and traffic accidents, but the data is not very applicable to the situation in London.

There have been several controversial theories in the past which have linked unusually hot weather with more risk of public disorder. The most extreme idea of ‘weather determinism’, suggested that hot weather events could actually *produce* public disorder, though most commentators have discredited such ideas which fail to take account of the underlying structural and economic reasons why discontent exists (Shackley & Wynne 1994). A more moderate suggestion is that exceptionally hot and humid weather would be more likely to encourage certain types of anti-social behaviour amongst certain individuals who were already pre-disposed to such behaviour patterns. However, adaptation and acclimatisation is likely to occur, judging on the record of other societies which already exist in hotter climates. Underlying socio-economic, cultural and political conditions are widely considered to be much more important determinants of crime and disorder.

6.16.4 Indirect Impacts to Crime and Security

The high cost of housing in London is already having a serious impact upon the ability of 'key workers' in the public sector such as teachers, social workers, local government, health workers, fire and ambulance emergency-services, etc. to live and work in the capital. The fact that many such posts are currently unfilled means that the ability of London's emergency services to respond effectively and rapidly to climate change-induced emergencies and disasters is likely to be impaired. This could have a very significant effect upon the damages to humans and property, and the level of disruption, associated with events such as heat waves, floods, water shortages, etc. since the impact is tightly coupled to the level and effectiveness of response.

Evacuation of people from their homes into temporary communal emergency centres which may occur due to a climate related emergency is not only stressful to many, but may also encourage crime and anti-social behaviour to emerge amongst some of the temporary occupants. Property and possessions are especially open to theft in such circumstances and the fragmentation of communities means that there is frequently no pre-existing 'social network' to help manage such situations. Community development professionals and social workers might play an important role in assisting such temporary communities.

If climate change led to more outdoors drinking of alcohol in pubs and bars, as presently occurs on hot days in spring and summer now, there could also be a knock-on effect in terms of violence and anti-social behaviour, and possibly drink-driving, with associated accidents. Adaptation to 'hot' weather is likely, however, such that hot sunny days cease to be anything exceptional and therefore not *per se* a reason to 'go for a drink' (which they presently are for some).

If the attractiveness of London were to decline as a consequence of climate change, then economic conditions might deteriorate, creating the conditions in which crime and disorder would grow. Much would depend, however, on the distribution of wealth and other socio-political policies and programmes.

It may be necessary for the public to utilise public buildings which have air cooling systems in the case of a heat wave, or in case of a severe flood event. In Toronto, there have recently been three heat waves during which public buildings with AC have been open to members of the public who are becoming heat-stressed. This sort of emergency public service provision is relatively novel in the UK, but procedures for the utilisation of public or even private-sector infrastructure may be necessary in the future to cope with climate change-induced extreme events.

6.17 Towards Analysis of Feedback Processes

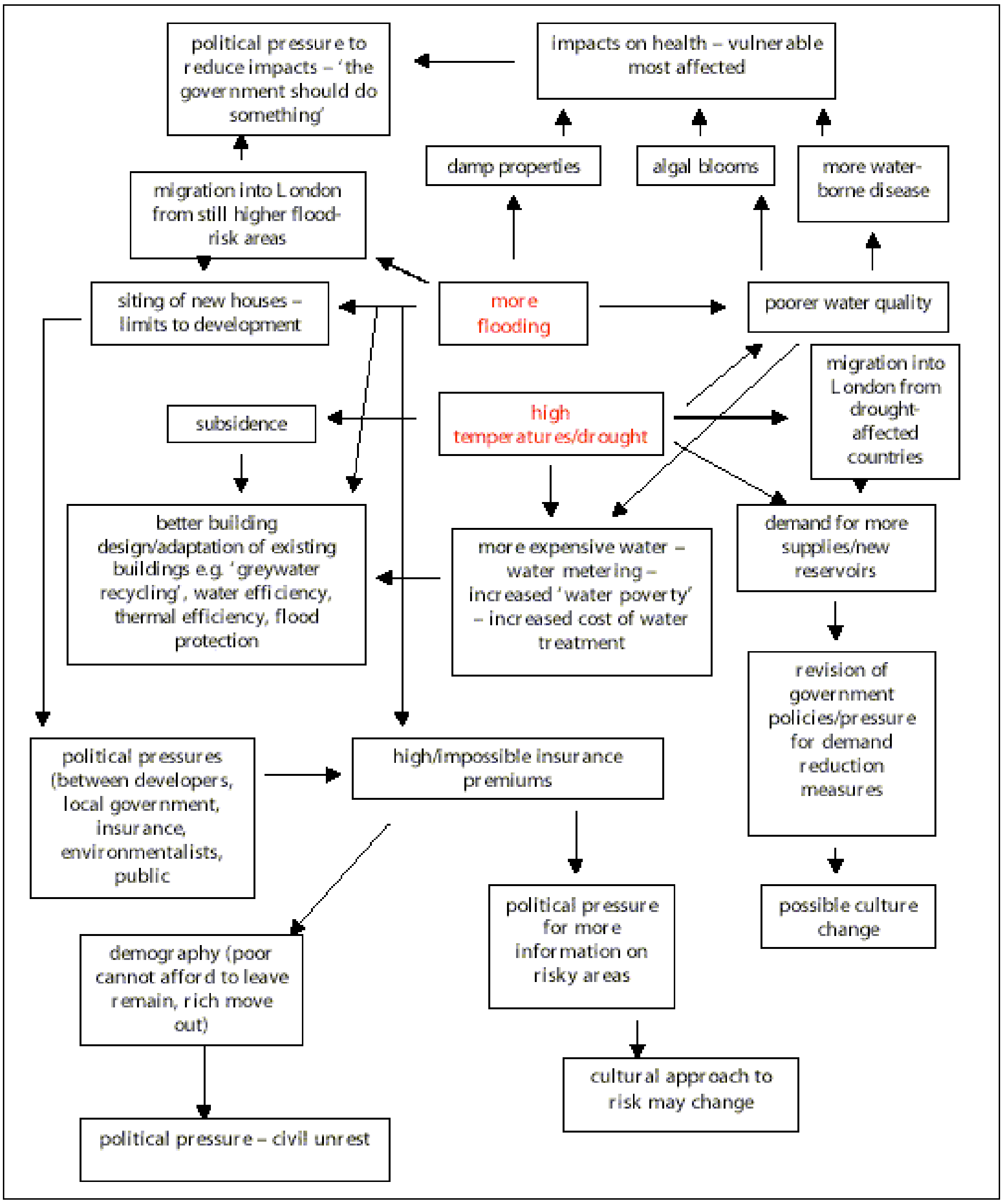
In many of the preceding discussions we have described *feedbacks* between climate impacts and social and economic aspects of life. These are multiple links between different aspects of climate change (such as increased frequency of hot days or increased winter rainfall) and their consequences. Analysis of these feedback processes is important because the complex interplay between climate change impacts and adaptation measures can sometimes produce results unexpected from a simple analysis. In this study we have only skimmed the surface of assessing feedbacks within a system as complex as how London may respond to climate change. To demonstrate some of the complexity involved, we now present an example from the second workshop in which we examined interactions between three key areas – demography, high temperatures and increased flooding. We identified two classes of feedbacks:

i) those between social, economic, environmental impacts **within** each different aspect of climate change e.g. hot days -> poor air quality -> health goes down (*social impact*) -> worker productivity goes down (*economic impact)*

ii) those **across** different aspects of climate change: e.g. hot days -> poor air quality -> health goes down (*social impact*) -> people move out (*demography*) -> fewer new houses needed on flood plain -> impacts of flooding are reduced (*social and environmental impacts*)

Both types of feedbacks are represented in the resulting diagram (Figure 6.5). The direct changes in climate are highlighted in red and the consequences follow along the links chains. Note especially the bold highlighting of the social, cultural and political impacts of climate change.

Figure 6.5 An example of the feedbacks between different impacts of climate change. Bold text highlights social, political and cultural consequences.



6.18 Summary and Conclusions

To summarise the discussions in this Section, we return to the concept of attractiveness introduced in Part 1. For each section, we made an overall assessment of how climate change is likely to alter the attractiveness of London, and our conclusions are summarised in Table 6.5. It is important to note that it is a qualitative judgement based on the material presented in this section and the discussions which lie behind it, and the experience of the research team. It should not be taken as more than a first and very tentative attempt to evaluate impacts. The largest difference of opinion within the research team itself concerned the impacts of climate change upon green and open spaces: according to the more optimistic view point climate change would result in an increase in such space as an adaptation measure; whereas this would not occur to the same extent in the more pessimistic view.

The summary table does indicate that on balance the social impacts of climate change upon London are perhaps somewhat more negative than positive. There are, however, some potentially significant benefits for a number of sectors such as tourism and leisure. We have also identified some fairly small benefits for a number of additional sectors including transport, housing, historical and cultural legacy, jobs, health and so on. The larger negative climate change impacts for housing, redevelopment, built environment, health, clean city, cost of living and open and green spaces are all highly uncertain, in part because the scale and precise character of the impact depends on the adjustment and adaptation responses. Most of the larger negatives are attributable to potentially increased flooding, greater incidence of summer heat waves, exacerbation of existing air pollution problems and increased pressures upon open and green spaces. Clearly, suitable adaptation policies and management could limit the incidence of the most negative impacts. A further factor in our assessment is that many of the potentially positive impacts of climate change are somewhat intangible and highly distributed across society. Some of the largest potential negative impacts are more highly concentrated in their distribution, e.g. flood risk, and this can make them appear to be more significant. Compared to the other regional studies of climate change impacts in the UK, there are some significant differences, but also some interesting similarities.

- It is interesting to note that the pattern of 'pluses' and 'minuses' in the summary table are rather similar to the pattern obtained in other regional studies (available at www.ukcip.org.uk).
- The main differences in assessment arise because the area covered by Greater London is much smaller than the other 8 English regions, and does not include anywhere near the same amount of open countryside. Hence, the knock-on social impacts arising from the effects of climate change upon agriculture, large biodiversity resources, long stretches of coastline, and so on, do not apply to the same extent in the London case. The high population density in London (twice that of most other UK cities) and the exceptionally strong growth and population pressures upon the city, and its role as a global city, all serve to make the London study a 'special case'.
- The impacts on London will also spill-over in important ways and come to affect the South East and East of England regions (as well as further afield), especially for recreational and leisure purposes. Yet, the pressures from climate change upon the coastline and other beauty spots in the South East are considerable, as indicated in its 1999 climate impacts study (Wade, et al. 1999).
- Climate change impacts on transport, buildings & built environment, parks & gardens, air pollution, tourism, and so on, are all exacerbated in London compared to other cities and regions, because of the strong pressures already being exerted upon these systems and sectors.

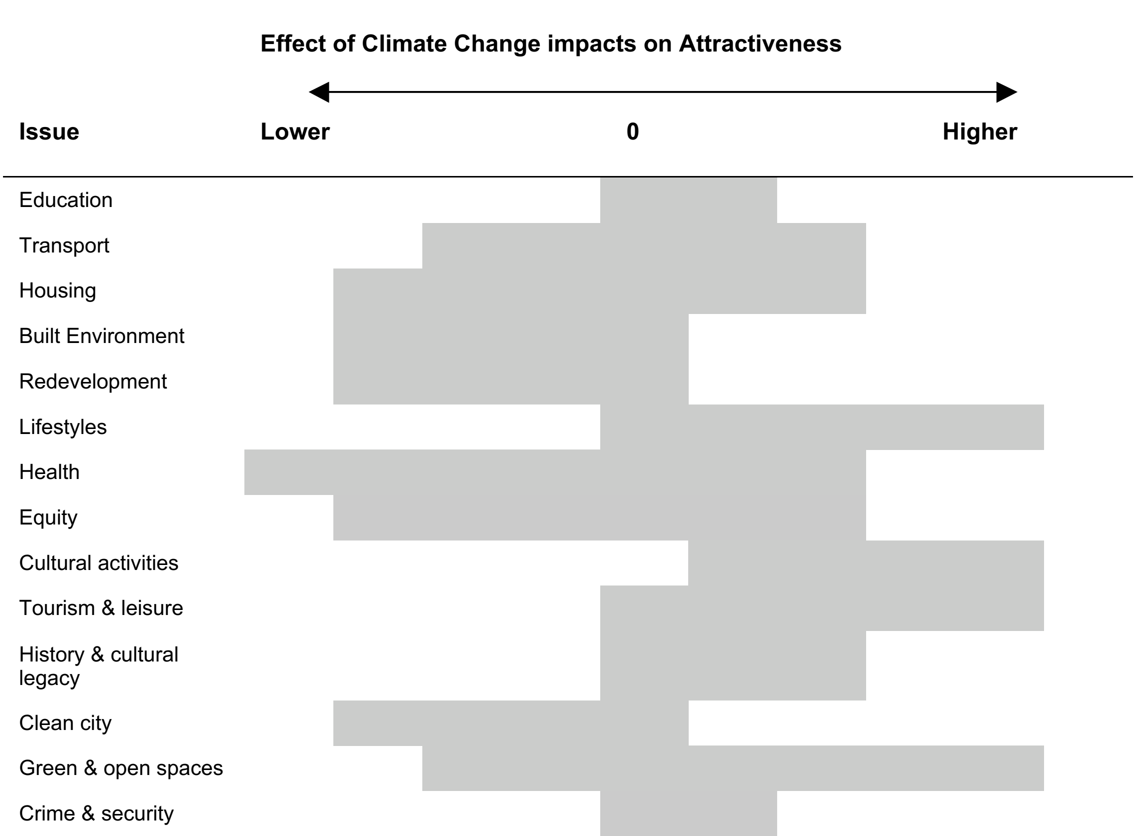
- Whilst climate change is, potentially, an opportunity for the built environment and redevelopment (or at least can be tackled through use of natural ventilation) in other parts of the UK, it is more difficult (whilst not impossible) to see the 'silver lining' in the case of London. This is because of the higher baseline temperature in London, the urban heat island effect and the very high pressure for new housing and new commercial development.

- The draft London Plan argues that it is most appropriate to compare London to other global cities such as New York, Tokyo, Paris, Berlin and so on. The very preliminary comparison of climate change impacts in Tokyo and New York, suggests that the adverse effects in those competitor cities would be slighter greater than in London, at least in the current socio-economic conditions.

- Impacts upon other comparative European cities have not been evaluated. London starts from a cooler climatic baseline than most continental cities, however, and will continue to be cooler than cities further south in a situation of climate change. Provided that necessary adaptations can take place, then London will perhaps fare better under future climate change than competitor cities in many other parts of central and southern Europe.

- The most robust conclusion to draw is that a preliminary comparison between competitor cities indicates that London does not face any significantly greater adverse or beneficial impacts than other cities. A more robust comparison between impacts on global cities is an important future research task.

Table 6.5 Summary of the effect upon London's 'attractiveness' of climate change impacts on different systems and sectors. 'Lower', for example, indicates London becomes less attractive from the perspective of that sector under climate change



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7. The Potential Economic Impacts of Climate Change in London

7.1 Introduction

London's role in the UK and international economy ensures that any climate change impacts on its economy are likely to have significance in terms of economic multiplier effects elsewhere - see Box 1. This section of the report identifies and evaluates the importance of potential climate change impacts on economic resources and economic activity in the city. We take as our starting point in this exercise the findings of the previous sections of climate change scenarios for London and the associated environmental and social impacts.

Furthermore, the socio-economic scenarios described in the preceding section are shown below to be important in determining the likely severity of the economic impacts in the future.

It has been agreed with the LCCP that it is most useful to consider economic impacts in terms of their sectoral classification. Thus, we adopt the sectoral classification suggested by the project Steering Group to include the most likely significant sectors in determining the future economic prosperity of London. These sectors are:

- Tourism and leisure;
- Insurance/financial businesses;
- Manufacturing industries;
- Public administration;
- Creative industries;
- Environmental businesses.

Consideration of these sectors will be in parallel with the cross-sectoral elements likely to be impacted by climate change in London. Foremost amongst these are: transport; energy and labour supply. Clearly, impacts on these (e.g. transport disruption due to flooding) will have consequent impacts on economic activities (e.g. disruption to freight) and these linkages are traced. A detailed analysis and evaluation of possible adaptation strategies is likely to be undertaken in phase 2 of this project.

London's present status as a world city rests largely on the fact that it supports a substantial concentration of economic activities that are critical to the global economy, principally including the financial services sector and its linkages with global trade and commerce. The potential impacts of climate change on this status are considered - relative to other competing world cities such as New York or Tokyo.

Box 1 A profile of the economy of London in relation to climate change

Greater London has an estimated GDP of £168.6 billion, and accounts for 20.3% of the UK GDP. This economic activity supports a workforce of 3.5 million, 32% of which are in business and financial services, 19% in the public sector , 16% in retail, 7% in manufacturing, 6% hotels and restaurants. It is estimated that London 'imported' from the rest of the UK £89 billion of goods in 1998 - supporting 4.7 million jobs outside the capital.

The title of Global City derives from the fact that it is one of the three largest financial centres in the world (alongside New York and Tokyo) and has the largest share of trading in many financial markets, including foreign exchange of which it controls 36% of the global turnover. The City of London has a GDP of £22 billion - equivalent to 2.6% of the UK GDP.

Manufacturing in London is responsible for 300,000 jobs (7% of the capital's workforce) and £11 billion output. The creative industries, including theatres/cinemas, contribute £7 billion to the UK's GDP, whilst the city also has the characteristics of a knowledge economy, being a centre of academic excellence and providing research and consulting services throughout the world.

Box 1 presents an overview of the London economy. It demonstrates that whilst the economy of London is pivotal to the UK, and perhaps, global, economy, it is by its nature therefore heavily inter-dependent on the national and global economies. Any impacts on London of climate change are therefore likely to have significant wider implications. At the same time, climate change impacts of perhaps greater magnitude elsewhere in the world are likely to be felt in the economy of London. The purpose of this section is to provide a first assessment of the extent of these potential impacts.

7.2 Outline of Methodology

This section is compiled from the output of two work phases within the project. These two phases are: the Review Phase and the Consultation Phase. The Review Phase has surveyed available literature in order to establish i) the way in which economic activities undertaken by the private and public sectors might be expected to be impacted directly by climate change in London, and ii) how climate change impacts in other parts of the world may impact on the economic activities in these sectors in London.

The section is divided in the following way. First, climate change impacts associated with the key sectors that have direct cross-sectoral roles - transport, energy and labour - are identified, described, assessed in terms of their possible severity, and their amenability to adaptation. Following this, the financial services, insurance, manufacturing, public administration, tourist/creative, environmental business sectors are considered in the same way. There is then an assessment of the possible consequences for economic development of climate change. Comparative analysis with other large cities is undertaken where possible and global climate change linkages are identified and assessed.

In the case of each sector considered, a summary table is provided that shows:

Climate change variables and associated impacts
The climate change variables that are presented are crude characterisations of the variables quantified in detail over the different time horizons in the scenarios presented in Section 4. It was found in the course of the stakeholder consultation that these characterisations were more useful in eliciting responses as to possible types of impacts. The impacts themselves are rough encapsulations of the principal impacts described in the main body of text.

Intra-sectoral severity ranking of economic impacts
The climate change impacts presented in each summary table are given a weighting (H = High; M = Medium; L = Low) according to the perceived severity of the impact on the economic health of the sector. Where it has not been possible to use a sectoral stakeholder perception (e.g. in the case of transport) the project team has made a judgement on the severity ranking.

Employment effects associated with impacts
Adopting the principle used in making the severity ranking, the assessment of employment effects is with regard to the level of employment presently in the industry. It is not therefore an assessment of the net employment effect in the economy. It should be emphasised that most of the employment effects identified are *diversionary,* or represent *transfer,* within the economy, rather than creating new jobs. Again, where it has not been possible to use a sectoral stakeholder perception the project team has made a judgement on the severity of the employment effect.

Uncertainty rating
Working Group II of the IPCC Third Assessment Report (IPCC, 2001) provides a detailed rating scale for the degree of uncertainty that is currently attached to specific climate change impacts globally. We have simplified this rating scale to High, Medium and Low, but present the broad sectoral rating made by Working Group II for the impact identified for London.

Sensitivity to socio-economic scenarios
The socio-economic scenarios are identified in Section 6. Where possible, we have indicated how each economic impact is likely to be determined by the two different scenarios: Global Markets (GM), and Regional Sustainability (RS).

Key non climate change sectoral drivers of change
In recognition of the fact that climate change impacts need to be considered in the context of how the sector is changing more generally, we highlight the principal drivers currently behind such change. This information should be seen as background information needed to develop a subsequent adaptation strategy for the sector.

Key stakeholders in impact and adaptation analysis
Identification of key stakeholders is also a prerequisite for looking to develop a subsequent adaptation strategy for the sector. Before developing such a strategy one would clearly conduct a full stakeholder analysis that maps the relations between primary and secondary stakeholders. This is a first task for phase 2 of the current project.

In the final column in the table (‘current availability of adaptation options’):

- 'Y' indicates that adaptation options have been identified by stakeholders to reduce climate change impacts. They are currently being considered for inclusion in general sectoral development strategies.
- 'N' denotes the fact that options either have not been identified, or are not being considered in strategy development.
- '-' denotes that it is inapplicable i.e. the impact identified is a beneficial one.
- '*' denotes the net effect is indeterminate.

There is then presented a brief overall summary of economic impacts on London.

7.3 Transport

7.3.1 Context

London is a national and international transport hub for road, rail, air and shipping in addition to supporting movements within the city. Each working day 466,000 peak period commuters come into the city centre and 7 million walking trips are made. It is therefore critical to the effective workings of the city's economy. The Mayor's Transport Strategy[1] for London notes, though, that whilst the city has "seen two decades of rising population and a decade of expanding economic growth and employment, this growth has not been matched by the investment necessary to provide the public transport, affordable housing and public services that are essential for economic efficiency and the wellbeing of London's population".

The Strategy document goes onto say that there is therefore "a growing crisis on London's transport system – with some roads approaching gridlock and severe overcrowding, discomfort, unreliability and equipment failures on the Underground and National Rail network". The Strategy therefore envisages a significant expansion and improvement in public transport provision in London, including cross London rail links, three new river crossings in and around London, the completion of the Channel Tunnel rail link and substantially increased capacity at airports in the eastern half of the metropolitan area.

Against this background, the stakeholder consultation suggests that the following types of impact on London's transport system may be most significant:

- Disruption to transport modes from flooding and other extreme weather events;
- Changes in the types of journey taken e.g. if summer heat island effects have significant impacts on the willingness to commute into central London;
- Switches between transport modes as a result of changing travel conditions.

These impacts are explored in more detail below, on a transport mode basis. We then draw together conclusions as to how climate change may impact on the operation of the existing transport strategy.

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[1] http://www.london.gov.uk/approot/mayor/strategies/transport/index.jsp

7.3.2 Rail Transport

Context

There exists a dense and extensive network of rail track in and around the Greater London area - extending across the UK - that supports business, commuter and leisure travel in London.

Stakeholder consultation with sectoral representatives has borne out the general perception that the rail network is climate sensitive and has vulnerabilities associated with climate change. These are identified below.

Flooding and Rainfall Intensity Impacts

Clay shrinkage impacts upon structures on which the rail network is reliant, including bridges, tunnels, embankments and cuttings. Therefore more reinforcement is necessary if an increasing rate of disruptions is not to be expected. Land-slips may result for the same reason, if higher winter rainfall intensities lead to increased instability in banking and slopes. A change of this type has already been noticed in other parts of the UK e.g. South Scotland.

Flooding when drainage systems cannot cope. Water on the rails acts as a conductor for the electricity in the rails and therefore its presence mimics the presence of a train at that location. Consequently, the network control systems need to send engineers to such locations in order to check what is happening. This checking process therefore results in delays to those trains that are using the track. Bridge scour when high levels of river water, combined with debris, works at the foundations of bridges. This reduces their stability and requires preventative expenditure. It also results in disruption to the network when bridges are closed.

Flooding would cause disruption and reduce the mobility of Londoners, and cause knock-on impacts through out the city. A recent example of the impact on flooding was on the 7th August 2002 when five of London's mainline stations were closed due to floods after intensive rainfall. Travel within the capital, and into and out of the capital, was seriously affected by these floods.

The most vulnerable areas are those which are located in the flood plain of the Thames and its tributaries (such as the Rivers Lee and Wandle). Areas of flood vulnerability are currently the subject of targeted investment in flood mitigation schemes. High risk flood areas, such as those associated with surface water drainage failure and shallow groundwater flooding, can also be outside the flood plain.

Temperature Change Impacts

Direct sunlight accompanied by summer heat can causes 'hot rails' to buckle. The imposition of speed restrictions in this situation is in order to mitigate the risk of buckling. In order to avoid this, the rails need to be de-stressed which is a manual practice. The problem is most likely to occur when there are rapid temperature changes between night and day and in extremely hot weather.

Point heaters are used to ensure that points remain functioning in freezing conditions. It is expected with the warmer winters predicted in the climate change scenarios that these point heaters are likely to have to be used less often. There are therefore less likely to be technical difficulties with the operation of these heaters, and less subsequent delays.

Impacts Due to Wind Storms
Lightning can damage integral parts of rail infrastructure including signalling equipment and telecommunications since, whilst some surge protection exists, it is not presently 100% reliable.

Leaves are a major problem in autumn when compacted into mulch on the rails since they result in braking and traction problems. There may be higher likelihood of the mulch being created as a result of climate change. Six key species are: Sycamore, Small Leaf Lime, Black Poplar, Horse Chestnut/Sweet Chestnut, Ash and Beech – the latter where leaf fall is in high quantities. It has not yet been established by the project team as to whether climate change is likely to result in greater growth and expansion of these species.

Wind affects overhead lines e.g. on the East Coast line from London, and some suburban routes in the Greater London area. Fallen trees that block the train line are likely to cause similar disruptions in the future if storm intensities increase.

General Climate Change Impacts
The issues identified above clearly affect the efficiency of the Channel Tunnel transport link to continental Europe. If these issues are perceived by international business travellers who use this link as significantly increasing the time unpredictability of the journey, this is likely to reduce the attractiveness of London as a business centre relative to other European cities - assuming no adaptation measures are implemented in response.

7.3.3 Case Study

The case study below, presents a costing of an historical analogue of a potential future climate change event - flooding of a commuter train line to London Paddington railway station The methodology is that developed for UKCIP (UKCIP, 2002). As explained in the introduction to this section, any costing exercise performed on an historical analogue should not be interpreted as a prediction of future climate change impact costs.

This case study uses evidence supplied by Railtrack on the extent of disruption to rail services caused by flooding to a rail line. The costs estimated below relate to: i) the time lost due to flooding at Stroud's Bridge, on the rail link between Oxford and London between 13th and 18th December, 2000. The disruption of rail services is measured by the number of minutes by which each train is delayed, having reached its final destination. In this case, the total number of minutes lost (calculated by multiplying the delay to each train by the number of delayed trains) has been estimated to be 22,338. The appropriate economic unit values we adopt here are taken to be £55/minute delay (based on the Strategic Rail Authority's (SRAs) official average rate, charged to Railtrack). These values are then multiplied by the 22,338 minutes lost, as identified above, to give estimates of the economic costs to Railtrack. It should be emphasised that the estimates presented below do not include the infrastructure repair costs which the flood damage necessitates. The cost estimates also do not include the value of lost time suffered by train passengers as a result of the disruption since the data needed to make estimates of these economic cost elements is not currently available. However, it is likely that these cost elements would be comparable to - if not significantly greater than - the costs presented below.

Table 7.1 Total Cost of rail network disruption: Stroud's Bridge, Oxfordshire

Total time loss (minutes)	Unit value (£/minute)	Total value (£)
22,338	55	1,228,590

Clearly, since this track represents a major commuter line to London, much of this disruption cost is likely to be borne by London's economy. It should be emphasised that these estimates are for one track flooding estimate only. It is likely that the floods of November and December 2000 resulted in an economic cost from disruptions on the rail system as a multiple of this value.

Investment measures needed to bring about **adaptation** of the rail network to counteract the type of potential climate change impacts identified here can currently only by funding that requires the submission of cash requirements on a five-yearly basis to the Office of the Rail Regulator and the Strategic Rail Authority.

7.3.4 The London Underground Rail System

Flooding and Rainfall Intensity Impacts

Similar economic consequences are likely to result from possible flooding incidents that may result from inundation of water either from overflowing drains or from one of the London rivers as a consequence of a high intensity rain event identified by the climate change scenarios. The consequence of such an event would be disruption of tube services and the resulting loss in time to businesses as personnel are delayed. The possibility of a flood event may be exacerbated by the rising water levels that some parts of the city are presently experiencing.

The risk of flooding in the Tube system is a major and urgent one, and is being taken very seriously by London Underground Ltd. The extent of the problem was revealed on 7th August 2002, when intensive rainfall led to flooding of a number of tunnels and closure of stations and parts of the network, including Chalk Farm, Kentish Town, Belsize Park and Wandsworth. The amounts of water entering tunnels, either from groundwater seepage or flooding from the surface, have been increasing but no figures for amounts are available. There are well-established procedures in place to deal with pumping water from tunnels, including a combined water pumping strategy, in which groundwater surrounding the tunnels is pumped via boreholes to local water courses, preventing water from entering the tunnels at all. Such pumping does raise the risk of the pumped water being replaced by saline water intrusion. Many lines have flood gates to prevent water entering stations.

A detailed 25-year plan showing the risks of flooding to different parts of the system also exists, but is currently confidential. Maps have been designed indicating the likely timings of impacts resulting from an overtopping of river walls.

Temperature Change Impacts

Stakeholder consultations identified that extreme weather events were likely to be the principal way in which climate change impacted directly on the London Underground train system. In particular it was suggested that a tendency towards more very warm days during the summer months would result in increased discomfort in travel in the underground where there is little air circulation.

High temperatures have been regularly experienced by passengers in hot weather on the underground, e.g. with reports of temperatures having reached 40°C in one instance. The health implications of this are potentially highly serious. Interestingly, however, hot spells produce no decline in number of travellers. The London Underground Ltd. (LUL) has examined the possibility of installing air conditioning but has indicated that this is not a practicable option. The reason is that the Underground was not designed with AC in mind and there is not enough space within the tunnels for additional AC units to be attached to carriages. The London Underground is the oldest in the world, dating back to 1863, and only in the most recent systems, such as those in Hong Kong and Singapore, has AC been employed. Even in these more modern systems, however, a problem has emerged of what to do with the waste heat displaced by AC. Because of the energy consumed in the AC unit itself, there is more heat to deal with than without AC. The waste heat would probably build up in the tunnels and platform areas, becoming unpleasant and a fire hazard. New stock on the Jubilee, Northern and Central lines have, however, recently been installed with forced air pressure ventilation systems. These operate automatically when certain temperature and humidity thresholds are reached. The main part of the network relies upon natural ventilation through the windows at the end of each carriage.

An interesting adjustment response to high underground temperatures by LUL in July 2001 was to distribute cold bottles of mineral water to all passengers at selected stations, e.g. Oxford Street and Piccadilly Circus. Other potential strategies include using water pumped from tunnels as a coolant, and several collaborative projects with universities are trying to deliver ‘cool, clean air’ into the Underground. The infrastructural costs of installing water-based heat exchanges would, presumably, be high.

General Climate Change Impacts

An indirect effect of the occurrence of these type of events may be to encourage both businesses and individuals to review their current working patterns and location decisions. One stakeholder commented that “it only needs a couple of consecutive very hot summers for people to commit themselves to working at home more, or relocating out of town”. Businesses may therefore be forced to follow suit in order to retain a qualified or experienced work force, assuming there is a sufficient pool of labour in the new location (e.g. M4 corridor).

7.3.5 Water Transport

Context

Both the Thames and several of its tributaries (e.g. Deptford Creek, Barking Creek) are used for commercial and recreational shipping, but the largest freight ships go to Tilbury Docks (operated by the Port of London Authority or PLA) in Essex rather than into London. Navigation along the tidal Thames, and its navigable tributaries, is the responsibility of PLA. The PLA still handle about 10.5 million tonnes of cargo in and out of London a year. The River Thames is also used to move 750,000 tonnes of waste each year, which eliminates the need for 59,000 lorry journeys. The PLA is beginning to address the potential impacts of climate change, and is involved in the Environment Agency study on flood risk management in the Thames Estuary (EA 2002). The PLA has not yet encountered any problems arising from sea-level change. The Mayor’s Transport Strategy notes that the River Thames in London presently provides transport for 3 million journeys each year - either for leisure or commuting purposes. The Strategy is looking to promote both aspects of river use.

Flooding and Rainfall Intensity Impacts

Both passenger and freight movements on the Thames (tidal and non-tidal) and the city's canals may, however, be jeopardised either by low flows that might, for example, accompany low summer rainfall, or by high flows resulting from higher intensity rainfall events. Both climate change-related events are suggested as threatening the navigability of the river. The 1976 drought provides a possible analogue for the first event possibility. In this case, the Thames was threatened with total closure for any forms of traffic. It had significant impacts on the supplies of raw materials for manufacturing and food products. Whilst the air freight system is now likely to better cope with any equivalent event for food products, water transport remains essential for bulk freight shipments. There may therefore be a significant disruption in international trade links in raw materials for manufacturing and food products, and the domestic industries that use these materials.

Operation of the Thames barrier blocks off shipping. More frequent operation of the barrier in recent years has not compromised the viability of upstream docks, however. This is because there is always at least one point in the day (i.e. low tide) when the barrier is open (even when the barrier is operational) so some shipping can get through (although at low tide the larger ships may not pass). However, much more frequent closure of the Thames Barrier, and the construction of new barriers to combat future flood levels, may cut some areas off for docking in the future. Inundation of docks may be a problem if both riverine flooding and sea level rise contribute to rising river levels both up and downstream of the barrier.

With a more explicit strategy of using the estuary upstream or downstream of the Barrier for water storage as an adaptation to climate change, e.g. during high tides or during periods of high rainfall, then flooding of docks might increase. The draft London Plan includes the suggestion that more freight could be handled using the River Thames and observes that there are 29 protected wharves between Wandsworth/Hammersmith and Greenwich/Newham. It also notes the potential for freight operations on the Lee Navigation and the Grand Union canals (GLA 2002a). Clearly, the vulnerability of such water-based freight to a change in rainfall patterns and more frequent use of the Thames Barrier requires investigation as part of the development of the freight strategy.

Indirect Effects

River service disruption may act as a disincentive to potential tourist visits to the city from overseas, though it is thought likely to change the length of stay in London rather than resulting in a switch to an alternative destination.

Most of the 3 million a year boat journeys are for leisure purposes but with extensive development in the Thames Gateway, it is likely that there would be enhanced demand for travel along the river as a pleasant alternative to busy terrestrial routes. Some of London's canals could even potentially be used for this purpose, as happens in, e.g., Amsterdam. There is existing empirical evidence that the London Thames does act to cool the air in areas adjacent to the river (Graves et al, 2001).

7.3.6 Road Transport

Context

The Mayor's Strategy notes that high car use rates in London currently ensures that the city experiences high levels of road congestion - and therefore lost time - on a daily basis.

Flooding and Rainfall Intensity Impacts

Climate change impacts on use of road transport are suggested to include travel disruption due to flooding incidents on vulnerable stretches of road, resulting from high rain intensity events.

Temperature Change Impacts

Buckling of road surfaces may occur in spells of hot weather during summer months. This was the case of the historical analogue of summer 1995 when asphalt roads were subject to 'bleeding' and 'fatting up' due to the binder materials melting and resulting in road rutting. Indeed as a result of this event, the British Standard specification for road surfacing performance was amended (Palutikof (ed.) 1997). It is not known whether the revised specification will be adequate for future climate change related hot days.

The 1995 analogue also provides evidence that car use (and indeed rail use) for leisure is positively related to spells of warmer weather. Participants in the stakeholder workshop also felt strongly that alternative forms of transport, and particularly bicycle, would have increased in usage. It was noted at the same time - and in fact is confirmed by the 1995 analogue - that there might be more bicycle-related accidents as a consequence. This risk is clearly one that could increase in London if there were better weather. However, it is likely that there would be an adjustment in the behaviour of both cyclists and motorists over time, which would reduce the risk (i.e. as drivers became more used to a higher volume of cyclists on the roads, and as cyclists became more knowledgeable and experienced about the cycling conditions). Much would depend upon safe design of cycling routes and lanes. More cycling to work would create a higher demand for showers at work, requiring installation into new buildings at least, and increasing the water demand of offices.

Stern and Zehavi (1989) conducted research on a road affected by high temperatures (above 24°C) and found that the risk of accidents increased during hotter weather. The research had been carried out on a desert highway, however, which did not have obstacles such as parked vehicles and trees, and found that most accidents consisted of cars running off the road or turning over - a result of heat stress on driver concentration. Thornes (1997) (after Maycock 1995) reports that a survey found that 9% of drivers felt that warm weather induced drowsiness whilst driving. Hotter weather would not only make the experience of driving a car or other vehicle in London less pleasant: it might therefore also increase the risk of accidents. At the same time, the impacts of higher external temperatures would be overcome by the use of AC within cars. This is an increasingly common feature of new cars, and could be expected to become a routine accessory in the next decade or so (at least under GM), even though it reduces fuel efficiency.

A further issue raised by stakeholders as a possibility is that in the event that public transport improvements do not keep track with climate change (air-conditioning was given as an example) this might force people to use private cars more often.

It is also suggested[2] that a significant effect of higher winter temperatures, and in particular lower incidence of frost and snow, would be to reduce the level of resources committed to road maintenance during the winter. This would result in a saving in local authority road maintenance budgets for activities such as salting/gritting that prevent ice forming on road surfaces.

Impacts Due to Wind Storms
High winds, though highly uncertain in the UKCIP02 scenarios, are always a problem for surface transport because of more debris and vegetation which finds its way onto rail lines and roads, causing obstruction and delays. It may be assumed that poorer weather would increase the number of accidents on the roads. At the national scale, that is not the case: the vast majority of road accidents occur in fine weather (Edwards 1999). Thornes (1997) points out that in 1995 two thirds of road accidents occurred on dry road surfaces. One hypothesis of why there are more accidents in better weather conditions is that drivers are much more careful in their driving habits when there are poor weather conditions: there is some evidence of a reduction in accidents in poor driving conditions.

7.3.7 Air Transport

Context
London supports four international airports and three national airports and whilst not all of these airports are within the Greater London area, their workings help to determine the economic functioning of the city, and are determined by the city's economy. London Heathrow is believed to have the highest volume of air traffic of any airport in the world - at approximately 700,000 transport movements per year. With 80 million passengers and an expanding freight burden London Heathrow has a significant role in the local and national economies. Over 120,000 people are currently directly employed in London airports and air transport logistics.

Stakeholder consultation revealed the following potential impacts of climate change on the air transport sector.

Flooding and Rainfall Intensity Impacts
One impact follows directly from the discussion of water freight transport to London, in the sub-section immediately above. If low flows in summer months on the River Thames make navigation by freight carriers more perilous it is likely that there will be some substitution, (though as yet un-quantified), between river and air freight transport modes, with a clear increase in air transport demand and possible positive knock-on effects on road and rail freight links within London.

Temperature Change Impacts
A reduction in winter snowfall and frost frequency will result in reduced time disruption costs as flights are less disrupted, and a reduction in associated cold weather aircraft and runway infrastructure costs.

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[2] J.Palutikof Pers. comm.

It was suggested in the stakeholder consultation that there may be substitution between tourist destination in the event of an increased incidence of hot summers. Domestic holidays may be taken instead of international holidays, with an associated fall in demand for international flights. In the case of the 1995 analogue it was estimated that an extra £1.2 million were spent on domestic flights, whilst £12 million less were spent on international tourist flights. The remainder of the increase in domestic travel was met primarily by car and train modes of transport. The issue of tourist travel patterns is discussed in more detail in the Tourism section below.

Impacts Due to Wind Storms

There may be more disruption from storm events (with high winds and lightning frequency) in winter months.

7.3.8 Historical Analogue of Climate Change Event

The analysis above has made reference to the 1995 analogue of a hot summer. The report by Palutikof et. al. (1997) on the economic consequences of this summer (and unusually warm year more generally) provides a quantitative summary of the costs and benefits involved for the UK as a whole and this is reproduced below in 2002 prices. It is recognised that these results should be scaled down according to the proportion of the costs and benefits the transport infrastructure of London contributes to the UK total, though we have no reliable way of doing this. In any case, the values are no more than indicative of the type and scale of costs/benefits that would be involved in the future.

Table 7.2 Estimated costs and benefits of the weather of 1995 on air, rail, road and water transport (£ million)

Transport Mode	Benefits	Costs
Air Transport	Increased internal holiday flights (£1.16m)	Loss of overseas holidays (£11.6 m)
Rail Transport	Increased revenue from holiday and leisure trips (£11.6 m)	Rail buckles (£1.16m)
		Speed restrictions (£1.16m)
		Lineside fires (£1.16m)
Road transport	Reduced maintenance costs (£9.4 m)	Increase in pedal cycle accidents (£14m)
		Road rutting repairs etc (£11.6 m)
Water transport	Reduced delays to offshore shipping (£1.16m)	Closure of canals - loss of income (£1.16m)
Totals	Benefits £23.32m	Costs £41.84m

7.3.9 Socio-Economic Scenario Differences

It is difficult to say whether pressure of use on the underground, trains and buses would be greater under GM or RS. Under GM, there would be more people in the capital, but under RS there would be a move towards more public transport, both of which result in higher underground use. Under GM, the response to unpleasant travelling conditions on the underground and trains might well be greater use of private cars, increasing congestion on the roads and, presumably, encouraging more private-sector investment in public transport, so acting as a negative feedback (i.e. improving public transport). Under RS, the response might be greater use of walking and cycling. In an RS world, people might live nearer to where they worked so facilitating such solutions. At the same time, under RS, many people might not be able to afford to commute long distances due to general reduction in wealth. Any impacts upon aviation would be more keenly felt under GM than RS, because of the greater international mobility experienced in GM.

It is also difficult to distinguish between GM and RS with respect to the pressure on the transport system heading out of the capital. It would be greater under GM due to more affluent and mobile inhabitants wishing to go on more day-trips or short-breaks around the UK and beyond. On the other hand, under RS there would be more use of local places for holidays, reducing pressure upon airports but potentially increasing demand for travel to traditional holiday destinations around the UK. Under GM, however, we would envisage more car-based pressure, and under RS, more public transport-based pressures. Under GM, air conditioning in cars would be standard, whereas under RS it would be discouraged by government because of the energy penalty. Also, the higher price of fuel under RS would act as a deterrent to automatically include AC in a car purchase. This might mean that car drivers under RS are *more* irritable because of hot weather than car drivers in GM, exacerbated as they are under RS by the poor state of the roads due to lack of investment. On the other hand, under GM there would be more cars and lorries to start with, so that the aggravation of higher congestion levels would be greater than under RS.

7.3.10 Comparison with Other Cities

As noted above, cities with more recently constructed underground systems (Singapore, Hong Kong) have the benefit of being able to include air conditioning, though not without problems. Congestion from cars is a common problem in cities in the industrialised world, though some have tackled it more aggressively through restricting entrance and high zonal charging (e.g. Singapore & Hong Kong). Cities which can use waterways as main transport routes have a slight advantage in that the travel conditions would be more attractive. London might even have a slight edge here over other cities such as New York and Tokyo which, whilst located on the coast, do not have the same accessibility to the inner city areas from rivers running through the urban mass. By contrast, many commercial, cultural, retail and tourist destinations are quite accessible from the River Thames. The transport infrastructure in New York (with its large bridges, docks, harbours, etc.) also seems to be at a greater threat from sea-level rise and extreme events than in London. The large number of tunnels and railway lines located on low-lying coastal strips makes NYC's transport infrastructure very vulnerable to sea-level rise and coastal inundation (Rosenzweig & Solecki 2001). Indeed, one of the structures of a new tunnel bringing water to the New York City (Third Water Tunnel) was raised in response to climate change.

Table 7.3 Summary Table of Impacts - Transport

Climate Change Variable	Associated Impacts	Potential Severity Ranking	Employment Effects	IPPC uncertainty rating	Current availability of adaption options
Increase - winter rainfall	Flooding - time loss, damage repair	H	L - ve	H	Y
Decrease - summer rainfall	Low river flows - freight, tourist disruption	L	L -ve	H	Y
Higher winter temperatures	Less snow - less infrastructure damage	L	L-ve	H	-
Higher summer temperatures	Heat stress - damage repair Greater transport use - leisure Lower transport use - work	L L M	L +ve L +ve L +ve	H H H	Y - -
Increased severity - wind storms	Infrastructure damage, time loss	H	L -ve	H	Y
Sensitivity to socio-economic scenarios		Impacts exacerbated under GM scenario			
Key non climate change sectoral drivers of change		Transport pricing regimes, economic development/planning priorities			
Key stakeholders in impact and adaption analysis		GOL, LDA, TFL, LUL, Port of London Authority, BAA, Local Authorities User Associations			

7.4 Energy

7.4.1 Context

The Mayor's draft Energy Strategy shows that energy consumption in Greater London currently stands at 154 TWh, close to 30% of the UK total. Gas is the most important fuel in London, accounting for 56% of total energy consumption, followed by electricity with 22%. Domestic use accounts for 44% of total energy use, followed by the service sector with 29% and industrial use, with 7%. Some 40% of electricity is generated by power stations located inside the capital. The cross-sectoral importance of energy is underlined by the Mayor's draft Energy Strategy document which states that "Energy supply and use underpin most of the Mayor's eight statutory Strategies - in particular Economic Development, Spatial Development, Transport, Air Quality, Municipal Waste Management and Noise".

7.4.2 Flooding and Rainfall Intensity Impacts

Changes in rainfall patterns with wetter winters and drier summers will have a detrimental effect on the foundations of electricity pylons. In addition, increased wind speeds and increased gust return periods will increase the stresses and fatiguing on power lines, pylons and related assets.

Stakeholders have also suggested that less rainfall in the summer and the associated reduction in cloud cover will provide an opportunity for the solar energy market to expand, both in London and on a national basis.

Clay shrinkage may also impact negatively on the robustness and effectiveness of these networks. An increase in lightning events may also increase the risk of disruption to energy supply as a consequence of damage to the infrastructure.

In the case of hydro-power, which is being mooted as a possibility in conjunction with Thames Water, wetter winters and drier summers will concentrate production even more during the winter months than at present.

7.4.3 Temperature Change Impacts

The most prominent potential climate change impacts on the energy sector are the changes in energy demand that are thought likely to result from higher mean winter and summer temperatures, namely:

- A reduction in the demand for space heating, primarily in spring and autumn; and,
- An increase in the demand for air cooling, primarily in the summer.

Information from a key stakeholder (National Grid) states that evidence has shown, (Palutikof, et. al. 1997), that electricity consumption is beginning to increase during the summer months, almost certainly due to the increased use of air-conditioning and refrigeration. The hot summer of 1995 Quarter 3, (Q3), showed an increase of 2.1% over the temperature corrected consumption. The 1995 Q3 temperature is about 2^0C above the 1961-1990 Q3 average so an increase of 5^0C suggests a summer increase in electricity consumption in excess of 5%, using established non-linear relationships. As the use of air-conditioning in the UK increases from climate and non-climate factors this can assumed to be a lower limit.

In fact it is estimated that more air conditioning (AC) will increase the demand for summer energy, perhaps by 10 to 15% by 2050s, and by 20 to 25% by the 2080s. Warmer winters will generally reduce electricity demand. Energy for heating in the winter is usually provided by gas, whilst AC runs off electricity. Hence, the provision of summer cooling is more expensive than winter warming. Detailed work is required to assess what the change in energy demand in London would be as a consequence of climate change, and hence what is the balance between the increased use of electricity in the summer and decreased gas use in the winter. The increased demand for electricity for AC during 'peak' hours (midday to evening) requires a disproportionately high increase in generation capacity, which would remain idle for much of the time and would therefore incur high capital costs.

This will put further strain on the transmission and distribution networks with a consequent increased risk of 'black-outs' occurring in the system, with associated costs to the economy from disruption of business activities.

To compound the problem, increased average temperature will restrict the load that can be carried by the transmission and distribution networks due to the increased risk of overheating.

It is clear that climate change is likely to exacerbate seasonal differences in demand and perhaps result in a greater degree of associated seasonal demand for contract workers in the energy sector.

7.4.4 Impacts Due to Wind Storms

From the point of view of wind power, increased wind speeds will mean increased production. A 1% increase in wind speed is equivalent to a 3% increase in available wind power. This will be significant for a wind farm off the south-east coast which produces greatest output during the winter months. On the other hand, increases in storm events and more frequent return gusts will increase wind turbine fatiguing.

7.4.5 Communications Infrastructure

The impacts on communications infrastructure as a result of possible climate change in London is considered here since it shares many common features with the discussion of energy infrastructure above. The stakeholder consultation showed that communications are considered vulnerable to a number of climate change related weather patterns including:

Exposure of above-ground infrastructure, e.g. radio masts in the London area, to extreme wind events and a resultant increased risk of service disruption and repair costs. There may also be service disruption to customers in London as a result of damage to infrastructure elsewhere in the UK.

Decrease in summer rainfall resulting in clay shrinkage in many parts of London that may reduce the resistance of below-ground infrastructure, e.g. cabling.

7.4.6 Socio-Economic Scenario Differences

Under GM, one might argue that the costs of climate change would be absorbed by the vibrant state of the economy, and increased energy costs from AC would be readily absorbed. There may, however, be 'thresholds' beyond which comparative costs elsewhere, and perhaps other types of innovation and development to make other cities 'greener' and more pleasant places to live in, would begin to make a difference to the choice of business location (i.e. away from London). These could ultimately suppress the economy, i.e. act as a negative feedback.

7.4.7 Comparison with Other Cities

As for energy demand profiles, climate change will clearly increase the demand for cooling in other cities in Europe, America and Asia. As temperatures and humidity rise, the relative efficiency of AC will decline, meaning that more energy has to be used to achieve successively greater levels of cooling. The Tokyo Electricity Company has estimated that there is a need for an increased electricity capacity of 1,600 MW for each 1°C rise in summer air temperature to cope with the peak demand. This is equivalent to a large power station. The costs of cooling to cities which start from a higher extreme temperature and humidity baseline will be larger, therefore. On the other hand, many of the commercial buildings in London, and most of the domestic buildings, will not already have in place the physical infrastructure of AC units. The capital costs will therefore be greater, though there will possibly be benefits achieved through installation of more efficient modern AC units. The possibilities for more sustainably-sourced energy for air conditioning or cooling have been discussed above (fuel cells, borehole cooling, district CHP, etc.).

7.4.8 A Case-Study of New York City

Peak summer electricity loads already far exceed winter peaks in New York City, because of air conditioning, and the higher temperatures under future climate change will exacerbate this difference, putting further stress upon the electricity system during summer heat waves (Hill & Goldberg, 2001). In the summer of 1999, four successive heat waves hit NYC, the temperature rising to more than 90°F (32°C) for 27 days (and to more than 100°F (38°C) for two days). The peak electricity demand occurred on the 6th July. Brown outs (when electrical power is partially reduced, causing lights to dim) and an extended blackout occurred in the primarily minority neighbourhoods of upper Manhattan and South Bronx (ibid.). Loss of electrical power has serious social, political, economic and health impacts. For instance, the more vulnerable such as the young and elderly are less able to deal with heat stress, and those in high-crime neighbourhoods face increased risk of crime during power cuts. Residents and local politicians in the areas most affected argued that the electricity supplier had not properly maintained the equipment, putting the resident populations at risk. An energy forecasting model has projected that the daily peak load increases in NYC will range from 7 to 12% in the 2020s, 8 to 15% in the 2050s and 11 to 17% in the 2080s (Hill & Goldberg, 2001) (relative to July 1999). (Further research with an appropriate energy model would be necessary to state what the effects of climate change upon load increases in London would be).

Table 7.4 Summary table of impacts - Energy

Climate Change Variable	Associated Impacts	Potential Severity Ranking	Employment Effects	IPPC uncertainty rating	Current availability of adaption options
High winter temperatures	Lower space heating - demand fall	M	L -ve	H	
Higher summer temperatures	Greater air conditions - demand rise	M	L +ve	H	
	Risk of network overheating	M	L -ve	-	
Increased severity - wind storms	Damage to wind power turbines	L	L?	-	
Sensitivity to socio-economic scenarios		Impacts exacerbated under GM scenario			
Key non climate change sectoral drivers of change		Energy pricing - climate change mitigation; regulatory structure			
Key stakeholders in impact and adaption analysis		Regional electricity companies; National Grid; National Power			

7.5 Insurance

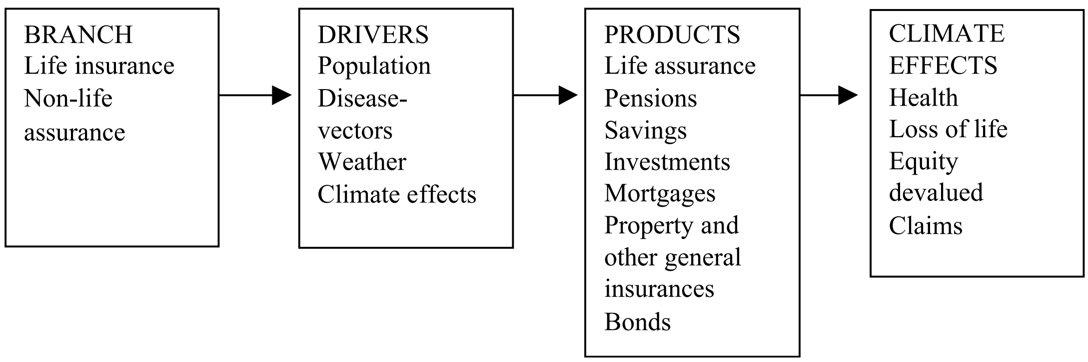
7.5.1 Context

The London based insurance industry comprises approximately 90% of the total UK employment in the industry, (about 300,000), contributing 1.4% of UK GDP. The UK Insurance market is the third-largest in the world and contributes around £8 billion a year to UK overseas earnings, reflecting a broad exposure in global economic activities. The London Market's Gross Premium Income was £17.734 billion in 2000. Insurance companies are the largest domestic owners of UK shares - owning 21% of UK ordinary shares. This compares with 18% held by company pension funds, 2% by unit trusts, and just over 1% by banks. The UK insurance industry in 2000 held £796.5 billion worth of assets globally.

The UKCIP Scoping Study for the South East of England describes in general terms how the UK based insurance industry is likely to be impacted by climate change in the UK. The study notes that since "many activities within the insurance sector are weather sensitive, the industry has developed wide experience and understanding of how weather conditions impact on its operations. These include claims associated with severe short term events including rain and windstorms, freezing weather and longer term events such as hot, dry spells the latter increasing building susceptibility to subsidence".

Dlugolecki, in Chartered Institute of Insurers (CII) (2001) generalises the interaction between insurance and climate change as illustrated in Figure 7.1 below.

Figure 7.1 Life and non-life insurance activities and climate change



The diagram shows that the core activities of insurance companies are likely to be impacted by climate change either by changes in risk transfer arrangements, changing vulnerabilities of financial and non-financial assets held, and wider economic changes. The different types of climate change impacts most likely to be important to the London insurance market are discussed in more detail below.

7.5.2 Flooding and Rainfall Intensity Impacts

As noted elsewhere in this report, London is exposed to far greater potential damage from flooding than any other urban area in the UK. This is due to the scale of the city and the fact that a significant proportion of London lies within the floodplain of the River Thames and its tributaries.

The UK is unusual in that flood insurance is currently offered as standard with buildings and contents policies. Property damage as a result of river, and other sources of, flooding is covered to some degree for almost all insured properties in the UK. Thus, the higher rainfall incidence predicted for the UK by the London and UKCIP02 climate scenarios is likely to result in an increased value of claims against the insurance industry. A recent analogue of this type of event were the floods of Autumn 2000. In this case, 12,000 properties were damaged and a further 37,000 properties were classed as 'near misses' by the Environment Agency. The total cost for the UK insurance industry to date is over £1.0 billion.

The causes of flood risk are not confined to tidal or river flooding. Other particular concerns for London include:

- The large size of urban catchments;
- The rate of development of new housing and associated development in the main drainage tributary systems;
- Particular hazard of short duration, intense storms on the drainage systems (foul and storm);
- The ageing condition and lack of capacity of existing drainage systems;
- Impact of rising groundwater in conjunction with surface flooding.

Even new drainage systems are designed to cope only with normal rainfall levels. Recent research has shown that climate change will mean that many of these systems will surcharge several times a year in the future (Futter and Lang, 2001). Stakeholders hope that the threat of this flood risk will be reduced by the Sustainable Urban Drainage Systems (SUDS) initiative promoted by the Environment Agency and the Scottish Environment Protection Agency which aims to promote good practice in the construction of robust drainage systems with sufficient capacity to cope with rainfall events foreseen by the London climate change scenarios.

Exposure to River Flood Risk and Adaptation Strategies
A number of adaptation options for reducing flood risks likely to arise from climate change in London are outlined in Section 5 and the section on water resources in this section, above. In the following paragraphs an insurance industry perspective on the current development of flood prevention strategies is presented.

7.5.3 Temperature Change Impacts

Palutikof (nbu.ac.uk web-site) points out that freezing weather causes damage even in a relatively mild winter, when a short episode of very cold temperatures can cause substantial claims for burst-pipe damage. Also householders are more likely to take a winter holiday, leaving the house empty and unheated. The balance of opinion in the industry suggests that these two factors more or less cancel in the present climate. Potential claims from this type of weather event are significant for the industry (though less than flood and storm costs): it is estimated that £250 million of claims resulted from such an event in 1996 in the UK. This type of effect may be expected to reduce in frequency as a result of the warmer winters expected under the climate change scenarios for London.

According to the Association of British Insurers, their members already incur costs of nearly £1m every day on average from subsidence. This is likely to be a growing issue as summers become drier and warmer, causing soils to shrink. Subsidence should not be a major hazard - the fact that it is so costly in Britain, especially England, is more to do with issues around building foundations and building standards. A new technique using satellite data, called Permanent Scatterer Synthetic Aperture Radar Interferometry (PS InSAR) is making it possible to measure sub millimetre movements in buildings. This could identify the worst subsidence areas. It could also give early warning of failure of mass structures such as bridges, flood defences, power stations and dams.

7.5.4 Impacts Due to Wind Storms

It is becoming clear, whether or not storms will become more frequent and severe with climate change, that storm tracks are changing. In the past, it was normal for stable cold high pressure areas to develop over Switzerland and Germany in the winter. These 'blocking highs' diverted Atlantic storm tracks over the North of Scotland or Spain where houses have been designed to cope with them. As winters in central Europe become milder, the blocking highs are becoming weaker or shifting to the East (Parry et al., 2000). When there are milder winters in central Europe, more storms track across the South of England and the North of France (Dronia, 1991) where buildings are designed and constructed to lower standards. Existing historical analogues show that there are high costs for the insurance industry of these type of events. The October 1987 storm cost insurers £1,500m at 1987 prices for UK damage alone. Overall, including continental European losses, the economic loss was $3,700m of which the insured loss was $3,100m. Two further such storms in England in January and February 1990 ('Daria' and 'Vivian') caused insured losses in England of £2,400m (at 1990 prices). The overall European economic losses were $10,050m of which insured losses (at 1990 prices) were $7,200m. Three big storms in December 1999 ('Anatol', 'Lothar', and 'Martin') did not affect England seriously, but devastated large areas of Northern and Western Europe, causing economic losses of $12,700 m of which insured losses were $6,200 million (Munich Re, 2002).

Future extreme wind storm events are expected to be one of the most significant of the climate change impacts for the insurance industry because of the associated claims for business disruption, utility and transport infrastructure damage and domestic property damage.

An insurance stakeholder view is that there is a clear lesson here for adaptation strategies. Storms in London are likely to become more severe and frequent, but as buildings in London have been designed for relatively benign weather conditions, they are likely to be more vulnerable to storm damage. This needs to be taken into account when revising the Building Regulations. It will also be necessary to have more stringent control through inspections on the quality of construction and the resilience of buildings to storms or floods.

7.5.5 Raised Reservoirs

A study was carried out of the climate change impacts on the safety of British Reservoirs, using the UKCIP98 climate scenarios. The study concluded that under a medium-high climate change scenario the total surcharge (i.e. rise in water level above normal retention level during a storm) could increase by about 5% by the 2050s and that embankment dams might be more vulnerable than concrete and masonry dams. The report also strongly recommended that climate change should be taken into account in future reviews under the Reservoirs Act 1975. (Babtie and Institute of Hydrology, 2002). It should however be noted that reservoirs in the London area do not impound rivers but are filled by pumping water into them from rivers under a managed operational regime.

More than 50% of Britain's reservoirs are over 100 years old and made of earth embankments. The Reservoir Act 1975 stipulates a regular inspection program for all reservoirs which ensures that structural integrity is maintained.

There are several raised storage reservoirs in the Greater London area for example along the Thames and Lee valleys. These are often situated along rivers but may also be near urban areas. Although the risk of failure is low, planners need to be aware of the potential hazard when considering new housing developments in such areas. Future climate change impacts are considered as part of the mandatory maintenance and inspection program of all dams and any new development built near to the reservoirs have the same level of protection as existing properties under the class A rating of the dams, this is a statutory provision under the Reservoir Act 1975.

7.5.6 Potential Meso- and Macro-economic Effects of Climate-Change Related Impacts on the Insurance Industry

The current practice is for insurers to offset underwriting losses - of the type identified above as resulting from climate related events - against investment income. A consequence of this is that investment returns are likely to fall, with a subsequent re-alignment of premium payments - and therefore consumer prices - upwards. A related consequence if the climate event is severe enough - as it was for the 1987 windstorm - is that insurance companies may be forced to reduce their level of capitalisation in capital market or property market equity. In this instance, there will be a downward shift in equity prices which reduces liquidity in the financial sector and has a deflating effect on investment in the economy, and therefore economic growth. Such a reduction in the level of capitalisation of the industry is also likely to be accompanied by internal retrenchment of insurance operations and a shrinkage in employment levels in the sector.

The threat to the sector identified above in the UK is exacerbated significantly by the high level of inter-dependence that exists in global capital and insurance markets. The scale of climate change impacts identified for the UK may potentially be significantly increased by climate change in other parts of the world, where assets are insured against damage in the London insurance market. For example, where an incidence of increased tropical storms is expected (as in the southern states of USA and the Caribbean), buildings and transport infrastructure are likely to suffer increased levels of damage - assuming existing construction specifications - leading to increased claims against the insurance industry. Indeed, such claims will impact on the London-based insurance and financial services industries even if the insurer claimed against is not based in London since there might be a (marginal) global squeeze on financial liquidity. These types of future risk changes are already being considered in the development of the global market strategies within the London insurance industry.

IPCC (2001) notes as a measure of insurance vulnerability the ratio of global property/casualty insurance premiums to weather-related losses fell by a factor of three between 1985 and 1999. The IPCC synthesis concludes that 'there is high confidence that climate change and anticipated changes in weather-related events that are perceived to be linked to climate change would increase actuarial uncertainty in risk assessment and thus in the functioning of insurance markets'. As one insurance sector representative commented in the course of the project consultation, "insurance has historically been about predicting the unpredictable. Climate change means that predicting the unpredictable itself becomes unpredictable."

To avoid this level of exposure to loss, the UK insurance industry is engaged with the sectors - such as property, transport and regulatory authorities - to develop effective and equitable adaptation strategies. Some specific adaptation options are highlighted above and CII (2001) gives further detail on these.

7.5.7 Socio-Economic Scenario Differences

Under the GM scenario there will be an expansion of the global insurance market as regional markets are increasingly linked with each other. This will be reflected in a greater degree of trading opportunity for economic assets of all sorts and a consequent increase in the need to insure them. This effect is more significant at the global scale rather than the national scale since in the UK property already has a high degree of insurance coverage. Under this scenario, therefore, the insurance industry may be more exposed as climate change reduces the robustness of existing actuarial calculations relating to the rates of premiums that are based on non-climate change weather patterns. The RS scenario is likely to feature a consolidation of the global insurance industry - increasingly based around regional commercial centres.

7.5.8 Case Study

Since 1961, private insurers in Britain have had a form of partnership with government in that they offer flood insurance for every household at a reasonable price. This arrangement is unique to Britain. The insurance industry has recently reviewed its position because:

- In the United Kingdom, the government regulator for insurance is the Financial Services Authority (FSA). In 2001, the FSA issued risk-based criteria for assessing the solvency of insurers. One of the effects of this is that if an insurance company takes on too much business in areas at risk of flood, it could be subject to FSA audit. This may be unlikely in the short term, but it is a possibility that directors of insurance companies must take into account, and they will need to ensure that accumulations of flood hazard exposures are properly managed.

- In recent years there have been an increasing number of new housing developments in floodplains to the extent that there are now large accumulations of exposure in flood hazard areas especially in London. The reasons include increased demand for housing in such areas where suitable sites are limited, together with the continuing availability of insurance that has enabled people to borrow money to buy the houses.

In addition the widespread flooding in Autumn 2000 in various UK locations led insurers to review the sustainability of flood cover in high-risk areas. Insurers (through the Association of British Insurers) responded to concerns over the continued availability of flood cover by committing to a two-year agreement for existing domestic properties and small business policyholders. At the time of writing this agreement expires at the end of 2002. In return the insurance industry is seeking a greater investment by the government in prioritised flood defence expenditure and a tightening of planning control on development in the floodplain through the implementation of Planning Policy Guidance Note 25 ‘Development and Flood Risk’.

Table 7.5 Summary table of impacts - Insurance

Climate Change Variable	Associated Impacts	Potential Severity Ranking	Employment Effects	IPPC uncertainty rating	Current availability of adaption options
Increase - winter rainfall	Flooding - insured damage to property	H	H -ve	H	Y
Decrease - summer rainfall	Subsidence to insured property	M	L?	H	Y
	Damage to dams - break over property	M	L?		
Increased severity - wind storms	Infrastructure damage - insured	H	H -ve	H	Y
Sensitivity to socio-economic scenarios		Impacts significantly exacerbated under GM scenario			
Key non climate change sectorial drivers of change		Economic growth; development of global insurance markets			
Key stakeholders in impact and adaption analysis		CII, ABI, UK Govt., Banks, Construction companies			

7.6 Financial Services

7.6.1 Context

The financial services sector is the largest employer in London (32% of total), and excluding the insurance industry, employs about 700,000. Professional and support services such as legal services, accounting and management consulting employ a further 600,000 people. The draft London Plan envisages the protection and enhancement of this sector as a principal mechanism by which London's economic development can be driven, and by which London's status as a global city can be maintained.

7.6.2 Flooding and Rainfall Intensity Impacts

Much of the discussion on climate event risk changes and their repercussions for the insurance sector are relevant to the wider financial service sector in London because of the inter-linking of insurance and capital markets. Figure 7.2 below illustrates the extent of these linkages.

As an example of the linking mechanisms, the case of lending can be cited (IPCC, 2001). Most private and corporate loans are secured by property. If a region such as London becomes more exposed to climate-related natural disasters such as floods or windstorms, the prices for property could fall - which may result in a loss of confidence in the local economy and may trigger a credit crunch of the sort described in the section on insurance. An indirect consequence of this is that other types of business such as management of private assets and granting of private loans that are not backed by property will also be affected (Bender, 1991; Thompson, 1996).

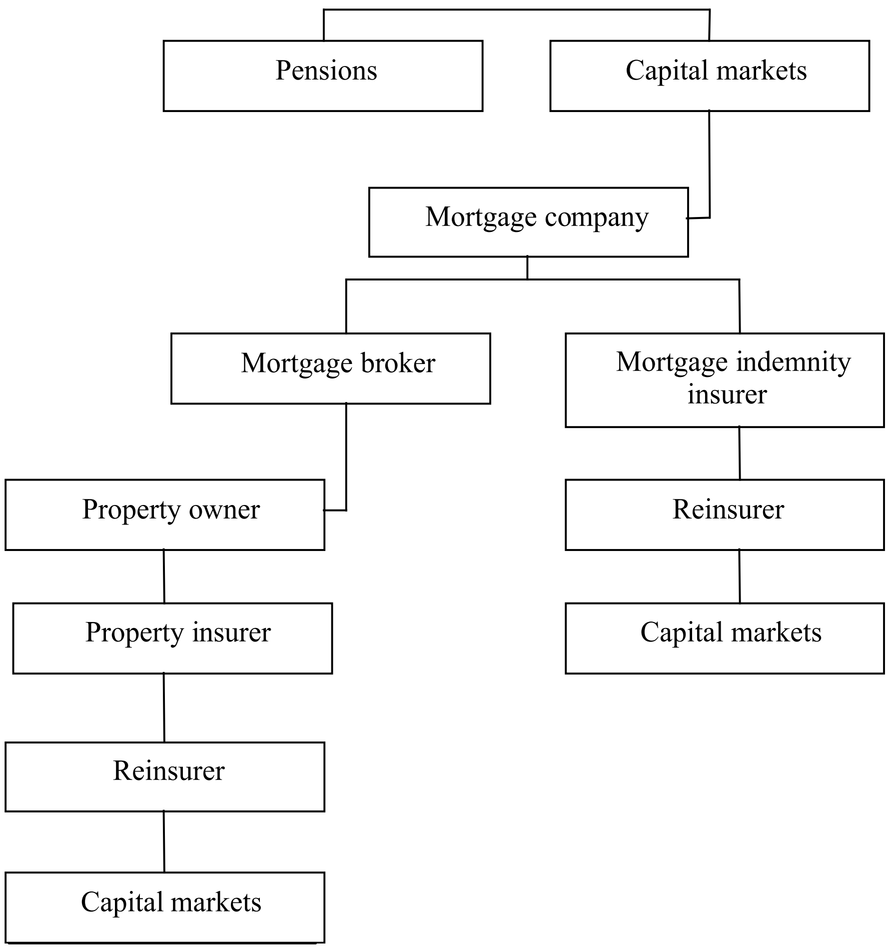
7.6.3 General Climate Change Impacts

There are divergent views on how the banking sector will be impacted by climate change. One view is that the nature of the industry - large, diversified banking institutions - means that any loan exposure will be minimal since no substantial portion of the loan will be kept for any long period. Alternatively, should their customers operations or financial circumstances change as a result of climate change, (e.g. international tourism), the banks performance could be affected indirectly.

The stakeholder consultation did, however, identify a strong feeling that the risk management of potential climate change impacts, coupled with the implementation of regulatory regimes for greenhouse gas emission mitigation, provide significant business opportunities. Risk management is resulting in the development of markets for e.g. catastrophe bonds and weather - related trading in the international financial markets.

Similarly, the reality of a carbon-constrained future for all business is already manifesting itself in the application of energy-focussed audit work for consultancies as energy use becomes a part of companies' business strategy. There is likely to be a major verification role as Kyoto Protocol regulatory mechanisms such as Joint Implementation and Clean Development Mechanism are enforced. Finally, there is a developing market in carbon trading which London is in a very good position to exploit as an established trading centre. It was noted by one stakeholder, however, that Chicago currently lead the way in this market, benefiting from the fact that the US are likely to be the major buyers of carbon credits in future! All these opportunities for mitigation are likely to be enhanced as the recognition of potential climate change impacts, e.g. flood risk to London, that should be avoided stir a greater regulatory response from national governments.

Figure 7.2 Insurance - Capital Market Linkages



7.6.4 Socio-Economic Scenario Differences

As with the insurance sector, the financial services industry in London will have significant opportunities to expand in the GM scenario. The rapid rate of expansion in IT technologies and communications on a global basis would allow increased opportunities for participation in the trading of climate change mitigation and weather risk financial instruments. Under the RS scenario, there may be a further development of e.g. EU permit trading regimes but the level of growth will be less than under the GM scenario.

Table 7.6 Summary table of impacts - Financial

Climate Change Variable	Associated Impacts	Potential Severity Ranking	Employment Effects	IPPC uncertainty rating	Current availability of adaption options
Increase - winter rainfall	Flooding - property damage - equity market falls	H	M -ve	H	N
Increased severity - wind storms	Infrastructure damage - equity market falls	H	M -ve	H	N
Existence of climate change impacts	Devt. of new weather risk management tools	M	L	H	-
	GHG mitigation regulation	M	L	H	-
Sensitivity to socio-economic scenarios		Impacts significantly exacerbated under GM scenario			
Key non climate change sectorial drivers of change		Economic growth; merger strategies			
Key stakeholders in impact and adaption analysis		Corporation of London, UK Govt, Banks, Consultancies			

7.7 Manufacturing

7.7.1 Context

Whilst the sector has suffered a long term relative decline, manufacturing in London is presently responsible for 300,000 jobs and £10 billion of output. It comprises 10% of all UK manufacturing. London's largest manufacturing industries are: food and drink, advanced automotive, aerospace and precision engineering, as well as high-tech industries such as pharmaceuticals, fibre-optics and computing. It is these industries which the draft London Plan envisages consolidating and expanding to 2015.

In general terms, manufacturing businesses are most likely to be impacted upon by climate change in the following ways, where the industry is dependent on climate-sensitive natural resources, and their supply is affected:

- Through consumer behaviour that is sensitive to climate variability;
- Through transport disruption that affects just-in-time industrial processes.

7.7.2 Flooding and Rainfall Intensity Impacts

The economic costs of transport disruption were identified in the section above on transport. The stakeholder feeling is that disruption to road and train modes from flood and storm damage are likely to be the most costly for industry.

There was a stakeholder recognition that changes in water resource availability and/or prices in the London region - highlighted above - may have impacts on certain industries in the city that use large amounts of water in their manufacturing processes. The most likely impacted industries are thought to be the drink sector (and particularly brewers) and the automotive industry, though no work is known to have been undertaken on this issue.

7.7.3 Temperature Change Impacts

The effect of climate-induced changes in consumer behaviour are generally related to temperature changes. The study by Palutikof et. al. (1997) of the 1995 hot summer provides an analogue of how such conditions may impact on retailing and manufacturing in the future. They found that there was a net cost to the retail market in total of £102 million (2002 prices), whilst the loss for the clothing and footwear market was estimated at £410 million for the UK as a whole. There was a small gain of £27 million in the fruit and vegetable markets. Clearly, these types of effects have parallel knock-on impacts on the associated manufacturing sector.

A general point common to all the sectors included in this analysis - but perhaps particularly relevant to the manufacturing sector - is that warmer weather in summer will result in more uncomfortable working (and travel) conditions. This may have an effect on productivity, and an adaptation strategy will need to weigh up these productivity costs against e.g. building ventilation. As mentioned elsewhere, there may also be sectoral and geographical relocation resulting from this climate change impact.

7.7.4 Impacts Due to Global Climate Change

The dependency on climate-sensitive natural resources, and possible supply disruption is thought by stakeholders to be most relevant to the food and drink industry where there is a heavy reliance on imported food stuffs. However, the range of evidence on changes in food production is very wide, and it has led IPCC (2001) to draw a single conclusion: that, with very low confidence in its robustness, a global temperature rise of greater than 2.5°C is likely to exceed the capacity of the global food production system to adapt without price increases. However, results are judged to be too mixed to support a defensible conclusion regarding the vulnerability of the global balance of agricultural supply and demand to smaller amounts of warming than 2.5°C.

7.7.5 Socio-Economic Scenario Differences

Under the GM scenario, traditional manufacturing continues to decline whilst high-tech manufacturing increases. It is possible, therefore, that the threat to the traditional part of the sector from supply disruption caused by climate change events elsewhere in the world will be reduced in the GM scenario but increased under the RS scenario.

Table 7.7 Summary table of impacts - Manufacturing

Climate Change Variable	Associated Impacts	Potential Severity Ranking	Employment Effects	IPPC uncertainty rating	Current availability of adaption options
Global climate change impacts	Prince increases in e.g. food stuffs	M	M -ve	L	Y
Increase - winter rainfall Decrease - summer rainfall	Likely net deficit in supply - dem and balance - price rise	M	L - ve	H	Y
Higher winter temperatures	Changes in consumer behaviour	L	L?	H	-
Higher summer temperatures	Changes in consumer behaviour	L	L?	H	-
Storm frequency/severity	Distribution disruption	M-H	M -ve	H	Y
Sensitivity to socio-economic scenarios		Impacts possibly mitigated under GM scenario			
Key non climate change sectorial drivers of change		Economic growth; international market competition			
Key stakeholders in impact and adaption analysis		Corporation of London, UK Govt, FSB, CBI, Unions			

7.8 Environmental Business

7.8.1 Context

Environmental business is most commonly associated with the recycling of materials though the definition should be broad enough to cover any business activity that is responsive to environmental issues and problems. Thus, the substantial business that has arisen in the regulation of environmental impacts (e.g. environmental impact assessment, greenhouse gas emission trading etc) may be considered under this heading. This activity is discussed in the Financial Services section. Other environmental businesses include those related to energy efficiency, flood protection engineering, waste management, consultancies etc. According to the draft London Plan, the size of the sector in London is now equivalent to the pharmaceutical sector, and forecast to double by 2010.

7.8.2 Impacts Due to Global Climate Change

The most significant climate change impact thought likely to affect the recycling industry in London is the possible increased demand for recycled materials in manufacturing and retail sectors as a result of relative price changes between recycled and virgin raw materials from climate change impacts elsewhere in the world. The argument is that climate change impacts in other parts of the world, such as South Asia, may have an impact on the supply of certain raw materials for manufacturing. If supply is restricted – either by transport disruption or cultivation patterns changing as a result of negative changes in temperature or rainfall – the price of the commodity will rise, other things being equal.

Moreover, assuming a constant price of recycled raw materials, it is likely that there will be some switching of demand from virgin materials to recycled materials, and a consequent expansion of this type of environmental business. This argument may be the case for paper of which a significant part of the market share is presently manufactured from virgin pulp in South and East Asia. Current estimates of cultivation pattern changes (IPCC, 2001) tentatively suggest a 1-5% increase in price for paper pulp in the next 15 years as a direct result of temperature and rainfall changes. Although low confidence is placed in these estimates at present, it is recognised that any change in relative prices of this nature will have a positive effect on UK paper recycling industry. A similar argument can be made for the rubber recycling industry since virgin rubber is also presently supplied from Asia. There is therefore a potential opportunity to be exploited here – though it is clearly a regional, rather than a global, welfare gain.

7.8.3 Impacts Due to General Climate Change

Two closely related arguments suggest that climate change impacts might have a positive effect on environmental businesses.

First, it is possible that with heightened awareness of human responsibility for environmental change, (such as the link being made between greenhouse gas induced climate change and the Autumn 2000 floods in the UK), more pro-active steps will be taken by producers or consumers to ensure that their actions have less of an environmental impact. This might manifest itself either in reduced consumption levels or the use of more recycled materials, (and hence benefits for environmental businesses), or both.

The related argument is that as a result of such increased awareness within the general public and in government, increased regulation of activities that have environmentally detrimental consequences will result, with benefits for environmental businesses more generally. It should be noted, however, that this outcome may simply shift employment from one sector (e.g. the regulated industry) to another (environmental consultancy), with no net gain. A wider perspective on this might suggest, moreover, that it is preferable for producers to be pro-active and look for opportunities with which to exploit an environmental profile to competitive advantage without relying on a legislative driver.

7.8.4 Socio-Economic Scenario Differences

The RS scenario, with its greater awareness of the value of the environment for its own sake, is likely to exacerbate the tendency for environmental business sector to expand as increased awareness of climate change results in increased demand for all kinds of environmental product or service. It is possible also that the GM scenario will result in the expansion of e.g. recycling markets, with an increased consequent scope for exploiting virgin-recycled price differentials.

Table 7.8 Summary table of impacts - Environmental Businesses

Climate Change Variable	Associated Impacts	Potential Severity Ranking	Employment Effects	IPPC uncertainty rating	Current availability of adaption options
Global climate change impacts	Price increases in virgin raw material relative to recycled	M	M +ve	L	-
Existence of climate change impacts	Changes in producer/consumer behaviour	L	M +ve		-
Sensitivity to socio-economic scenarios		Impacts exacerbated under RS scenario			
Key non climate change sectorial drivers of change		Sustainability awareness			
Key stakeholders in impact and adaption analysis		Recycling/environmental businesses; UK Govt.; manufacturers; consumers			

7.9 Tourism and Leisure

7.9.1 Context

Tourists visiting London from elsewhere in the UK account for approximately 10% of total UK domestic tourism (ONS 2001). London is by far the most popular UK destination for overseas tourists, however, accounting for just over half of all overseas tourists and associated expenditure. In 1998, 13.5 million overseas tourists travelled to London. The domestic tourists bring in just over £1 billion, but the overseas tourists contribute nearly £7 billion to the London economy (ONS 2001). Hotels and restaurants comprise 5.8% of London's GDP.

London has an impressive set of facilities and attractions for tourists including the following (LTB at www.englishtourism.org.uk 2002):

- 1200 hotels (269 of which are of historical interest);
- 12,155 restuarants;
- 5,245 pubs and bars;
- 200 museums;
- 108 theatres.

7.9.2 Flooding and Rainfall Intensity Impacts

- Sports and recreational fishing could suffer in dry summers;
- There may be insufficient water to maintain inland canal navigation. This could also effect the attractiveness of canal-side commercial and residential developments;
- Increased likelihood of algal blooms on watercourses with aesthetic and health implications.

7.9.3 Temperature Change Impacts

There is a high degree of uncertainty as to what the net effect of climate change is likely to be on Tourism in London but the principal arguments are:

- Southern Europe and other destinations might become less attractive as a destination for summer holidays since climate change there will result in intolerable hot temperatures. More summer holidays will therefore be taken domestically, with time spent in London being one component of such a holiday.
- A recent study, (Agnew and Viner, 2000), has identified potential impacts of climate change on ten overseas holiday destinations. The threats of these predominantly negative effects (examples of which are shown in Table 7.9 below) will strengthen the argument above.

Table 7.9 Potential impacts of climate change on holiday destinations

Location	Climate Change impacts
Greece & Turkey	Heat stress/mortality; water supply restrictions; forest fires, urban smog
Southern Spain	Re-emergence of malaria; heat stress; flash floods; forest fires
Florida & S.E. coastline of USA	Sea level rises affecting recreation and tourist activities concentrated along the state's beaches; severe storms discouraging holiday makers; erosion and coral bleaching; threat to geomorphology and ecology

To exploit this possible opportunity will require maintaining a high quality environment, efficient transport systems and sufficient capacity to cope with a rise in tourist numbers (visitor management). If climate change also results in increased visitors to the UK as a whole, this would have implications for London, since the city's airports and stations are the gateway to most visitors to the UK. On the other hand, heat waves might deter visitors to London. In the workshop, it was recognised that tourists do still visit Italian and Spanish cities in the summer. London in 50 years would be unlikely to exceed the temperature of popular tourist cities in southern Europe now, so it seems unlikely that the temperature *per se* would be off-putting.

Indeed, if temperatures were to increase significantly in other cities which are currently popular tourist destinations, such as Venice, Florence, Rome, Barcelona, Seville, New York, etc., then it could be argued that they would indeed become less attractive tourist destinations, at least during the summer. In this case, there could be a transferral of visitors to London from those cities, at least during the hotter parts of the year. Many hotels in London do not have air conditioning at present, however. This, or alternative means of cooling rooms, would be necessary to provide a high quality destination. Similarly, cafes, restaurants, visitor attractions and retail centres would also require air cooling systems to remain at a high quality. Increased air pollution related to climate change would likely have an adverse impact upon tourism, as is suggested from the experience of Athens and Los Angeles.

The changing climate may also have an impact upon the availability of some natural recreational resources Rivers, canals and other bodies of water would probably become more attractive destinations, provided that water quality could be maintained sufficiently. The draft London Plan includes the Blue Ribbon strategy which sets out a comprehensive agenda for utilising canals and rivers and other water bodies for leisure, recreation, tourism, redevelopment and commerce (GLA 2002a). As noted above, river-based commuting would be a cool option for some. There would be greater demands placed upon the existing swimming pools, of which there are 144 in Greater London, and outdoor recreation centres, including sites such as the Hampstead Heath Ponds. The Royal Parks would perhaps make their water bodies available for bathing, as they have done on very hot days in the past. This would carry with it health and safety implications, however, since water quality would have to be inspected and potential hazards from Lyme disease, broken glass and underwater objects, etc., would need to be monitored.

Summer heat-waves in London and the heat island effect will encourage London residents to leave the city for short recreational trips. Theme parks and similar out-of-town excursion destinations may benefit. Destinations such as Thorpe Park, Surrey, which specialise in water features may be expected to benefit substantially.

7.9.4 Socio-Economic Scenario Differences

Under GM, global tourism would continue to expand, mainly through aviation bringing individuals from around the globe to far-flung destinations. London would continue to draw in visitors from all over the world. Under RS, on the other hand, there would be much less global tourism. There would probably be less London-based tourism, as the spatial pattern of tourism demand would tend to distribute more evenly around the UK. The international tourism market is, by contrast, strongly concentrated in and around London.

Table 7.10 Summary table of impacts - Tourism and Leisure

Climate Change variable	Associated Impacts	Potential severity ranking	Employment effects	IPPC uncertainty rating	Current availability of adaption options
Global climate change impacts	London more attractive compared to traditional destinations	L	M + ve	L	-
Higher summer temperatures	More trips outside London	L	L?		-
Lower summer rainfall	Water-based recreational occupations threatened				
Sensitivity to socio-economic scenarios		Impacts limited under RS scenario			
Key non climate change sectoral drivers of change		Economic growth			
Key stakeholders in impact and adaptation analysis		LDA; GLA; London Tourist Board			

7.10 Public Administration

7.10.1 Context

It is estimated that 19% (600,000) of the labour force in London are currently employed in public administration. The structure and content of the work of public administration is led by the elected political representatives at local, regional, national and EU level. The sector is therefore important as an employer, and in determining patterns of economic and social development in the city.

London's local authorities have a key role as community leaders and service providers. Many have already started to address climate change issues in their Unitary Development Plans as well in their community and Local Agenda 21 strategies. They have a key statutory role in implementing strategies in a number of areas affected by climate change such as housing, transport and environment. Many local authorities are committed to working with their communities as well as stakeholders including other public sector agencies and business to assess the potential effects of climate change and identify ways in which local authorities can adapt to climate change.

The chief potential impacts identified by public administration stakeholders consulted during this study, including the Government of London, GLA and local authorities etc. were:

- possible consequences for the supply of a well-educated labour force for senior positions;
- the need to incorporate more thoroughly the potential economic and social impacts of climate change in sector development strategies, and their operationalisation.

7.10.2 Impacts Due to General Climate Change

Possible general consequences of climate change on the attractiveness of London as a place to live and work have been described in detail elsewhere in this report. The stakeholders from the public administration sector specifically suggested that the move towards relocation from the city by parts of the public administration workforce may be significant - primarily as a result of the perceived heat island effect. This relocation may be accompanied by a shift to other sectors from those parts of the workforce with more transferable skills, and an increase in tele-working and consequent fall in commuter journeys.

The move towards greater inclusion of potential climate change impacts - and associated adaptation measures - in public policy design was identified by stakeholders as the general increase in awareness of environmental issues.

7.10.3 Socio-Economic Scenario Differences

A greater awareness of environmental values that characterises the RS scenario will exacerbate the impacts identified above for public administration. In particular, this awareness relating to climate change will result in an increased slant towards the content of public administration taking on environmental considerations to a greater degree than at present. An opposite effect might be expected under the GM scenario.

Table 7.11 Summary table of impacts - Public Administration

Climate Change variable	Associated Impacts	Potential severity ranking	Employment effects	IPPC uncertainty rating	Current availability of adaption options
Existence of climate change	Integration of CC impacts and adaption into strategy	M	L?	-	Y
Higher summer temperatures	Relocation - lower skilled labour supply	L	L -ve	M	-
Sensitivity to socio-economic scenarios		Impacts exacerbated under RS scenario			
Key non climate change sectoral drivers of change		Socio-economic development patterns			
Key stakeholders in impact and adaption analysis		GOL, LDA, GLA, UK National Govt, EU			

7.11 Creative Industries

7.11.1 Context

Key creative industries include music, fashion, new media, film and broadcasting. They employ more than 400,000 people in London and generate £20 billion per annum. It is one of the fastest growing sectors of the London economy. The sector - apart from in the broadcast media - is characterised by being made up of small and medium enterprises located in clusters in West London, as well as in areas such as the Lower Lee Valley and Deptford Creekside.

The project stakeholder consultation has identified the following as the most likely impacts of climate change in this sector.

7.11.2 Flooding and Rainfall Intensity Impacts

Further expansion of the industry into the Thames Gateway, as suggested by the draft London Plan may increase the flood risk of the properties that are occupied by the sector unless flood prevention measures are undertaken - as described in the sections above. One range of options is presently being generated by the sector itself - innovative urban design. The Mayor's Architect and Urbanism Unit is understood to be co-ordinating such work as part of the Mayor's 100 Spaces project. The work of this unit, and others involved in this area, is likely to contribute to other areas of building design that can mitigate climate change impacts on buildings and other urban areas, such as temperature and ventilation issues. This area of business can therefore be seen as an opportunity for London in terms of there being a new market arising out of the need for adaptation on a global basis.

7.11.3 Impacts Due to General Climate Change

Climate change impacts on labour supply to London may have a role in determining future growth of the sector. Specifically, any accelerated movement from the city because of a decline in its relative attractiveness against e.g. creative centres in Europe e.g. Paris, or in the US - most notably New York - may undermine such growth.

7.11.4 Socio-Economic Scenario Differences

Under the GM scenario media is likely to consolidate further at the global scale, with a parallel continued expansion in multi-media. If we consider the adaptation of buildings to flood risk and other climate change effects as an opportunity for the design industry globally, then it may be that a consolidation may be better able to exploit such an opportunity.

Table 7.12 Summary table of impacts - Creative Industries

Climate Change variable	Associated Impacts	Potential severity ranking	Employment effects	IPPC uncertainty rating	Current availability of adaption options
Increase - winter rainfall	Flooding - time loss, damage repair	H	M -ve	L	Y
	Risk of flooding - building/urban design for adaption	L	L - ve	M	-
Higher summer temperatures	Relocation - lower skilled labour supply	L	L -ve	M	-
Sensitivity to socio-economic scenarios		Impacts exacerbated under RS scenario			
Key non climate change sectoral drivers of change		Socio-economic development patterns			
Key stakeholders in impact and adaptation analysis		GOL, LDA, GLA; FSB; CBI			

7.12 Summary of Economic Impacts of Climate Change

The preceding analysis of potential climate change impacts enables us to draw the following general conclusions.

- The increased flood risk to areas of London vulnerable to river and drainage flooding from higher rainfall intensities predicted in the climate change scenarios is a significant threat to many economic assets, including property, communication and transport infrastructure and people.
- The indirect costs of a perceived increased flood risk arise from relocation of business and commercial activities to other (global) cities and/or a relocation of highly skilled parts of the labour force. These costs are thought by stakeholders to be as significant as the direct costs. A response to this threat appears to lie in improved flood prevention schemes.
- The future pattern of economic development for London needs to take account of any such increase in flood risk.
- Adaptation strategies for flood prevention are being developed. There is evidence of broad stakeholder involvement in this process though the process is at an early stage.
- Flood risk threats to buildings and infrastructure - along with changing atmospheric conditions associated with a warmer climate - present immediate challenges in building and urban design. These climate change issues do not relate only to London. There therefore appears to be a significant opportunity for London's established creative industries - particularly design and architecture - to capitalise on existing Sustainable City initiatives to exploit this evolving global market.
- The London insurance industry is vulnerable to claims made against damages caused by wind storms and flood events that might require reductions in capitalisation. Any major selling of assets (stocks, property etc.) would have a significant effect on credit availability in the financial capital markets, with negative repercussions for activity in the wider economy. An event that results in insured losses over £1 billion in the UK or globally, (of which the 1987 windstorm was one), may trigger such economic impacts.
- The link between the insurance and financial markets identified in the preceding bullet point ensures that the financial service sector will also be impacted indirectly by climate change related extreme weather events. The size of this impact will be determined by the extent that the insurance sector has been able to pass on risk to other financial instruments. It is believed, (IPCC, 2001), that the policy of portfolio diversification which large financial institutions have will ensure that this risk is reduced and the impact mitigated. This conclusion is not well established and needs to be supported by further research.
- The financial services sector is starting to exploit the opportunities provided by the regulation associated with a carbon constrained future, including work in the implementation of revised accounting guidelines, consultancy in energy related

business strategy, verification of Kyoto Protocol flexible mechanisms implementation. Emerging markets in carbon trading are developing and London is currently well-positioned to become the leading centre for that market.

- The economic costs of disruption to London transport systems was the economic impact most widely identified by stakeholders in the consultation process. Detailed modelling of transport flows to, and within, the city, in combination with climate change model scenarios, are required to accurately assess the likely extent of such costs. Historical analogues of a single weather-related disruption on only one stretch of the rail network suggest costs of broadly £2 million.

- The existing net deficit of water resources for the Thames region is predicted - with a low level of confidence - to be exacerbated by future climate change. Key stakeholders are currently developing and costing strategies to meet such a deficit that will - in time - be expected to result in the adoption of a supply option that increases supply significantly (e.g. a new reservoir). The economic effects of such strategies are not known at present. For example, possible resulting water price increases may be subsumed in negotiations with the water regulator.

- The net balance of change in energy demand as a consequence of climate change in London is not clear. The supply infrastructure network is vulnerable to windstorms and clay shrinkage. The economic impacts of disruption to the power supply for extended periods has not been estimated in quantitative terms but is believed to be significant.

- Manufacturing is subject to disruption of raw materials (e.g. food stuffs) that are supplied from parts of the world adversely impacted by climate change. Consumer prices may then be expected to rise. The same mechanism may result in opportunities for recycling environmental businesses, where the price of virgin raw materials (e.g. rubber, wood pulp) increases and makes recycled substitute products more competitive.

- The net economic impact of climate change on tourism and leisure is uncertain. Revenues may increase as London - and the UK - becomes a more attractive destination in summer relative to those in Southern Europe and elsewhere that are likely to suffer from adverse climate change impacts such as the increased threat of forest fires. However, more trips may be taken from London to escape e.g. uncomfortable heat island impacts.

- Flood risks, transport disruption, and heat island effects are climate change impacts that might result in the relocation of workers, or changes in commuting patterns. These impacts might impact on the supply of labour to London's public administration, and other economic sectors or the relocation of employers.

- Increased general awareness of potential and actual climate change impacts in London is likely to focus policy makers minds on the need to reduce carbon emissions and adapt to such impacts locally and globally in the future.

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