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GREATER LONDON AUTHORITY

ECONOMY-ENVIRONMENT MODEL

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EXECUTIVE SUMMARY

This report documents the first stage of a model that will enable the GLA to assess the environmental and health implications of London's future economic and demographic development.

The Economy-Environment Model has been developed over a period of nine months in 2003 with the assistance of several staff within the GLA. The model assesses the impact of over 250 policy variables on three key sectors – transport, commercial and domestic – and the resulting impact on six environmental media between 2003 and 2016. Health effects and the monetary values attributed to these effects are explicitly modelled.

As well as attempting to quantify the impact of economic growth on London's environment, the model also examines the contribution of seven of the Mayor's environmentally related strategies. These are:

- The London Plan;
- The Municipal Waste Strategy;
- The Energy Strategy;
- The Transport Strategy;
- The Air Quality Strategy;
- The Biodiversity Strategy; and
- The Noise Strategy.

Model Structure

The model is based on a series of linkages that relate economic activity through to environmental and health outcomes. The main inputs to the model are in the form of three input economic variables which describe the growth in population, tourism and employment until 2016. These follow the trends defined in the GLA projections.

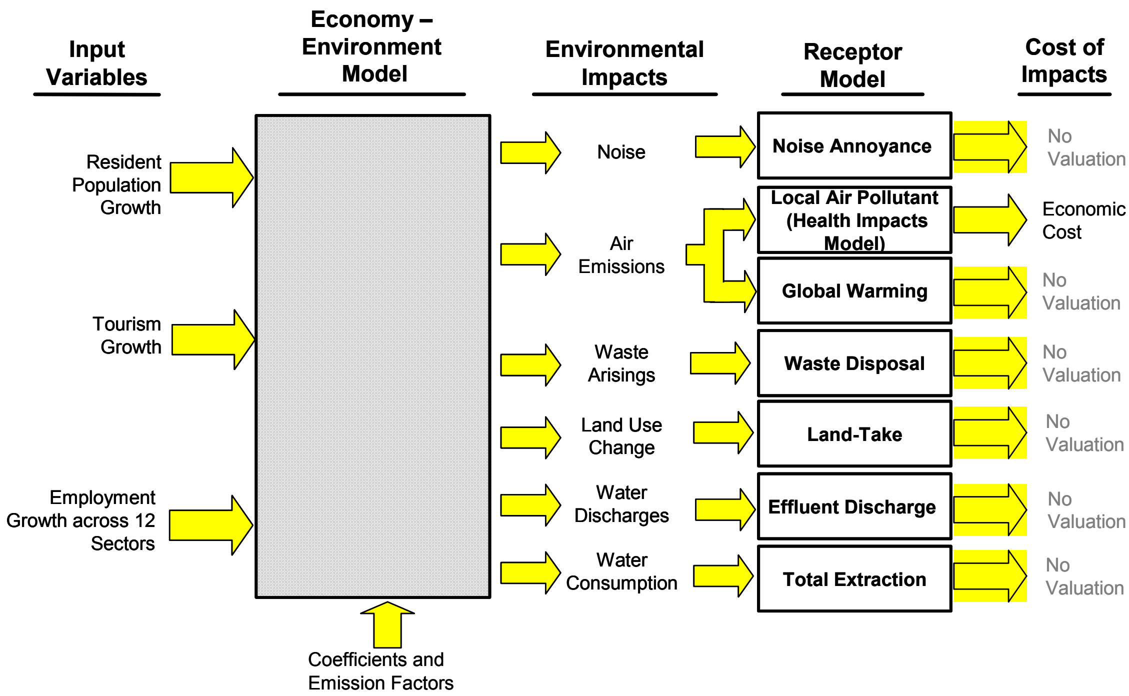
These input economic variables are then used to drive a set of intermediate economic variables embedded within the model. The most important of these intermediate economic variables are GVA output by sector, household numbers, dwelling numbers and commuting patterns. Co-efficients and emission factors link the input and intermediate economic variables with each environmental impact allowing projected changes in the input economic variables to be transposed into an environmental impact over time.

The environmental impacts then drive various receptor models for each environmental media. These receptor models describe the effects of changes in emissions on the quality of the environment, and policy decisions regarding the management of environmental impacts. In the case of local air pollutants, the receptor model quantifies the health effects in terms of monetary impacts through the Health Impact Model.

Other than for health impacts where illnesses are valued in monetary terms, the Economy-Environment Model does not assign monetary values to the environmental outcomes, or indeed inputs. Importantly the model does not determine the costs of implementing the Mayor's various strategies.

The structure of the model is shown in Figure 1.

Figure 1 **Economy-Environment Model Structure**



Where possible the model has been adjusted to be consistent with other GLA data and models, eg energy and waste models. Given the different approaches to the modelling it is not possible to achieve consistency for every year and each environmental media but any differences are largely within the bounds of modelling error. The one exception is the analysis of air quality. For air quality the approach developed in the Economy-Environment Model is only an approximation to the more detailed air quality modelling undertaken by the GLA.

Although the Economy-Environment Model has, as far as possible, been made consistent with these external models, there are currently no direct links. Given that these external models will be more detailed and kept more up to date than the separate receptor components in the Economy-Environment Model, it is likely that the future development of the model will centre around its use as an integrating tool linking currently separate GLA environmental and economic models, rather than as a stand alone model that attempts to replicate these other models.

The outputs of the model shown in Section 7 of this report provide a snap shot of the key environmental and health indicators for London given a specific set of input assumptions. The real benefit of the model however is arguably not in the snap shot results, but in its role as a dynamic tool that can show the sensitivity of environmental and health impacts to changes in the shape of London's economy and the intervention strategies available to the Mayor. These benefits can only be realised through using and improving the model. GLA staff have been closely involved in the development of the model and should be in a position to assist in its further development.

Scenarios

In order to capture the numerous combinations of input variables three scenarios have been created:

- *Business as Usual (BAU)*: This assumes that the projection variables will change only due to national regulations, such as building regulations. Otherwise variables remain constant with historical values.

- *Mayor*'s *Strategies (MS)*: In the Mayor's Strategies we have applied policies highlighted in the Mayor's strategy documents to the model. It should be noted that the impact of many important policies are not quantifiable, or no figures were published quantifying their expected environmental impact. Where the environmental impact of a policy has not been defined numerically we have not included these policies in the current model.

- *High Sustainability (HS):* The high sustainability scenario projects the impact of achieving the most costly of the Mayor's policies, or exceeding policies included in the Mayor's strategies. The high sustainability scenario for example includes the effects of major infrastructure investments.

Results

Section 7 in this report provides the details of the modelling outcomes. These results are not repeated in this Executive Summary as the emphasis throughout this work has been on the development and testing of a model concept rather than the search for a quantified answer to a specific question.

This said, and not withstanding the still significant uncertainties in the model, one conclusion stands out: sustainable growth in London appears difficult to achieve even with the Mayor's suite of environmentally related strategies. This outcome is driven by the consequences of continued economic and population growth. Specifically, the model shows that whilst the Mayor's policies are expected to significantly reduce London's environmental impact they generally reduce the rate of growth of the impact rather than reverse the overall trend.

From a development point of view, we believe that the model has demonstrated the viability, a 'proof of concept', of an approach that can analyse the effects on London's quality of life of the growth in London's economy.

Recommendations

There are a number of ways in which this model could be enhanced and developed. These are categorised under "model scope and objectives" and "technical developments".

Model Scope and Objectives

- Having effectively demonstrated proof of concept the objectives of the model could be developed to allow the GLA to:

  1. assess the environmental and health impacts of different patterns of economic and population growth and intervention by the Mayor (current functionality);

2. assess the interactions between different Mayoral strategies (current functionality but can be improved);

3. understand the optimal sustainable development potential of London. This in turn will require:

   - a quantification of the cost of achieving different levels of environmental quality in London. This will require the development of environmental improvement cost curves for London; and

   - an expansion of the monetary valuations (currently applied to health impacts) to other environmental outcomes.

- The model could be more closely integrated with other GLA models. This will effectively require replacing the current dose response functions with links to these external models. This approach will enable the best aspects of economic and environmental modelling in the GLA to be used to create a more complete and detailed analytical tool. Moreover, incorporating into the Economy-Environment model the outputs from the relevant departmental models should provide a more supportive and wider-user base for the Economy-Environment model concept within the GLA.

Technical developments

- Disaggregation of the economic sectors to 2-digit SIC codes. This would allow for more effective modelling of the Part A industrial processes and non-energy related emissions.

- Disaggregation by employment types. Currently all employees are treated as full time employees. The work-force is more complex with part-time workers and home-workers, each with different resource use patterns.

- Development of cross-sectoral relationships. Currently the model only shows the impact of the economy on the environment through simple input-output relationships. These relationships could be developed further to model more complex interactions between sectors, as well as possible feedback effects of the environment on the economy.

- Inclusion of lifecycle effects. Lifecycle effects estimate the environmental impacts through-out a product's lifecycle from production, distribution, and consumption through to final disposal. To the extent that it is desirable to examine these supply-chain effects within and outside London these can be built into the model.

- General expansion in specific sectors, for example:

   - Linking transport with waste arisings and economic growth of each sector (if coefficients can be established);

   - Development of a waste stream for special waste; and

   - Linking water consumption explicitly with energy consumption in the utility sector.

- Improvement in the application of dose-response functions, especially for health impacts. Currently the model uses ExternE as the main source of reference for this. Research, however, is continually improving the scientific understanding in this area and the Economy-Environment model could be updated in the light of new information on the impact of pollution on human health.

1. INTRODUCTION

The GLA commissioned Enviros to provide a first stage model that would enable the GLA to assess the environmental and health implications of London's future economic development. Specifically the model provides a framework to assess:

- The extent of changes in environmental impacts arising from the Mayor's Strategies.
- The densities of future development required to avoid the use of land valued for its biodiversity.
- The implications for future energy requirements arising from expected growth patterns.
- The extent to which environmental changes will affect the quality of life in London.

The aim of the first stage is therefore to provide a strong model methodology which can be refined and developed according to the GLA's requirements and to explore the potential for developing an integrated model.

This report explains the model methodology that underpins the Economy-Environment Model, illustrates the variables which are used and illustrates three scenarios to demonstrate the model's use and applicability to the Mayor's Strategies.

This report is not intended to provide a detailed analysis of the Mayor's policies. This report provides a provisional analysis of the Mayor's policies to act as a user guide and inform debate about desirable model functionalities.

Throughout the work we have made every effort to integrate the model with existing GLA data sets and reported outputs.

2. THE MAYOR'S STRATEGIES

Since coming into office the Mayor has published twelve strategies focusing on a specific environmental, social or economic attribute of London. This project addresses the impact of seven of those strategies which are either specifically targeted at, or are closely linked with, environmental quality. These strategies are:

- The London Plan;
- The Municipal Waste Strategy;
- The Mayor's Energy Strategy;
- The Mayor's Transport Strategy;
- The Mayor's Air Quality Strategy;
- The Mayor's Biodiversity Strategy; and
- The Mayor's Noise Strategy.

The policies and proposals contained in these strategies have informed three scenarios developed within the Economy-Environment Model. In the rest of this section we provide a brief overview of each of the Mayor's strategies.

2.1 The London Plan

The London Plan provides a spatial development strategy for the greater London area. The plan identifies the key economic and demographic trends occurring in London and identifies the main policies which the mayor expects to use to accommodate and influence these trends. In particular the London Plan covers:

- Demographic scenarios;
- Economic scenarios; and
- The development of sub-regions;

The London Plan provides a reference point for the rest of the Mayor's strategies identifying the areas of growth that need to be accommodated and the interactions between different policies and strategy documents. The London Plan identifies the main underlying drivers to environmental change.

2.2 The Municipal Waste Strategy

The Mayor's Draft Municipal Waste Strategy identifies specific waste management objectives for dealing with London's waste. These objectives incorporate both national and local waste management targets.

The Municipal Waste Strategy identifies the disposal methods that the Mayor plans to introduce to reach the national targets and additional policies. These additional policies include encouraging:

- The use of home composting;
- The introduction of kerbside recycling collection of at least three materials;
- The introduction of at least one recycling site per 500 households where kerbside recycling is not practical;
- The composting of market and municipal parks waste;
- The establishment of recycling centres in schools;
- The pre-sorting of all incineration waste;
- Support for the development of anaerobic digestion plants;
- The re-use of nappies and furniture; and
- The use of new and emerging recovery technologies for waste that cannot be recycled.

Due to the interaction between local, national and European Policy it will be difficult to distinguish the change in waste management resulting from the Mayor's strategy and the change which is due to national legislation.

2.3 The Mayor's Energy Strategy

The Mayor's Draft Energy Strategy explains how the Mayor intends to reduce the energy intensity of London, to promote the consumption of renewable energy and to encourage the uptake of energy efficiency measures. The Mayor's polices include:

- A reduction in London's carbon dioxide emissions of 20% by 2010 (from 1990 levels);
- A minimum SAP rating of 30 for all dwellings in London by 2010 to reduce fuel poverty in London (SAP is the 'Standard Assessment Procedure' and provides a standardised methodology to assess the energy efficiency of domestic properties);
- The energy performance of new buildings to exceed existing building regulations;

- All new developments to consider the use of passive solar design, natural ventilation, solar water heating, borehole cooling, and photovoltaics;
- A target of 14% for renewable energy supply to London. 10% of this is to be supplied from renewable obligation certificates (ROCs) and a further 4% from green tariffs (ROCs are tradable certificates demonstrating energy supplier compliance with their renewable obligations); and
- New sites over 1,000 m^2 or greater than 10 dwellings should generate 10% of the sites energy needs from renewable energy sources.

The Energy Strategy develops a hierarchy to provide guidance to local authorities considering energy consumption in planning applications and identifies key measures and targets.

2.4 The Mayor’s Transport Strategy

Transport is one of the key strategies for London and is central to the Mayor’s economic and demographic growth projections. The Mayor’s strategy recognises the cost that a poor transport system imposes on London’s economy and the environment. As a result, transport is a common theme across all the Mayor’s strategies. Some of the key policies include:

- Increasing the frequency of trains on the underground;
- Increasing the capacity of the bus services by 40% in the next 10 years and the number of bus lanes;
- Introducing cleaner emissions EURO III buses;
- Encouraging walking and cycling;
- Promoting the completion of the East London Line extension;
- Promoting the Cross-Rail link and Thameslink 2000;
- Encouraging more efficient freight transport; and
- Reducing congestion by 15%.

The Mayor’s Transport Strategy includes a variety of policies that are hard to quantify which intend to change transport consumption patterns, and are targeted at air quality improvements.

2.5 The Mayor’s Air Quality Strategy

The Mayors Air Quality strategy pulls together the key factors determining London’s air quality and identifies the importance of regular monitoring and disseminating information on London’s air quality. The Air Quality Strategy concentrates on the following pollutants:

- Benzene;
- Carbon Monoxide;

- Lead;
- Nitrogen Dioxide;
- Ozone;
- PM10; and
- Sulphur dioxide.

Because of the close relationship between transport and air quality, many of the proposals for improving air quality encourage changes in the pattern of transport use, reducing vehicle emissions using alternative fuels and improved maintenance, and looking at the feasibility of introducing low emission zones for certain types of vehicles. Other initiatives address stationary sources and emissions from construction activities.

The Air Quality Strategy emphasises the importance of air quality on human health and highlights the need to meet binding European targets. Many of these targets are expressed as peak concentrations or means over a limited period of time. These are currently beyond the scope of the model.

2.6 The Mayor's Biodiversity Strategy

With over a half of London's land area occupied by green spaces the Mayor's Biodiversity Strategy sets out how the Mayor, in partnership with other organisations, can protect London's biodiversity. Some of the Mayor's key policies include:

- Working with partners to protect, manage and enhance London's biodiversity;
- Establishing the Blue Ribbon Network along London's waterways and establishing principles for the use and management of the water and surrounding land;
- Encouraging the management, enhancement and creation of green space for biodiversity and promoting public access;
- Encouraging the greening of the built environment;
- Supporting partnerships to produce and implement Biodiversity Action Plans;
- Increasing the funding for the acquisition and management of places of wildlife; and
- Compiling indicators to assess the losses and gains of wildlife sites in London.

Because the assessment of biodiversity is very specific to regional attributes and local planning decisions, the implications of some of the Mayor's strategy will be hard to assess within a broad London model. The Economy-Environment Model does however establish a methodology to assess the pressures on ecologically sensitive sites.

2.7 The Mayor's Noise Strategy

The Mayor's Noise Strategy is currently published in draft form. The emphasis of the document may therefore change in its final version.

The Draft London Ambient Noise Strategy is focused on reducing noise through better transport management, town planning and building design and has been developed in response to the European Environmental Noise Directive 2002 and in anticipation of the UK's National ambient noise strategy, due to be published in 2007.

The strategy concentrates on 'ambient noise' whilst 'nuisance noise', local noise aggravations, are dealt with by local boroughs. Currently the key policies include:

- Developing a noise map of London;
- Measures established in the transport strategy to alleviate congestion, and promote cycling, walking and public transport;
- Improving the road surface and extending the use of quieter surface materials;
- Moving freight from road to other transport modes;
- Introducing noise monitors to party boats; and
- Integrating noise control with existing projects and developing synergies with other strategies, such as the noise control barriers and photovoltaic cells.

Although noise modelling is too complex to replicate accurately in the first phase of the Economy-Environment Model we can establish general trends in ambient noise from changes in road and rail transport. The local and regional impacts of noise abatement measures are however currently beyond the scope of the Economy-Environment Model.

3. OVERVIEW OF MODEL METHODOLOGY

This section provides an overview of the methodology behind the model. Section 4 describes the input variables, coefficients and data sources in more detail.

3.1 Model Platform

The Economy-Environment Model is constructed in Microsoft Excel. Although Excel is not the most efficient tool for complex model development, it has the advantages of being familiar to most potential users, transparent and easily modified.

3.2 Model Boundary

The Economy-Environment Model covers economic and environmental changes occurring only in the area covered by the GLA (ie the 32 boroughs of Greater London and the Corporation of London). Impacts associated with goods and services manufactured outside London but consumed in London are therefore not taken into account in the model. Importantly, this excludes the health effects of emissions associated with power generated outside London, but consumed in London, and the environmental and health effects of waste disposed outside of London. It also means that the model is unable to assess the effects of economic and demographic growth patterns outside London, which may be affected by policy decisions made within London.

3.3 Model Structure

The purpose of the Economy-Environment Model is to show the effects on the quality of London's environment and health as a result of changes in London's economy from 1990 through to 2016.

The calculations are based on a series of ***linkages*** that relate economic activity through to environmental and health outcomes. These are shown schematically in Figure 2.

The main inputs to the model are in the form of three ***input economic variables*** which describe the growth in population, tourism and employment until 2016. These follow the trends defined in the GLA projections.

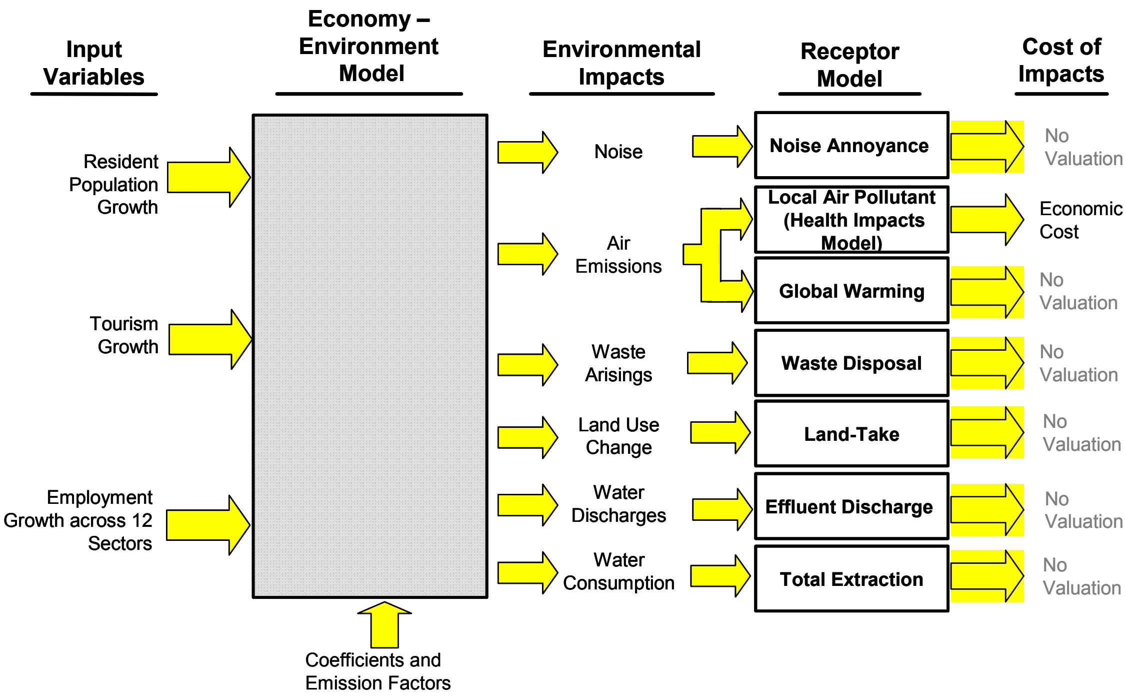
These input economic variables are used to drive a set of ***intermediate economic variables*** embedded within the Economy-Environment Model. The most important of these intermediate economic variables are gross value added (GVA) output by sector, household numbers, dwelling numbers and commuting patterns.

Co-efficients and emission factors link the input and intermediate economic variables with each environmental impact allowing projected changes in the input economic variables to be transposed into an environmental impact over time.

The environmental impacts drive various ***receptor models*** for each environmental media. These receptor models describe the effects of changes in emissions on the quality of the environment, and policy decisions regarding the management of environmental impacts. In the case of local air pollutants, the receptor model quantifies the health effects in terms of monetary impacts through the ***Health Impact Model.***

The Mayor's strategies primarily affect the coefficients and emission factors that drive the environmental impacts and the receptor models. In the Economy-Environment Model we assume that the Mayor's policies identified in the previous section, have a negligible impact on the three input variables.

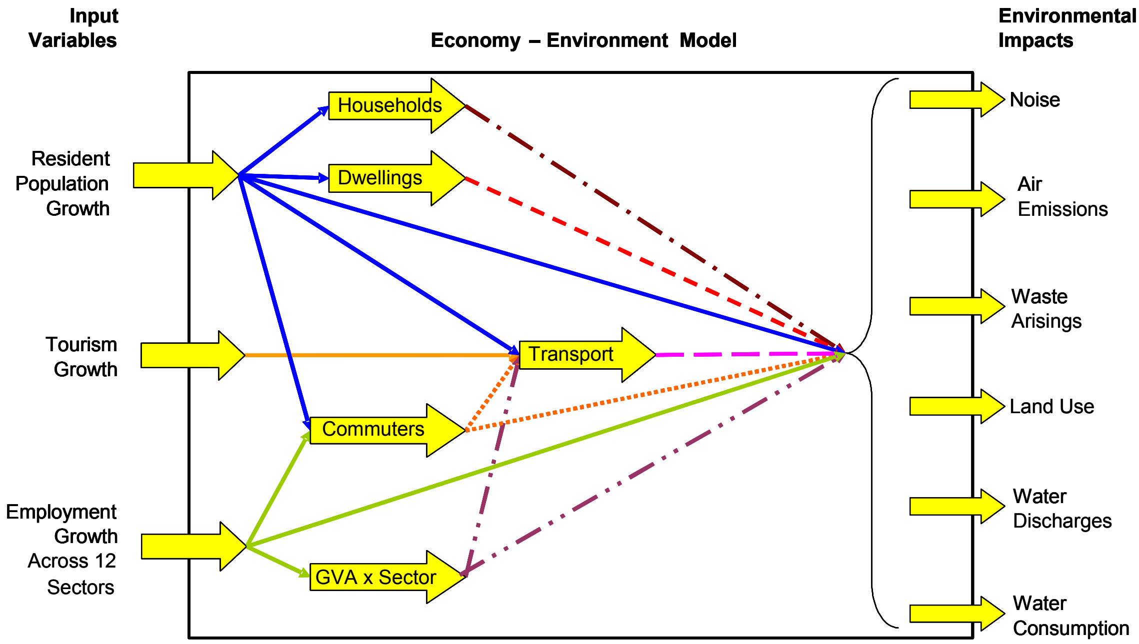
Figure 2 **Structure of the GLA Economy-Environment Model**



3.4 Input Variables

As described above, the input variables are independent of any other influences in the model. Effectively these input variables define the rate of growth in London's economy which in turn affects the state of London's environment. Intermediate variables are created to make the model more transparent. Because they drive off the input variables they have no real independence but they do serve to illustrate the impact that say economic and demographic changes have on commuting patterns. The links between the input and intermediate variables are shown in Figure 3.

Figure 3 **Input Variables Links**



Resident Population Growth

Resident population refers to the total population of the GLA area based on 2001 census data. In line with the GLA Data Management and Analysis Group (DMAG) projections, residential population is expected to grow linearly to 2016 at an annual rate of 1.3%.

Resident population determines the intermediate variables, the number of households and the number of dwellings. These intermediate variables are more closely associated with some of the environmental impacts, such as building energy consumption, than population.

Tourism Growth

Tourism is provided as a separate input variable because, whilst the economic effects of tourism are readily apparent, the sector industry classification (SIC) system does not define a distinct "tourism" sector. The main effects of tourism are captured in the hotel, restaurant and retail sectors.

Tourism growth features in the model by affecting water use and transport demand but not economic activity. Tourists are also assumed to be subject to health effects as a result of local air pollution. These environmental impacts are calculated via an intermediate variable of ***resident equivalents***. Tourism activity is measured in terms of number of visitors to London, and resident equivalents are calculated according to the average number of nights they are expected to stay in London.

In the model tourism from overseas tourists is assumed to grow at an annual rate of 2.5% and from domestic tourists at a rate of 3.5%, based on London Tourist Board projections until 2016.

Employment Growth

Employment growth drives two key intermediate variables of sector level GVA and the number of commuters. Employment was selected as the main independent economic variable because it is considered more reliable than GVA data. In the model GVA projections are derived from employment projections on the basis of assumed employment productivity factors.

Employment and GVA output are divided into the following 12 sectors, according to Volterra projections: Primary industry and utilities, Manufacturing, Construction, Retail, Wholesale, Hotels & restaurants, Transport & communication, Financial services, Business services, Public administration, Health & Education and Other services.

In the model, total employment across London is assumed to grow at an average of 1.6% p.a. Sector growth rates vary however, ranging from -1.8% for "public administration" to 4.6% for "other services".

3.5 Intermediate Variables

There are five main intermediate variables in the model: households, dwellings, gross value added, commuters and transport. Households and dwellings are calculated from population projections using occupancy ratios provided by the GLA. The three remaining intermediate variables are described below.

Gross Value Added (GVA)

In the model economic activity, expressed as GVA, primarily affects waste arisings from the commercial and industrial sectors.

Sector level GVA is calculated from employment projections and sector specific employment productivity factors. To ensure consistency with other GLA models, the sector specific productivity factors are adjusted so that the Economy-Environment Model GVA projections match the GLA's GVA projections in 2016.

Commuters

In the model commuters are defined as employees that travel from outside London to work in the London area. Travel to work by residents living within the London area is captured as a separate group, this allows us to distinguish between each groups transport use patterns.

The number of commuters is calculated from the total number of employees in London less the number of residents employed in London. For simplicity we assume no commuting travel out of London.

Total number of commuters from outside the London area = Total number of employees within London − (Working age population of London residents × % of working age population in employment in London)

The total number of commuters is converted into resident equivalents according to the average number of hours worked, in order to determine the effect on transport demand and water consumption.

Transport

Demand for transport is determined by the number of domestic residents, tourists, and commuters (those travelling into London to work) according to the type of transport mode and the average distance travelled using each type of transport.

Demand is subdivided into the following transport modes:

- *Road*
    - Car
    - Freight
    - Taxi
    - Motorcycle
    - Bus
    - Emission free travel (including cycling and walking)

- *Rail*
    - Under-ground (Tube)
    - Over-ground rail

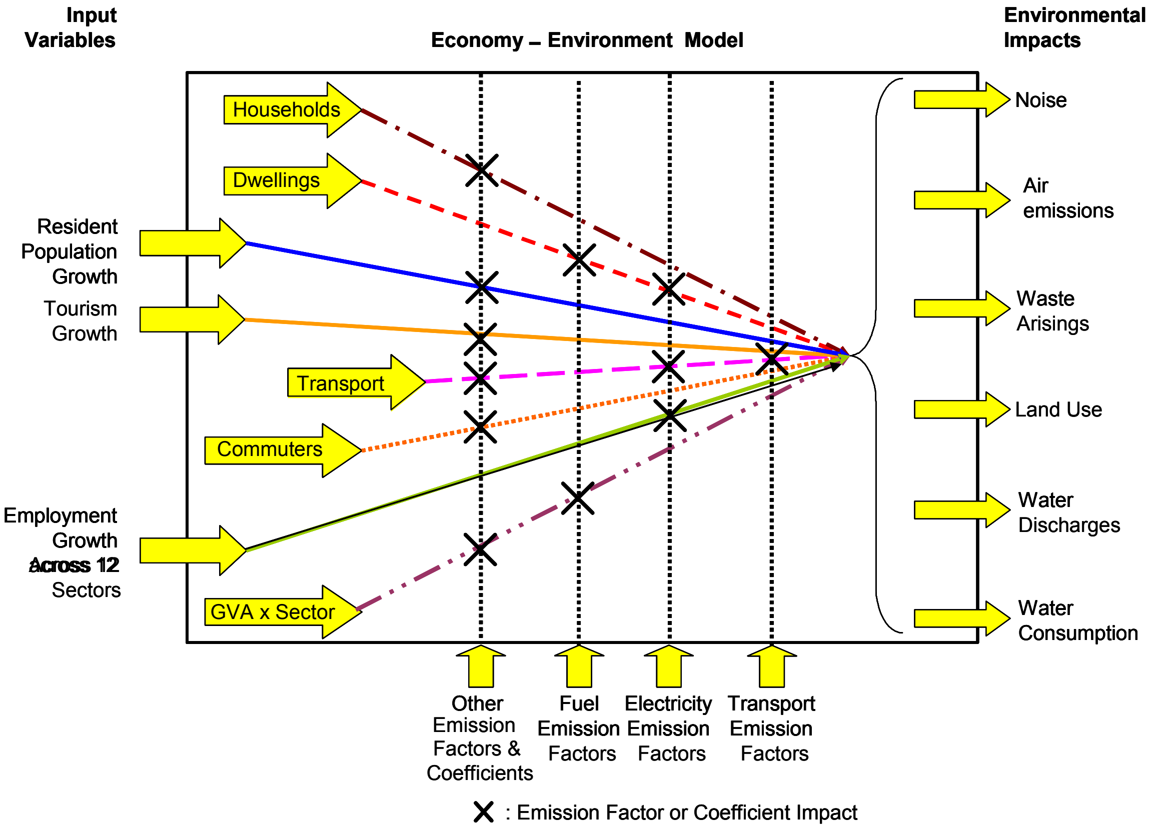
- *Air Travel*

Demand for road and rail travel is determined from the number of resident equivalents in London and their modal choice. Air travel on the other hand is determined by a ratio linking economic growth with air travel demand as well as the number of international tourists expected to visit London.

3.6 Coefficients & Emission Factors

Coefficients and emission factors convert input variables into environmental impacts and environmental emissions. Four categories of emission factors are used in the model; those related to fuel, electricity, transport and “other”. In each of these categories the emission factors convert the input or intermediate economic activity into environmental outputs. This effectively creates a complex matrix of emission factors. Some key interactions between input variables and emission factors are shown in Figure 4.

Figure 4 **Key Emissions Factors**



Fuel emission factors are used for oil and natural gas. The consumption of other fuels such as coal is insignificant in the London area. Fuel emission factors are assumed to be constant over time.

Electricity emission factors in the model relate to electricity provided through the national grid. Emissions associated with power generated by gas in London are calculated through fuel emission factors. Power generated in London from renewable sources is assumed to have no environmental impact. In the model, emission factors for imported electricity change over time according to changes in average generating efficiency and the fuel mix used to supply the national grid.

Transport emission factors have been subdivided to match each transport category (road, rail, air etc.). However, the method of calculating each emissions factor varies with each transport type.

Other emission factors and coefficients are determined according to the environmental media considered. These are described in section 4.

4. DESCRIPTION OF THE METHODOLOGY BY IMPACT

This section describes the methodology developed for the assessment of each environmental impact.

4.1 Air

The modelling of air emissions and their effects is the most complex aspect of the model. In the rest of this section we describe issues relating to the emissions of all pollutants (4.1.1), those relating to the calculation of ambient air concentrations in London (4.1.2) and then the modelling of associated health effects (4.1.3).

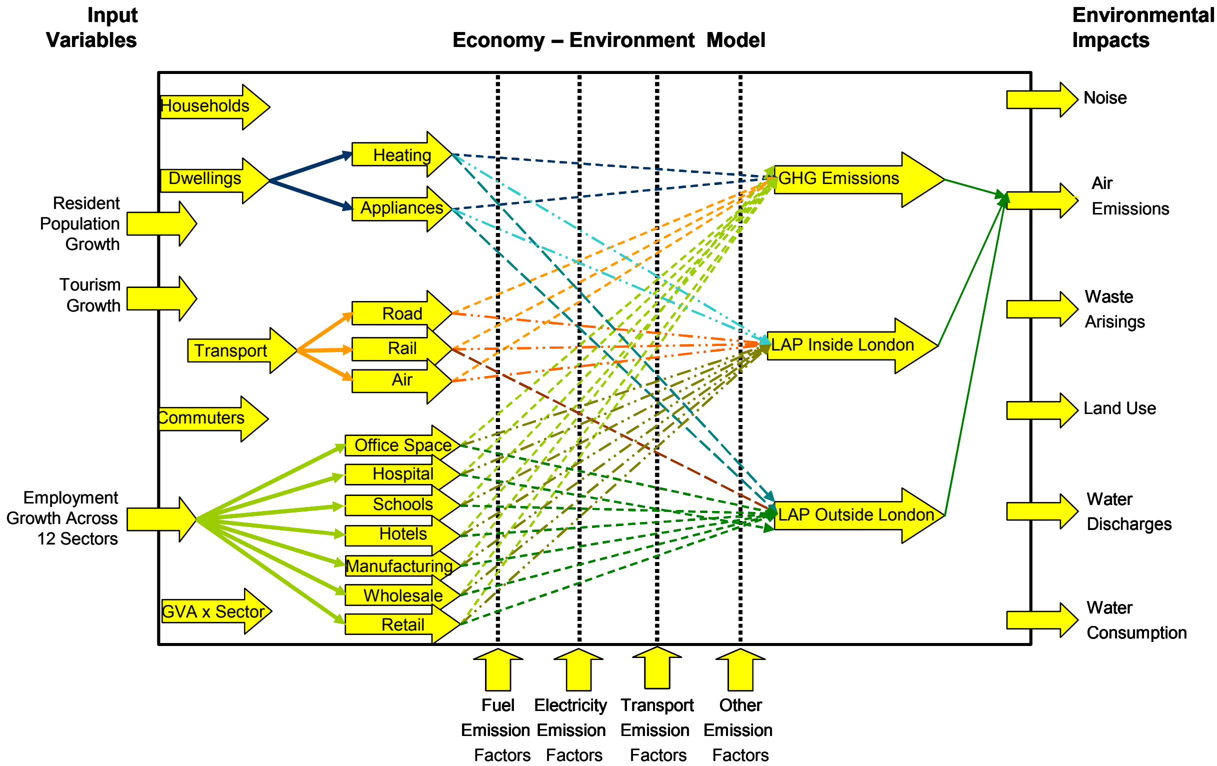
4.1.1 All Emissions

Three categories of air emissions are considered in the model: Greenhouse Gas (GHG) emissions (including CO_2, N_20 and CH_4), Local Air Pollutants (LAP) inside London (including NOx, SO_2, PM10, VOCs with Benzene and 1,3-Butadiene separated out and CO) and Local Air Pollutants outside London (covering the same LAP emissions as inside London but only for electricity consumed in London).

A significant amount of work on the impact of local air pollutants has been undertaken within the GLA. Rather than try to replicate this work the Economy-Environment Model calculates a broad annual emissions figure for London. The Economy-Environment Model assumes an even concentration of pollutants across London over the year. As such it does not model regional or time specific 'spikes' in pollutant concentrations.

The links connecting each input variable with the fuel consumption categories and the air emission categories are shown in Figure 5.

Figure 5 **Key Linkages in Calculating Air Emissions**



For greenhouse gas emissions the model expresses the environmental impact in terms emissions of carbon dioxide equivalent (CO2e). Emissions of CO2e are calculated by multiplying the mass release of each greenhouse gas by that gas's global warming potential (GWP).

It should be noted that the Economy-Environment Model only takes into account greenhouse gas emissions related to energy consumption. It is possible that there may be process emissions of greenhouse gases which would affect London's total emissions of global warming gases.

Emissions to air that have the potential to give rise to local air pollution effects outside London (exclusively emissions from power generation) are only captured in terms of their mass emissions. Their effects on local air pollution either inside London or outside are not modelled.

Air emissions arise from all three main economic sectors: the domestic sector (shown as dwellings in Figure 4), transport and business.

In the ***domestic sector*** emissions are driven by the energy used for heating and hot water (mainly gas), and for appliances and cooking (electricity and some gas). For heating and hot-water, energy use is determined by the expected SAP (Standard Assessment Procedure) rating of the average London dwelling, and an expected fuel split in energy used for heating and hot water. For appliances and cooking emissions are also derived from assumptions about the sources of energy used.

For the ***transport sector*** emissions are a function of the distance travelled in each transport mode (expressed as vehicle km). Vehicle km are determined from the number of people travelling by each mode, average journey distances and vehicle occupancy rates. Issues specific to each mode include:

- For road travel emission factors are determined from various DEFRA databases for a wide range of vehicle types. In these factors, the composition of the fuel used is assumed to remain constant over time, but the factor does vary according to the speed of travel.

- For rail travel, the emission factor takes into account the mix of electric (both underground and overground) and diesel trains. Diesel train emission factors remain constant over time, whilst electric train emission factors vary in accordance to grid electricity emission factors.

- For air travel, emission factors are determined from standard coefficients for Landing and Take Off (LTOs) cycles. Total air emissions attributable to the London area are determined only for London residents flying from London City Airport or Heathrow.

In the ***business sector*** emission factors are based on building related energy consumption. Process energy use and related emissions are not included in the model. The model includes seven categories of floor area. Emission factors for these categories take into account the expected fuel mix for the building as well as the building type.

4.1.2 LAPs in London - Ambient Concentrations

Ambient concentrations are only calculated for the following Local Air Pollutants in London: PM10, NOx, SO_2, CO, Benzene and 1,3-Butadiene. Although polyaromatic hydrocarbons (PAHs) feature in DEFRA's Air Quality Strategy, and a World Health Organisation (WHO) unit risk factor for cancer is available, the Economy-Environment Model does not provide data on quantities of PAHs emitted each year. This is because the National Atmospheric Emissions Inventory[1] does not presently provide emission factors for PAHs. The Economy-Environment Model also does not assess the effects of ozone. This is because of the complexity of the atmospheric chemistry linked to ozone.

In the Economy-Environment Model ambient concentrations are calculated from emissions by a linear relationship based on historical emissions and air quality data for London. Actual ambient air concentrations of the pollutants for London are taken from the UK National Air Quality Archive[2] for the years 1998-2000 (inclusive). The ambient pollutant concentration for the 1998-2000 period and actual emissions are used to calculate a conversion factor. The conversion factor is then applied to convert annual tonnes of emissions for a given pollutant into ambient air concentrations of that pollutant.

4.1.3 Health Impacts

The effect of ambient air concentrations of pollutants in London on health are calculated using dose response functions weighted by the population of London. The dose response functions (d.r.f.s) used in the Economy-Environment Model are shown in section 5.

1 http://www.naei.org.uk/
2 http://www.airquality.co.uk/

Since d.r.f.s used in the model are for the whole population (as opposed to, for example, the elderly, asthmatic, or children), changes the demographic composition of London are not taken into account, although changes in the total population are considered.

No d.r.f.s are available for VOCs as a category of pollutant, although there are for Benzene and 1,3-Butadiene, which are subsets of VOCs.

The only health impacts examined in the model are ones where there is a considerable amount of scientific evidence supporting the link between a pollutant and a specific health impact (Table 1).

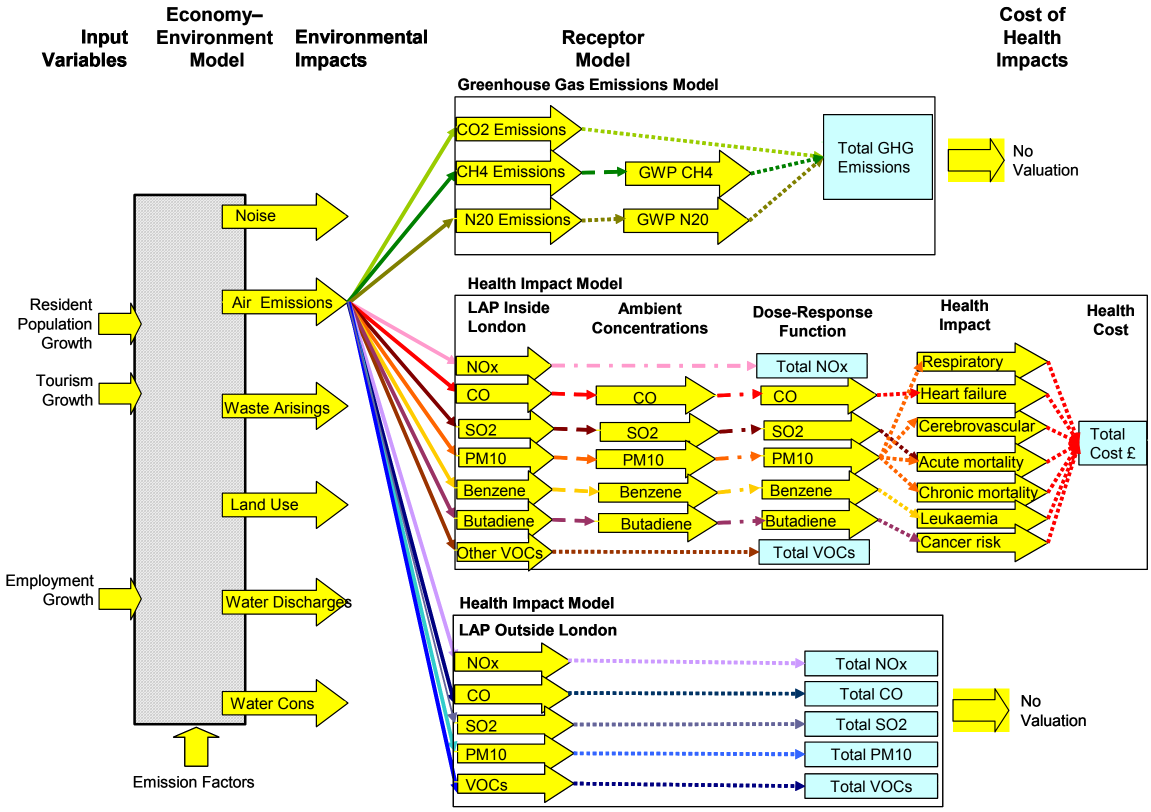
Table 1 Pollutants and Their Associated Health Impacts

Pollutant	Health Impacts
Benzene	Leukaemia
1,3-Butadiene	Cancer risk estimates
PM10	Respiratory Hospital Admissions (RHA)
PM10	Cerebrovascular hospital admissions
PM10	Chronic mortality
PM10	Acute mortality
SO2	Acute mortality, RHA
SO2	Respiratory Hospital Admissions
CO	Congestive heart failure - elderly
NO2	Respiratory Hospital Admissions

The last stage of the health impact for emissions in London is to assess the economic costs of the impact. A considerable body of research exists on valuing health effects (see section 5). Typically, these costs include the cost of treatment, the willingness to pay to avoid an illness and the loss of economic productivity associated with the illness.

Figure 6 summarises the process for modelling the effects of emissions to air.

Figure 6 **Receptor Model for Air Emissions**



4.2 Solid Waste

The Economy-Environment Model considers three categories of waste:

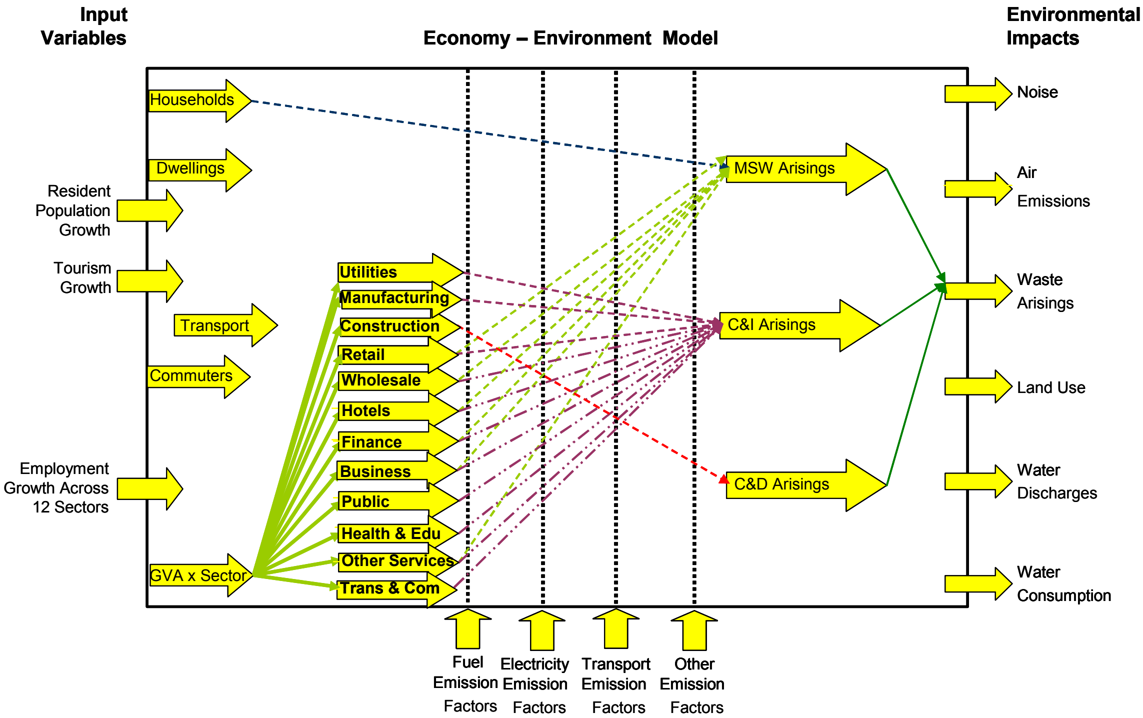
- *Municipal Solid Waste (MSW).* MSW is commonly defined to include the total solid waste generated by households as well as the small fraction of commercial waste collected by local authorities. In the Economy-Environment Model the commercial fraction of MSW is reallocated to the main C&I waste stream. The net MSW arisings are determined from coefficients relating arisings to the number of households in London.

- *Commercial and Industrial Waste (C&I).* In the Economy-Environment Model the C&I waste arisings include all waste generated by the business sector including that collected by local authorities. Arisings are determined by the level of economic activity in each sector and sector specific waste arisings factors per unit of GVA.

- *Construction and Demolition (C&D).* C&D waste arisings are determined as a function of the construction sector's GVA. In line with previous GLA waste arising models we have separated C&D waste from other C&I waste streams.

The links between input variables and waste arisings are shown in Figure 7. Because of the low volumes generated, special waste is not modelled.

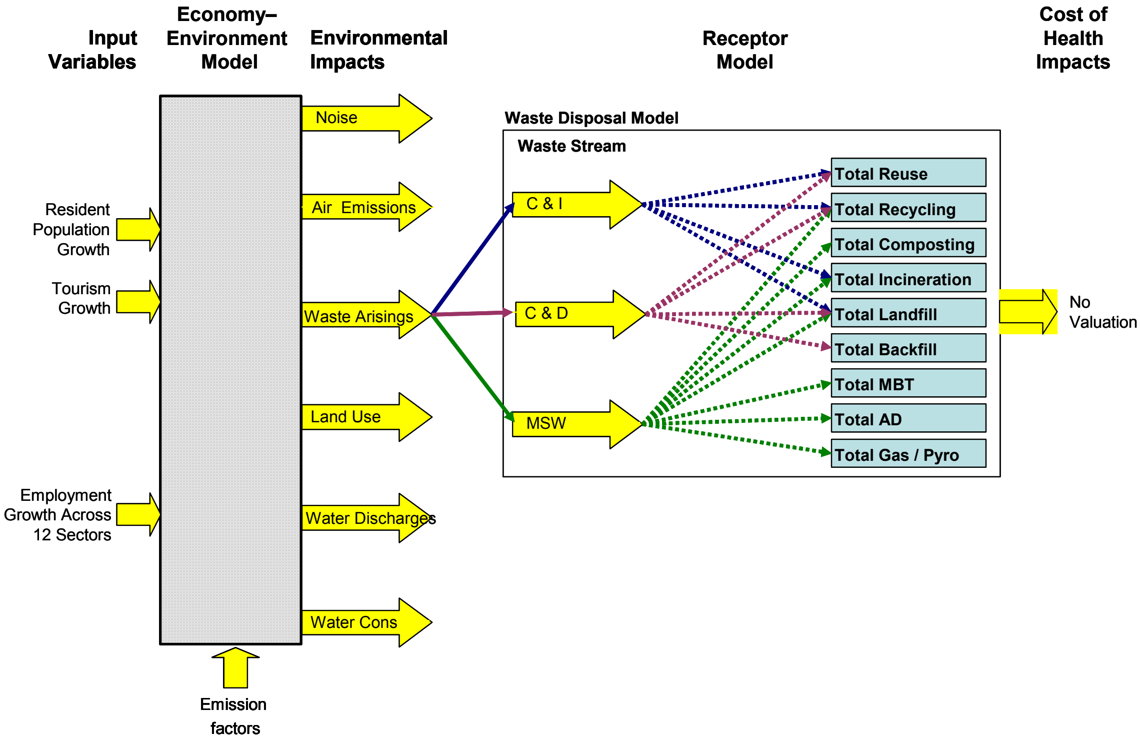
Figure 7 **Links in Waste Arising Projections**



The model then distributes the quantity of waste arisings between the following nine waste management options: Reuse, Recycling, Composting, Incineration, Landfill, Backfill, Mechanical Biological Treatment (MBT), Anaerobic Digestion (AD), and Gasification/Pyrolysis (Gas/Pyro). The latter three relate to MSW only and Backfill to C&D only.

The distribution of waste to each management route is a user defined input. Figure 8 illustrates the modelling of waste management routes. Emissions and health impacts of the various waste management options are not included in the model.

Figure 8 **Waste disposal model for arisings**



4.3 Water

Water related impacts are divided into water consumption (potable water) and waste water discharges. Consumption and disposal links are illustrated in Figures 9 and 10.

Water impacts are modelled for the domestic, business and transport sectors through coefficients that relate the level of economic activity or population to consumption levels.

For the domestic sector water consumption is determined by the number of residents. In the business sector, with the exception of restaurants and hotels, the amount of water consumed is linked to the number of employees. For the restaurant and hotels sectors, total consumption is dependent on the number of tourists and the dining patterns of the resident population (including tourists).

London's total water consumption takes into account the effects of leakage from the water distribution system.

For waste-water discharges three impact routes are modelled:

- *Road Run-Off* This is considered as runoff from the total road area and is assumed to be discharged directly to the water courses or through soakaways into the groundwater. Due to the uncertainty surrounding run-off and the variables which impact emissions the discharge of each pollutant per unit of road area is constant over time. The only changes occur as a result of changes in land area dedicated to roads.

Figure 9 **Links in Water Discharge and Consumption Projections**

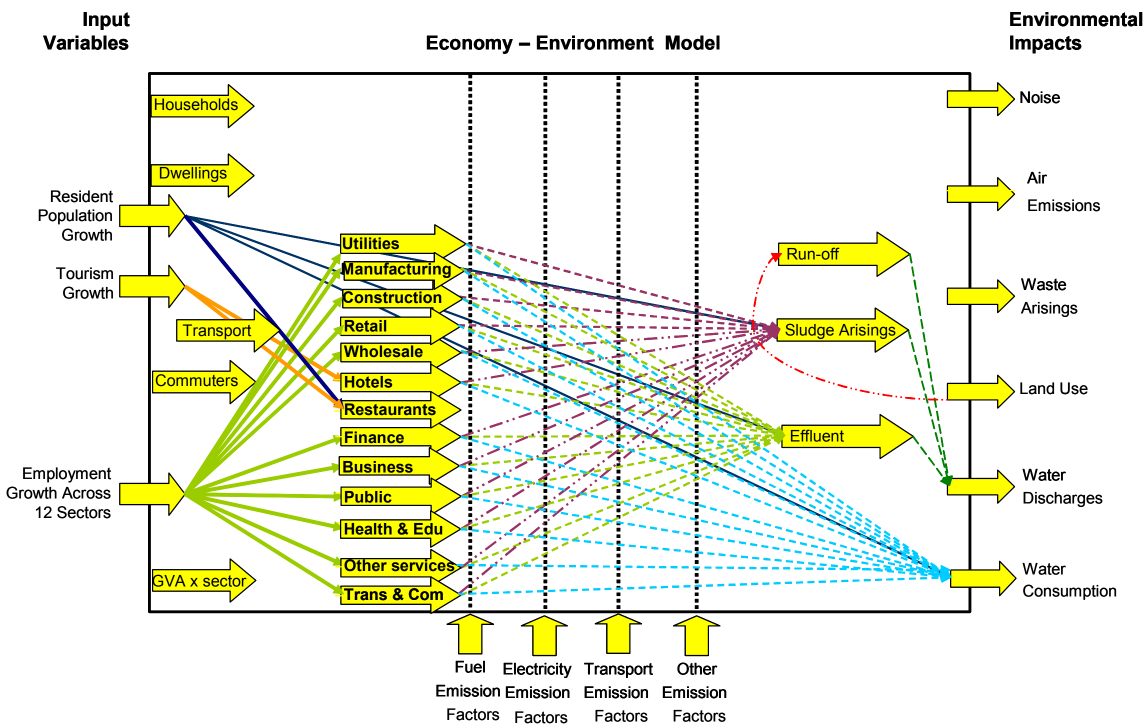
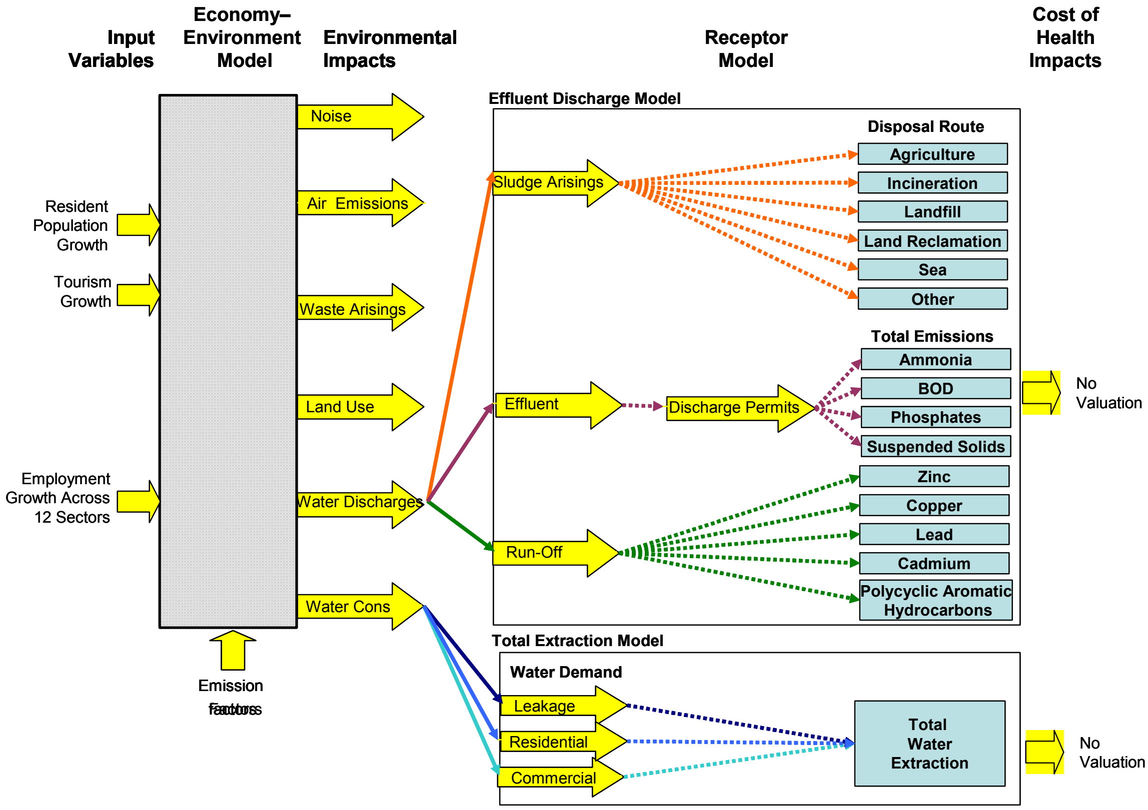


Figure 10 **Water Consumption and Discharge Links**



- *Effluent.* Effluent from all sectors is modelled at the point of discharge into the water course. The effects of treatment are therefore taken into account in terms of pollutants concentrations in the final discharge. Four pollutants are modelled:

  - Ammonia;
  - Biological Oxygen Demand (BOD);
  - Phosphates; and
  - Suspended Solids.

  The quantity of pollution in the effluent is estimated by the limits contained in discharge permits modified by changes in population. Currently no account is taken in the model of changes in future discharge consents as a result of the EC Water Framework Directive.

- *Sludge Arisings*. Total sludge arisings are determined according to the population equivalents of employees in the business sector, tourism and the existing resident population.

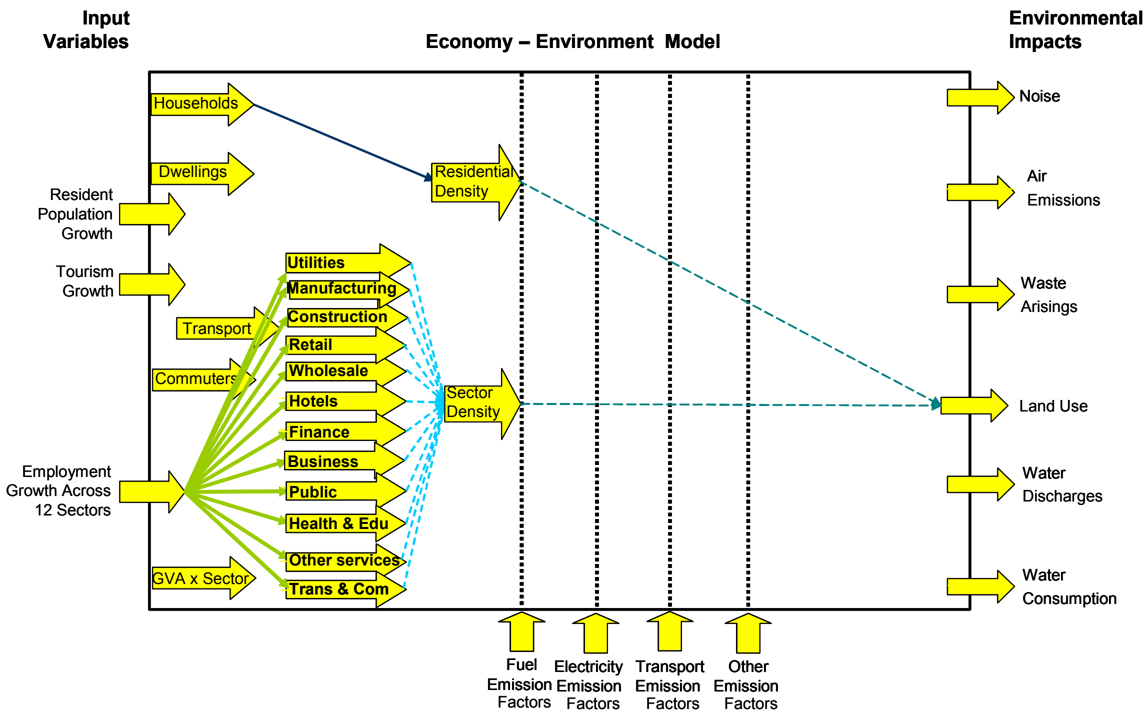
  The split between sludge disposal routes is set by the model user. Disposal options include: land spreading to agriculture, incineration, landfill, land reclamation, sea disposal and other. Disposal at sea is also included as an option, although only for historical purposes as it is currently prohibited by EU legislation.

4.4 Land Use

The Economy-Environment Model uses broad categories of land-use to demonstrate pressure on land-use patterns from projected growth forecasts according to the projected density of new developments. The model does not demonstrate changes in specific habitat types or their regional distribution. At this stage individual measures and policies given in the biodiversity strategy can not be represented in the model. When the underlying data sets are improved and the Economy-Environment Model is developed the land use section of the model can be made more representative of the different biodiversity types and the Mayor's biodiversity strategy.

The links used to model changes in land use are shown in Figure 11.

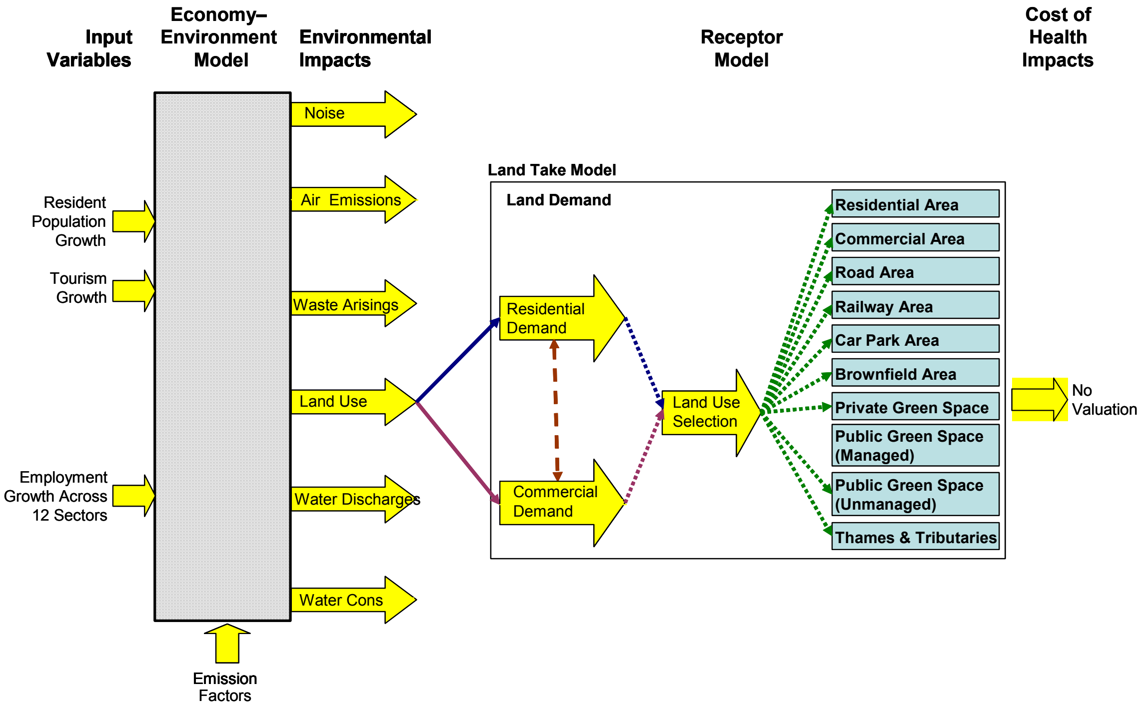
Figure 11 **Links in Land-Use Projections**



In the domestic sector the total land consumed is determined by the total number of households and the expected building density (m^2 floor space per hectare plot area). In the business sector, each sub-sector's land consumption is determined by that sector's expected floor area to plot area ratio and level of economic activity.

The complexity of the land-use model is due to the interactions between each of the sectors, changes in density, the churn of each market and assumptions about which types of land are developed to meet new land use demands. Figure 12 illustrates the links in the model used to assess changes in land use.

Figure 12 **Land-Take Model**



Two issues are of particular importance in the land take model:

- *The link between residential and commercial land area.* This refers to the transfer of land between commercial and residential uses for new development and redevelopment.

- *The land use selection.* This refers to the type of land used for new development. In the model, the process of land selection is represented by a user-defined hierarchy of land development choices. This simply prioritises the land type where development will occur.

Once these links have been specified the net change in different land-use types can be determined from changes in economic activity. No economic value has been attached to the environmental changes arising from changes in land use, although recent GLA work has looked at economic values associated with green-space.

4.5 Noise

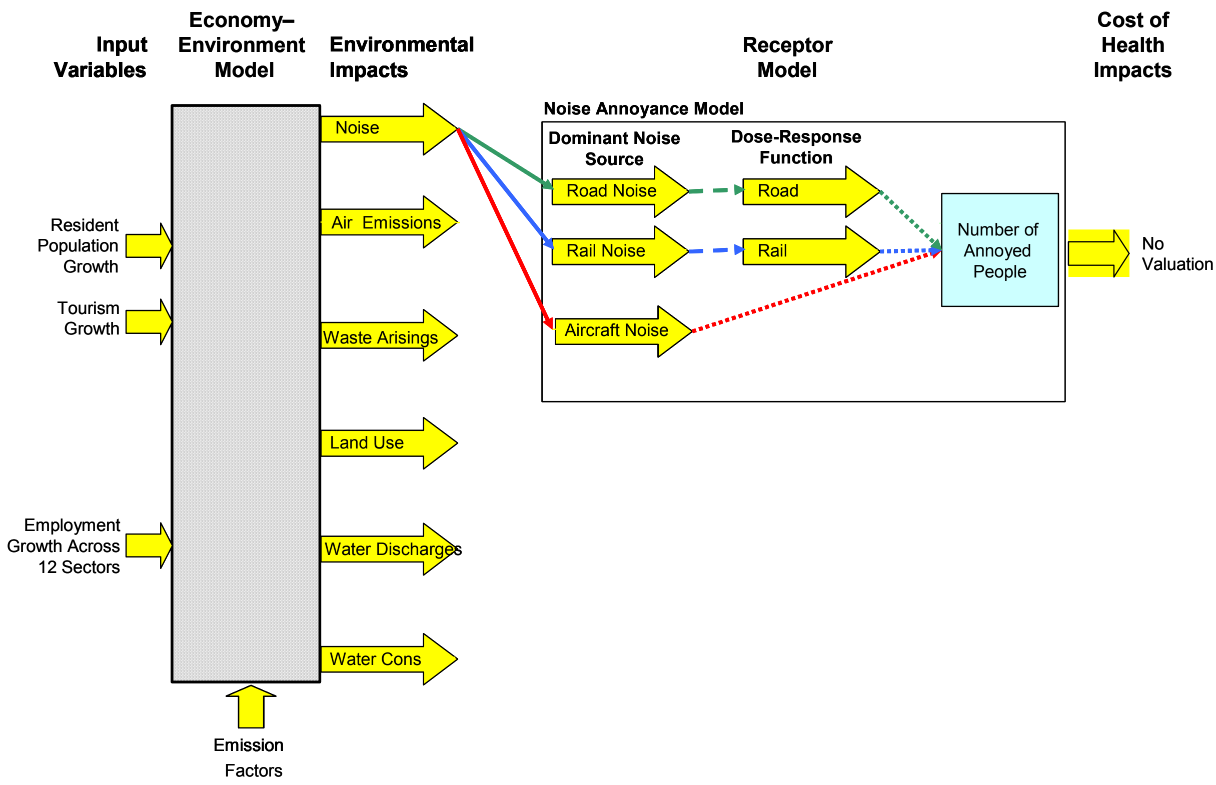
Noise is one of the most complex environmental impacts to model for London. There is uncertainty surrounding both the most suitable definition of noise to express an auditory impact in an urban area, and the actual noise emissions associated with different activities. Furthermore the temporary nature of noise prevents the aggregation of individual noise sources.

Given these difficulties the first phase of the Economy-Environment Model only develops a very simple relationship between transport and ambient noise. The noise abatement policies of the Mayor's Noise Strategy are not currently included in this model. Future developments, such as the London noise map and improved understanding of how noise affects the population, should enable the noise strategy to be more accurately represented.

The approach taken in the model is to assume a linear relationship between the activity causing the noise and the impacts on those affected (expressed as the number of annoyed). Only two sources of noise are modelled dynamically, road and rail transport. This is because they have the highest quantity of published information and defined dose-response functions. The effects of aircraft noise are taken into account in the model, but do not change with changing aircraft movements because of the complexity of the interactions of the size of plane and characteristics of the flight path.

No attempt has been made to model other sources of noise, such as construction noise, neighbours or background noise as the detailed information necessary to build a relationship is not available. The structure of the noise model is illustrated in Figure 13.

Figure 13 **Noise Annoyance Model**



5. VARIABLES, COEFFICIENTS AND DATA INPUTS

Section 4 described the general approach to modelling. This section provides more detailed information on the numerical inputs into the model under the headings of Input Variables (5.1) and Emission Factors (5.2). Each subsection lists the key variables used in the projections, a brief description of the variable, its source and any relevant comments on the data source or how it is used in the Economy-Environment Model.

5.1 Input Variables

The input variables to the model provide projected changes over time in the resident population (including commuters and tourists), and the number of employees. All these inputs are based on GLA data.

5.1.1 Population Variables

These inputs are summarised in Table 2.

Table 2 Sources of Input Variables

Variable	Description	Source	Comment
Resident Population			
Population Projections 1991 to 2016	Total population by age group and gender.	GLA, 2002 demographic projections.	• Population data projections for each year provided by the GLA.
Households	Conversion factor for the number of households per unit of population.	GLA coefficients based on population projections.	• Coefficients are given at 5 year intervals. • Intervening years are interpolated.
Dwellings	Conversion factor for the number of dwellings per unit of population.	GLA coefficients based on population projections.	• Coefficients are given at 5 year intervals. • Intervening years are interpolated.
National Housing Stock	Total number of households in the UK.	DTI http://www.dti.gov.uk/energy/inform/energy_consumption/table3_14.xls	• Total number of households in the UK is used to establish expected energy consumption of appliance energy use.
Commuter Population			
Work Patterns	Working patterns of commuting population.	Expected working patterns, no external reference.	• Time spent in London is used to determine the 'resident equivalents' of the commuting population.

Variable	Description	Source	Comment
Tourist Population			
Domestic Tourists	Number of tourists visiting London.	Historical figures and projections are given by the London Tourist Board,	• The current projections assume a 3.5% increase in the number of tourists each year,
International Tourists	Number of tourists visiting London	Historical figures and projections are given by the London Tourist Board,	• The current projections assume a 2.5% increase in the number of tourists each year,
Nights Rest	Number of nights stayed in London by domestic and international tourists.	Historical figures are given by the London Tourist Board.	• We use the historical average as the basis to determine the expected number of nights stayed. • The number of nights stayed determines the 'resident equivalents' of the domestic tourist population.

Total population projections are shown in Figure 14 and Table 3 shows the relationship between population, households and dwellings.

Figure 14 **Total Population of London (source GLA projections)**

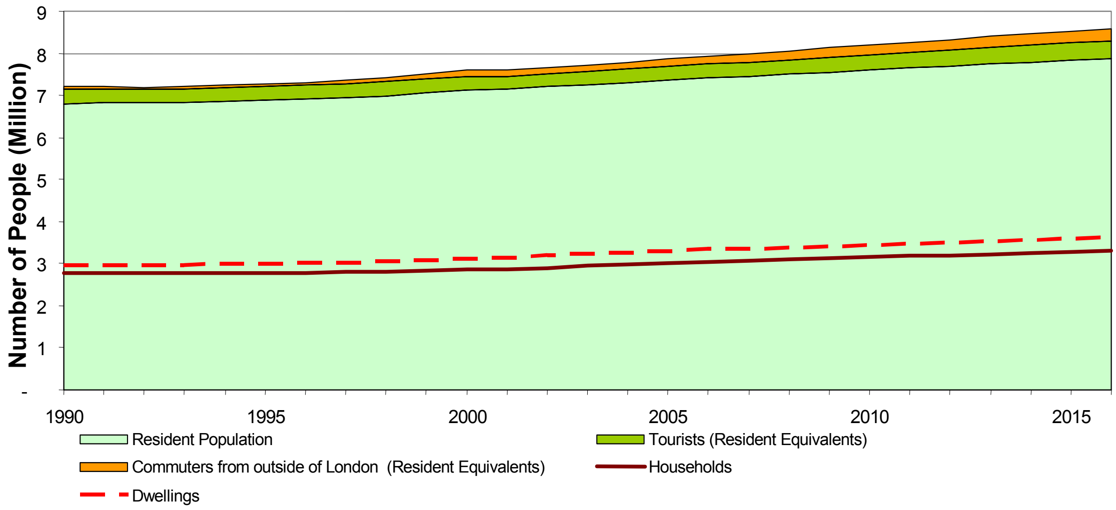


Table 3 Relationship between Population, Households and Dwellings

	1996	2001	2006	2011	2016
Households per head of population	0.406	0.401	0.411	0.415	0.421
Dwellings per head of population	0.434	0.439	0.449	0.453	0.458
Average Household Size	2.4	2.3	2.3	2.3	2.2
Total Population (rounded to the nearest 10,000)	**6,920,000**	**7,150,000**	**7,410,000**	**7,650,000**	**7,870,000**

5.1.2 Employment and GVA Variables

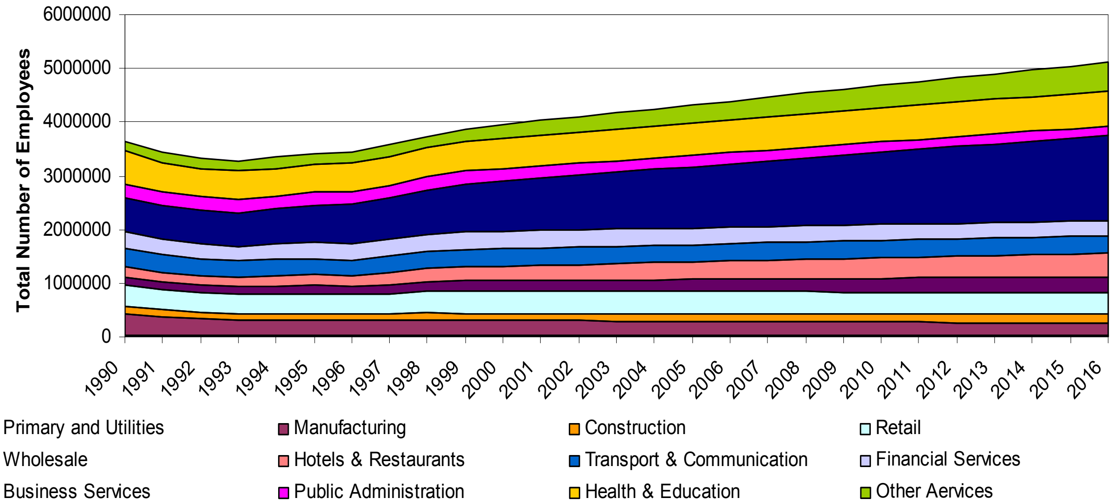
The sources of data used to project employment and GVA are summarised in Table 4.

Table 4 Description of Input Variables for Employment and GVA

Variable	Description	Source	Comment
Employment			
Number of employees (Historical)	The number of employees in each sector.	Annual Business Inquiry (ABI) study provided by the GLA.	This gives the total number of employees in each economic sector from 1990 to 1999. The ABI sectors have been aggregated to match economic sector definitions.
Number of employees (projected)	The number of employees projected in each sector.	Volterra study provided by the GLA.	Gives the total number of employees in each economic sector from 2000 to 2016. The interaction between projected and historical data can be either interpolated to reach the same 2016 end point (which avoids a step change in total numbers) or the Volterra figures can be used for intervening years.
GVA			
GVA per employee	Historical output of each employee according to sector.	Calculated in the model.	Calculated from GVA data and employment data to provide an average GVA per employee factor. Provides an annual rate of increase in GVA per employee. This is then adjusted to match the London GVA projections.
GVA by sector	GVA by sector at 1995 prices (£ billion).	EBS historical data and forecast provided by the GLA.	Gives the total GVA of each economic sector from 1982 projected forward to 2012. The sector totals have had to be adjusted to ensure that the total GVA attributed to London matches published figures.
GVA projections	Total GVA for London.	Volterra economic forecasts provided by the GLA.	Volterra provide three projected growth rates of 2.5%, 2.75% and 3%.

Figure 15 shows the resulting employment projection by sector. The average annual rate of employment growth for London is 1.6%, however this varies between sectors (-1.8% for public administration to 4.6% for other services).

Figure 15 **Total number of Employees by sector**



Gross value added is an intermediate economic variable. We have used historical data to create a sector specific productivity factor, average GVA per employee, and the historical rate of change in each sector's productivity factor to create a productivity growth rate. This allows us to link GVA with total employment over time.

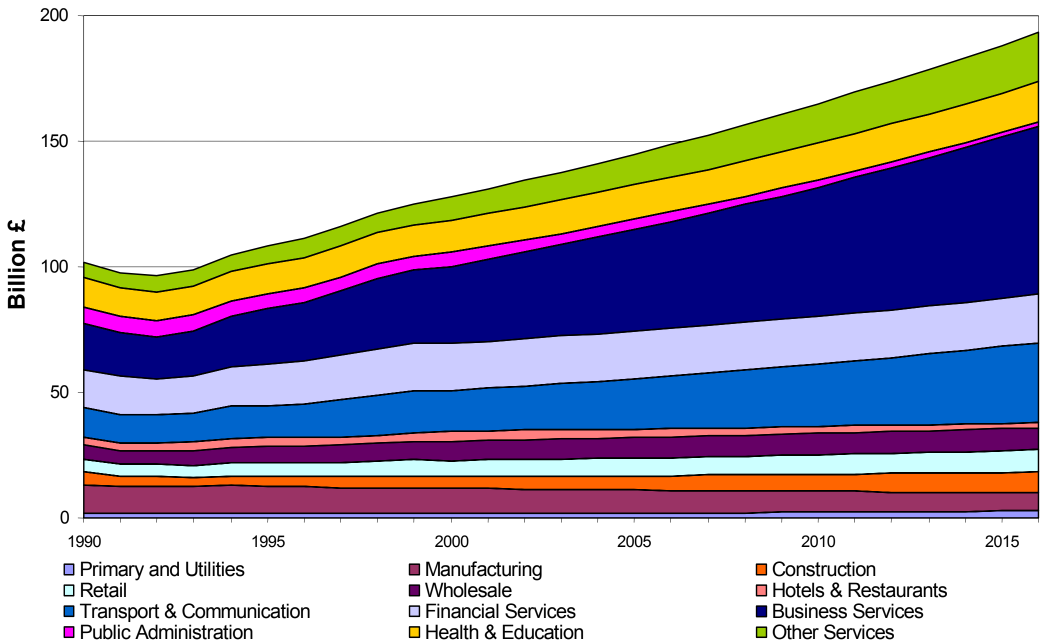
For projections until 2016, work by Volterra expects an annual GVA growth rate for the London economy of 2.5%. In order to maintain consistency with Volterra's projections we have adjusted each sector's productivity growth rate to match Volterra's projections. This adjustment adds approximately 0.1% onto each sector's productivity growth rate.

The average GVA per employee and the sector productivity growth rate are shown in Table 5. The variation in GVA per employee between sectors is largely due to differences in capital and labour intensity. The hotels and restaurants sector for example, which is more labour intensive, has a GVA per employee of £15,494. Primary and utilities on the other hand, which is more capital intensive, has a GVA per employee of £89,444.

Table 5 **Sector GVA variables**

	Average Productivity GVA (£ 1995) /Employee	Sector Productivity Growth Rate
Primary and utilities	89,444	4.4%
Manufacturing	35,875	-1%
Construction	38,691	1.6%
Retail	14,505	2.3%
Wholesale	40,640	-1.7%
Hotels & restaurants	15,494	-6.8%
Transport & communication	48,239	4.2%
Financial services	56,334	1.3%
Business services	32,491	1.5%
Public administration	24,413	-4.4%
Health & Education	22,873	0.2%
Other services	35,411	0.3%

Figure 16 **Total GVA projections by sector**



5.2 Emission Factors and Coefficients

This sub-section describes the emission factors and coefficients used in the model for each environmental media.

5.2.1 Air Emissions

Air emissions factors are described in terms of those relating to fuels, electricity and transport. We then describe the assumptions underpinning the evaluation of health effects.

Fuel Emission Factors

Two sources of emission factors for fuels are used in the model:

- National Air Emissions Inventory (NAEI). This provides information on emissions of CH_4, N_20, NOx, VOCs, CO, SO_2 and PM10s per tonne of fuel combusted.

- Digest of UK Energy Statistics. This is used for the calorific values of fuels.

Electricity Emission Factors

In the Economy-Environment Model electricity emission factors are varied over time according to technological changes and assumptions about the grid generating mix. As a result the electricity emission factor for each pollutant is calculated on an annual basis.

Where possible, these factors are based on projections in the DTI's Energy Projections Paper, EP 68. This gives projections for total electricity output and the type of fuel used until 2020 under three growth scenarios and a high and low carbon scenario. They also project CO_2 and SO_2 emissions until 2020 for two central growth scenarios. The model uses projections from the central growth scenarios.

EP 68 does not, however, project the emissions of other pollutants such as NOx, PM10, and VOCs. In order to derive emissions projections for these pollutants the model uses the expected emission factor for each generating source, and the expected electricity generating mix over time. The expected percentage change in emissions over time is then applied to current emissions to project future emission changes.

Transport Emission Factors

Transport emission factors are used for road, rail and air transport. Table 6 summarises the data sources used.

Table 6 Description of Input Data & Coefficients for Transport Emission Factors

Variable	Description	Source	Comment
Road			
Traffic Speed (Projected)	The projected traffic speed to the nearest 5km/hr.	NETCEN, NAEI Emissions Database	• We have restricted the choice to 9 average speeds from 5 to 40 km/hr because of the volume of underlying data. • A look up table provides the expected pollutant level according to the speed and the transport type. • Any change is assumed to occur only once and to be instantaneous.
Share of Road Traffic	Expected share of road traffic split by type of vehicle over time.	NETCEN, NAEI Emissions Database	• Urban vehicle fleet projections from 1996 to 2025. • Percentage of road users by vehicle types.
Vehicle Emission Factors	Expected emission factors according to the vehicle speed.	NETCEN, NAEI Emissions Database	• UK vehicle fleet projections from 1996 to 2025. • Projects the emissions, grams/vkm according to the vehicle category, EURO I, II, III or IV, and engine size.
Vehicle Emission Standards	Types of vehicle on the road.	NETCEN, NAEI Emissions Database	• UK vehicle fleet projections from 1996 to 2025. • Projects the emissions standards of vehicles on the road expected each year according to vehicle category and EURO I, II, III or IV emission standards.
Engine Sizes	Engine sizes of petrol and diesel cars.	NETCEN, NAEI Emissions Database	• Gives the percentage share of vehicles according to engine size. • We assume that size of car is constant over time.
Efficiency of Motorcycles	Fuel efficiency of motorcycles relative to petrol cars.	Expected efficiency base on reports, no reliable external reference.	• We have assumed each motorcycle contributes 40% of the emissions of petrol cars.

Variable	Description	Source	Comment
Rail			
Underground Train Energy Consumption	Electricity consumption per passenger kilometre.	London Underground Environmental Performance Report 2002	• The energy consumption over a 5 year period gives average watt hours/km. • This is kWh/pkm is converted into kWh/vkm by dividing by the expected occupancy ratio of VKM: PKM.
Electric Train Energy Consumption	33 kWh per vkm. This is based on the German high speed rail network.	Commission for Integrated Transport http://www.cfit.gov.uk/reports/racomp/a1.htm	• A high and a low value, 33 and 22 kWh/vkm respectively, were given. We have used the high value.
Split of train types	% of trains diesel and electric trains.	Expected split, no reliable external reference.	• We have assumed that 25% of trains are provided by diesel the other 75% are electric.
Diesel Train Emission Factors	kt of emissions per mt of fuel consumed.	http://www.aeat.com/netcen/airqual/naei/annreport/annrep99/	• Separate factors are given for freight, intercity and regional trains. We only use the regional train emission factor.
Diesel Train Fuel Consumption	0.54 kg/vkm – the average fuel consumed for a regional diesel train.	NAEI http://www.naei.org.uk/emissions/kb.php?action=showpost&question_id=54	• None.
Aircraft			
Emission Factors	Emission factors for landing and take-off cycles.	NETCEN - http://www.aeat.com/netcen/airqual/naei/annreport/annrep99/app1_210.html	• Aircraft emission factors for landing and take-off cycles are given for Heathrow for CO_2, NOx, CO, VOCs and SO_2. • CH_4 and N_20 are listed separately for each aircraft movement.

Health Impacts

The health impacts of air pollutants are modelled through the Health Impacts Model (HIM). This model first converts emissions into ambient concentrations. These are then translated into health effects which are then monetised using valuation coefficients.

The air pollutants included in the HIM are those with known and quantified health impacts (i.e. dose response functions). These include: PM10, SO_2, CO, Benzene, and 1,3-Butadiene. The dose response functions used in the model are shown in Table 7.

Table 7 Dose Response Functions

Pollutant	Health impact	Dose Response Function	Units	Source
PM_{10}	Respiratory hospital admissions	2.07E-06	cases/(yr-person-µg/m³)	ExternE
PM_{10}	Cerebrovascular hospital admissions	5.04E-06	cases/(yr-person-µg/m³)	ExternE
PM_{10}	Acute mortality	0.04%	%change in annual mortality rate/(µg/m³)	ExternE
PM_{10}	Chronic mortality	0.39%	%change in annual mortality rate/(µg/m³)	ExternE
SO_2	Respiratory hospital admissions	2.04E-06	Cases/(yr-person-µg/m³)	ExternE
SO_2	Acute mortality	0.07%	%change in annual mortality rate/(µg/m³)	ExternE
1,3-Butadiene	Cancer risk estimates	4.29E-06	Cases/(yr-person-µg/m³)	ExternE
CO	Congestive heart failure – elderly	7.77E-08	cases/(yr-person-µg/m³)	ExternE
Benzene	Leukaemia	5.9E-06	Individual lifetime risk (µg m-3)-1	World Health Organisation (2000)
NO_2*	No strong dose response function (COMEAP, 1998)			

(*) Note that no firm dose response function exists for NOx or NO_2. The economic values applied to these health effects are shown in Table 8.

Table 8 Cost associated with each health impact

Health impact	Value (2000 £'s)	Source
Respiratory hospital admissions	3,175	ExternE*
Cerebrovascular hospital admissions	12,297	ExternE*
Congestive heart failure	2,396	ExternE*
Acute mortality	735,000	European Commission*
Chronic mortality	360,150	European Commission*
Leukaemia	1,000,000	Enviros (2003)
Cancer risk estimates	500,000	Enviros (2003)

* ExternE and European Commission values are cited in BeTa (2002)

5.2.2 Waste Arisings & Disposals

The modelling of waste arisings in the Economy-Environment Model refers to previous modelling work carried out for the GLA under the Waste Strategy. Table 9 summarises the main variables.

Table 9 Variables used to determine waste arisings and disposals

Variable	Description	Source	Comment
Waste Arisings			
C&D Arisings	Construction and demolition waste arisings.	Technical Assessment for Waste Management in London, GLA report carried out by Enviros.	• Only two years of data for London is available to model changes in C&D waste stream. Arisings are assumed to be proportional to construction orders. • For years without data (including projections) total waste arisings are determined by a coefficient of waste arisings per unit of GVA.
MSW Arisings	Projected municipal solid waste arisings.	Technical Assessment for Waste Management in London, GLA.	• For years without data (including projections) MSW arisings are determined by a coefficient of waste arisings per household.
C&I Arisings	Expected waste arisings for each economic sector (excluding construction).	Technical Assessment for Waste Management in London, GLA report carried out by Enviros.	• The share of waste arisings attributed to each sector is determined according to their share of 1998 waste arisings. • Arisings are assumed constant across all economic sectors but each sector can be modelled separately.
Waste Disposal			
C&D Disposal Route	Disposal routes for construction and demolition waste.	Waste Options Modelling: Technical Draft for the London Plan, GLA.	For all waste streams: • The percentage of waste disposed via each disposal route is given in 2001. • For historical purposes, the disposal route used is assumed to be consistent with the earliest available data. • The waste disposal route projections are determined by expected disposal routes for 2016 given in previous GLA research. • Interim disposal or recycling targets are not included in the model.
MSW Disposal Route	Disposal routes for municipal solid waste.	Municipal Waste Options: Technical Report, GLA.	
C&I Disposal Route	Disposal routes for commercial and industrial waste.	Waste Options Modelling: Technical Draft for the London Plan, GLA.	

5.2.3 Water Consumption & Discharges

Water consumption is modelled by each sector in a similar manner to energy consumption and waste arisings. However, because of the variation in data quality, some sectors are able to be modelled with considerably more confidence than others, for example the hotel and restaurant sectors. Similarly with water discharges, whilst water discharges per head of population are well established water discharges from road run-off are subject to considerable uncertainty.

The variables used for generating the historical and the projected data are given in Table 10.

Table 10 Variables used to determine water discharges and consumption

Variable	Description	Source	Comment
Water Discharges			
Road Run-Off	High and low pollutant levels per litre of run-off a day.	Pollutants in Urban Waste Water and Sewage Sludge, European Commission.	• The original study is from France, although we would expect a significant variation between geographical locations. • The volume of pollutant per litre of run-off is combined with total rainfall to produce total emissions per unit of road area.
Effluent and Sludge Arisings	Litres of effluent per person per day and kgs of dry sludge per person per day.	Sewage Sludge Disposal: Operational and Environmental Issues, Foundation for Water Research.	• Provides a range of expected effluent and sludge emissions per day per person.
Disposal Routes of Sewage Sludge	Historical and projected disposal routes for sewage sludge in the UK.	Sewage Sludge Disposal: Operational and Environmental Issues, Foundation for Water Research.	• Provides a historical and projected disposal routes for the UK. • The historical data (average from 1996 to 1998) includes disposal at sea.
Consent Discharges	Number of consent discharges.	Environment Agency – Personal Contact.	• The number of consent discharges is used to estimate the share of total discharges attributed to London. This includes industrial and waste-water consents.
Total Sludge Discharges	Thousands of tonnes sludge discharged from sewage treatment works (1990-2001).	DEFRA http://www.defra.gov.uk/environment/statistics/des/inlwater/download/xls/iwtb23a.xls	• Total consented discharges for the UK are adjusted to the London area according to the number of Thames consent permits. • Using the estimated population of the Thames region, we calculate the expected discharges per head from 1990 to 2001.

Variable	Description	Source	Comment
Water Consumption			
Target Water Consumption for Offices	Cubic meters of water consumed per employee.	http://www.thameswateruk.co.uk/waterwise/frameset.html	• The published distinction between offices with and offices without catering on site forms the estimate of water consumed per restaurant customer. • As there is no published data on current consumption we have adjusted best practice target data.
Domestic Consumption per Head	Litres of water consumed per Thames Water customer per day.	Leakage and the Efficient Use of Water, 2000-01 Report OFWAT	• Provides an estimate of total consumption per head from 1995 to 2001.
Water Consumption of Hotels	Hotel water consumption per bed per year.	http://www.thameswateruk.co.uk/waterwise/frameset.html	• Gives an expected water consumption figure according to the type of hotel and the water efficiency.
Leakage Rate	Thames Water's leakage rate, litres per property per day.	Leakage and the Efficient Use of Water, 2000-01 Report OFWAT	• Used to develop an expected leakage rate according to amount of water supplied. • Historical leakage rate assumes the maximum rate recorded is maintained.
Types of Properties	Ratio of residential to commercial properties.	Leakage and the Efficient Use of Water, 2000-01 Report OFWAT	• As the leakage rate is given in the leakage per property we have to establish the expected number of commercial properties in the London Area.

5.2.4 Land Use

The land use model is relatively complex in terms of the interactions between each of the land use sectors. The model is developed for ten different categories of land and is applied in a series of five stages:

1. The current land is allocated to each sector according to historical data

2. The change in demand for floor area, assuming constant density, is calculated over time. This is then adjusted into a net demand for land according to whether there is surplus capacity.

3. The net demand for land is adjusted to take account of changes in building density over time.

4. The opportunity of substituting commercial for residential land, or vice-versa, is considered.

5. The net demand is subtracted from other land types according to the land-use hierarchy.

The variables used for generating the historical and the projected data are given in table 11.

Table 11 Land use variables and projections

Variable	Description	Source	Comment
Vacant Dwellings	Total vacant dwellings in London (1999)	Focus On London, Office of National Statistics	• The number of vacant dwellings is used to establish the total capacity available in London. • This is considered along with the natural rate of vacancy to determine the amount of property currently vacant.
Plot Ratios	The number of housing units per hectare and commercial floor space per hectare	Demand and Supply of Business Space in London, Roger & Tymm	• The plot density ratios are provided for current and high sustainability according to geographical region. A London average is developed from these figures.
Surface Area	Total surface area according to land type	GLA file, original data	• The original data is based on a 1992 study by Dawson & Worrell. New data should be published soon. • The Dawson & Worrell figures are adjusted according to more recently published data from Roger & Tymm on total commercial and residential land area used. • For commercial land use, the total area is assumed to be proportional to the floor space (ie constant density for each sector).

5.2.5 Noise

When analysing noise we only look at the impact of noise from transport. Whilst there are many other sources of noise that people consider as, or more, disturbing than transport noise this model is constrained by:

- The requirement of a defined relationship between an economic activity or population and the level of noise.
- The requirement that any relationship between an activity and the noise generated is suitably defined because noise is non-additive.
- Peoples' response to each noise source needs to be defined in a quantifiable way.

These three constraints are currently only met by transport. We have, therefore, only taken into account the level of annoyance caused by changes in transport noise over time. The variables used for generating noise annoyance are given in Table 12.

Table 12 Noise Variables

Variable	Description	Source	Comment
Level of Annoyance	The calculation methodology for determining the level of annoyance.	Position Paper on Dose-Response Relationships between Transport Noise and Annoyance – European Commission	• Gives the methodology for estimating the number of people likely to be annoyed at a given noise level according to the source of the noise.
Changes in Noise	Changes in noise level due to changes in traffic flow.	Calculation of Road Traffic Noise Department of Transport and Welsh Office	• This gives the expected change in noise (L10) due to a change in transport volumes, assuming that the type remains the same. • The methodology is for L10 applied to road traffic, however, we have applied this methodology the current measure of noise (L_{den}) and extended it to rail traffic. Air travel is assumed to remain unchanged.
Noise impact in London	A cumulative distribution of the percentage of population experiencing a level of noise according to the time of day.	Review of London Related Data from the 1990 and 2000 National Noise Incidence Studies - BRE	• This gives both the 16 hours noise level (morning and evening) and the 8 hours (night) noise levels to give an estimate of the percentage of population experiencing a given noise level. • This is information is then used to calculate the average L_{den} experienced by the London population.
Dominant Source of Noise	The percentage of the population hearing a particular noise source.	A review of London Related Data from the 2000 Noise Attitude Survey	• This gives the percentage of the London population hearing a particular noise source. • We use this information to suggest the percentage of population where a particular noise source is dominant.

6. SCENARIOS

To present the results of this model we have provided three scenarios:

- *Business as Usual (BAU)*: This assumes that the projection variables will change only due to national regulations, such as building regulations. Otherwise variables remain constant with historical values.

- *Mayor*'s *Strategies (MS)*: In the Mayor's Strategy we have applied polices highlighted in the Mayor's strategy documents to the model. It should be noted that the impact of many important policies are not quantifiable, or no figures were published quantifying their expected environmental impact. Where the environmental impact of a policy has not been defined numerically we have not included these policies in the current model.

- *High Sustainability (HS):* The high sustainability scenario projects the impact of achieving the most capital intensive of the Mayor's policies, or exceeding policies included in the Mayor's strategies. The High Sustainability scenario includes major infrastructure investments.

It should be noted that because there are currently no costs or cost abatement curves included in the model the full policy implications of each scenario are not considered. The model does, however, inform the scale of change that is needed to meet a particular target.

The projection variables used under each scenario are listed in the tables in Appendix 1.

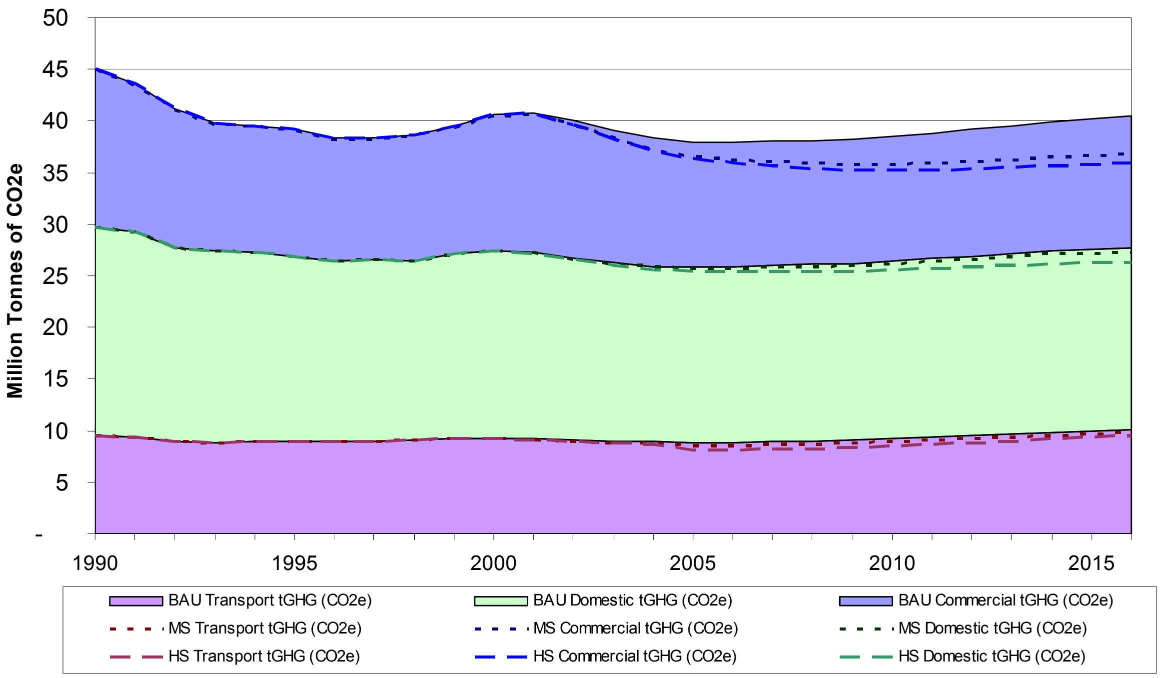
7. RESULTS

This section presents some of the preliminary results from the modelling of the scenarios described in the previous section on their impact on Greenhouse Gas Emissions, Local Air Pollutant Emissions, Health Impacts, Waste Arisings and Disposal, Water Consumption and Emissions, Land Use and Noise.

7.1 Greenhouse Gas Emissions

Figure 17 shows total greenhouse gas emissions for the commercial, domestic and transport sectors. These results include the total CO_2e (carbon dioxide equivalents) emissions from fuel consumption in London and electricity emissions related to London's electricity consumption. These results do not include CO_2e emissions from non-energy consumption.

Figure 17 **Projected Greenhouse Gas Emissions**



We can see from Figure 17 that by 2016 the Mayor's Strategies will reduce absolute GHG emissions from London by 20% from a 1990 baseline, compared with a 10% reduction under the Business as Usual scenario. The High Sustainability scenario reduces emissions by 24%. This suggests that if the Mayor's strategies, including the major infrastructure projects in the high sustainability scenario, were fully implemented then London would be on course to achieve the Mayor's target of a 20% reduction in CO_2 emissions from a 1990 baseline by 2020. This will, however, depend on the changes in the electricity emission factor which are outside of the Mayor's control.

Looking at the changes attributed to each sector in 2016, relative to the Business as Usual scenario, we can see that the most significant changes in GHG emissions occur in the commercial sector, table 13.

Table 13 Expected Change in GHG Emissions in 2016 from Business as Usual Scenario

	Mayor's Strategy	High Sustainability
Commercial	-29%	-36%
Domestic	-2%	-8%
Transport	-3%	-5%
Total	-11%	-16%

The most significant gains are made in the commercial sector. This is due to the high rate of turn-over of the building stock - compared with the domestic sector – which increases the uptake of improved building standards and the uptake of onsite renewable electricity generation. In the domestic sector, although significant changes are possible, the increase in energy efficiency is restricted by the relatively low turnover in the domestic building stock. Whilst in the transport sector CO_2 emissions resulting from reduced car usage are partially offset by increases in CO_2 emissions from electricity used in rail travel. In the high sustainability scenario overall transport emissions decrease further as more people are encouraged to walk or cycle.

It is important to note that the results in Figure 17 are consistent with the GLA's top down modelling of energy and greenhouse gas emissions. Specifically, the Economy-Environment Model incorporates various factors that ensure consistency given that the consumption data currently collected by the GLA is more accurate than the bottom up approach that characterises the Economy-Environment Model.

The main reasons for discrepancies between the bottom up and top down approaches are:

- The Economy-Environment Model does not take into account process emissions from energy intensive industries and electricity generation in the London area (all large scale power generation is assumed to occur outside London); and
- Differences in specific energy consumption between London's building stock and 'typical' building stocks as reported by the energy efficiency best practice programme. London's energy stock would appear to more energy intensive than average.

7.2 Local Air Pollutants

In this section we have maintained the distinction made in previous sections between local air pollutants occurring from fuel combustion inside London and outside London's geographical area.

Local Air Pollutants Outside London

For emissions outside London, which are related to electricity consumption, we can see that the Mayor's Strategies have a significant impact on emissions (Table 14). We can see in Table 14 that the high sustainability scenario reduces emissions by approximately 15%. This change is due to a higher level of energy efficiency being achieved and a greater use of renewable energy generation in London reducing demand for electricity relative to the baseline. The change observed for NOx emissions in 2016 is due to the larger share of natural gas in the generation mix.

Table 14 Impact of each scenario on Local Air Pollutants outside of London in 2016 (tonnes)

Tonnes of Pollutant	Business as Usual	Mayor's Strategies	High Sustainability
NOx	57,700	50,300	49,000
VOCs	1,000	800	800
CO	4,200	3,700	3,600
SO_2	2,600	2,200	2,200

Local Air Pollutants Inside London

For local air pollutant emissions inside London we have separated the total VOCs emissions into benzene, 1-3,butadiene, and other VOCs. This is because benzene and 1-3,butadiene are primarily related to road transport, and for other fuel combustion we do not have individual emission factors for individual VOCs.

The emissions of local air pollutants inside London are shown in Figures 18 and 19. They are shown on separate graphs due to the different scales of total emissions.

Figure 18 **Local Air Pollutant Emissions: VOCs, SO2, Benzene, Butadiene, and PM10**

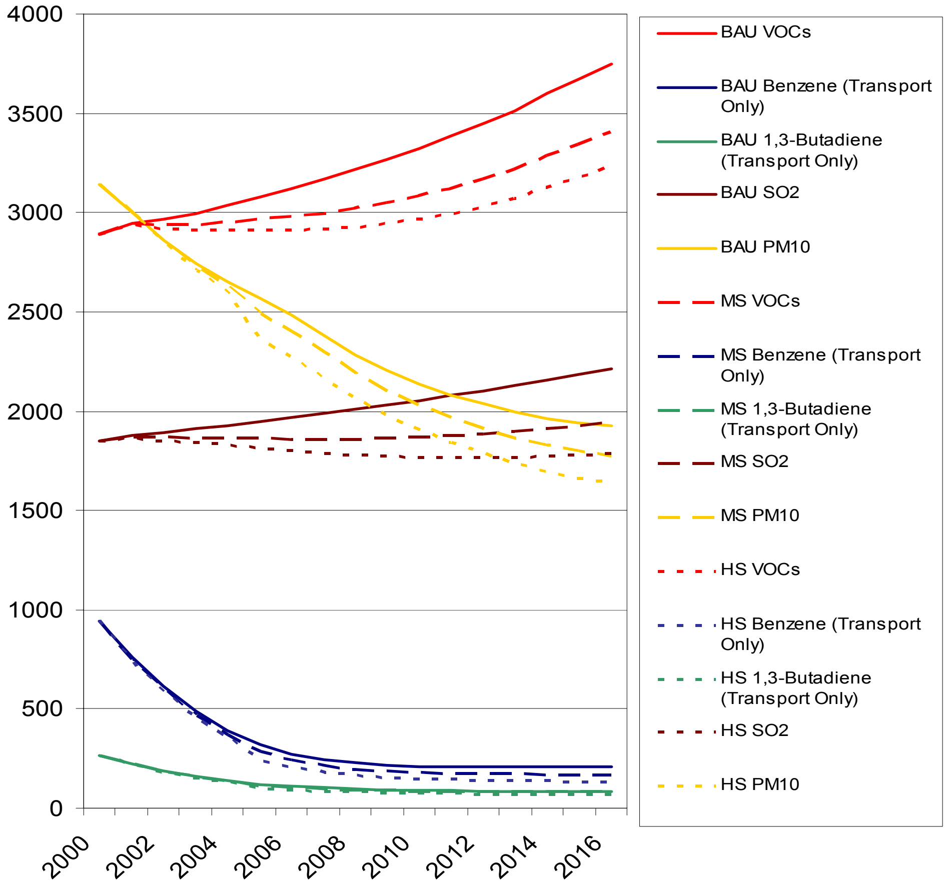
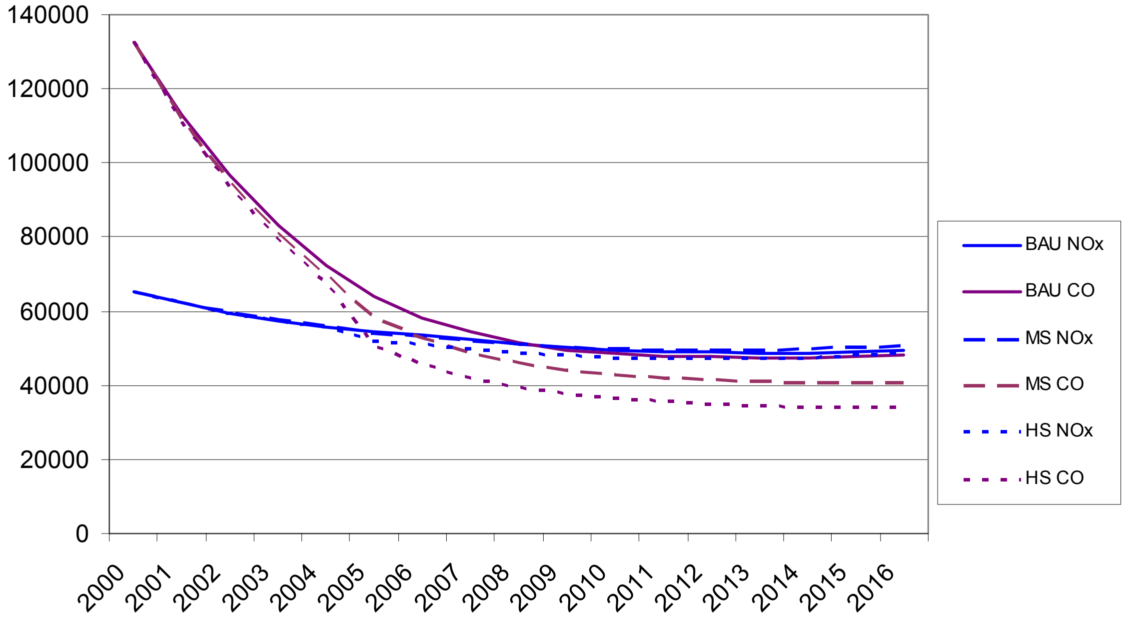


Figure 19 **Local Air Pollutant Emissions: CO and NOx**



We can see from these graphs that the emissions arising from road transport are expected to have the most significant decrease over the model's projections. This is due to significant improvements in engine emission standards as well as mode switching from road to rail induced by the Mayor's strategies.

For emissions associated with on-site combustion in the domestic and commercial sectors, SO_2 and VOCs (excluding Benzene and Butadiene), the projections are for an increase in emissions over time. This increase is due to projected economic and demographic growth in these sectors and that there are no strategies directly targeted at these emission sources. The impact of each scenario on local air pollutants in London is given in Table 15.

Table 15 Impact of Each Scenario on LAP in London in 2016 from a Business as Usual Scenario (% change)

	Mayor's Strategies	High Sustainability
NOx	3%	1%
VOCs	-9%	-14%
Benzene (Transport Only)	-20%	-37%
1,3-Butadiene (Transport Only)	-3%	-15%
CO	-15%	-29%
SO_2	-12%	-19%
PM10	-8%	-15%

Table 15 shows that in 2016 the Mayor's strategies increase total NOx emissions by 3% over the baseline emissions within London as a result of implementing the Mayor's Strategies. This change is brought about by the increased use of buses which have higher NOx emissions per passenger kilometre than cars. In the high sustainability scenario this increase is offset by increase walking, cycling and rail passengers.

In Table 16 we have compared two sets of figures from the Economy-Environment Model with the GLA's own Air Quality Strategy estimates. The percentage difference is shown between the Air Quality Strategy's figures and the Economy-Environment figures excluding emissions from electricity.

Table 16 Comparison of Recorded and Economy-Environment Model Emissions in 2000 (tonnes)

Tonnes of Pollutant	Air Quality Strategy	Economy-Environment Model: LAP inside London	Economy-Environment Model: LAP Inside and Outside London	% Difference between LAP inside London and Air Quality Strategy
NOx	68,100	65,100	102,500	-4%
PM10	2,700	3,100	3,100	15%
SO_2	3,600	1,800	3,600	-47%
CO	173,400	132,300	139,400	-24%
Benzene	1,600	900	900	-44%
1,3-Butadiene	400	300	300	-25%

We can see from Table 16 that, with the exception of PM10, emissions of local air pollutants attributed to fuel combustion in London are lower than those estimated by the GLA Air Quality Model.

For Benzene and Butadiene, the difference is probably due to the fact that the Economy-Environment Model does not separate out these pollutants from VOCs. VOCs under the Economy-Environment Model should therefore be higher than the GLA Air Quality Strategy.

For SO_2 emissions the difference is likely to be due to the assumption that all power generation occurs outside London. Given the still significant share of coal in the UK generating mix, omitting this contribution will show a lower emissions associated with coal combustion than modelled in the GLA Air Quality Model.

7.3 Health Impacts

The impacts of the three scenarios on health are presented in Figures 20 and 21. The only difference between the two graphs is the scale on the side. Different health impacts of the same pollutant are shown on different graphs. Note that we do not model the effects of NOx or NO_2 on health; this is because of the lack of evidence for discernable dose response functions between these gases and identifiable health effects.

Figure 20 **Health Impacts associated with total emissions: CO, Benzene, Butadiene and SO2**

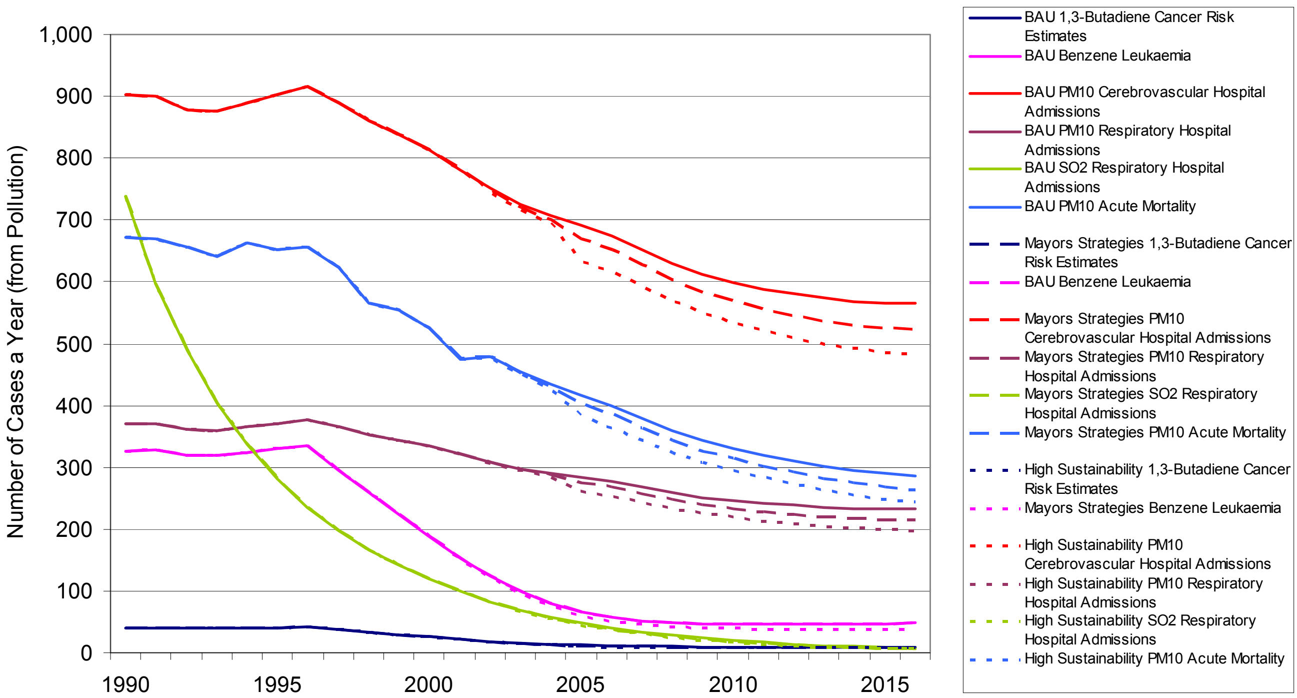
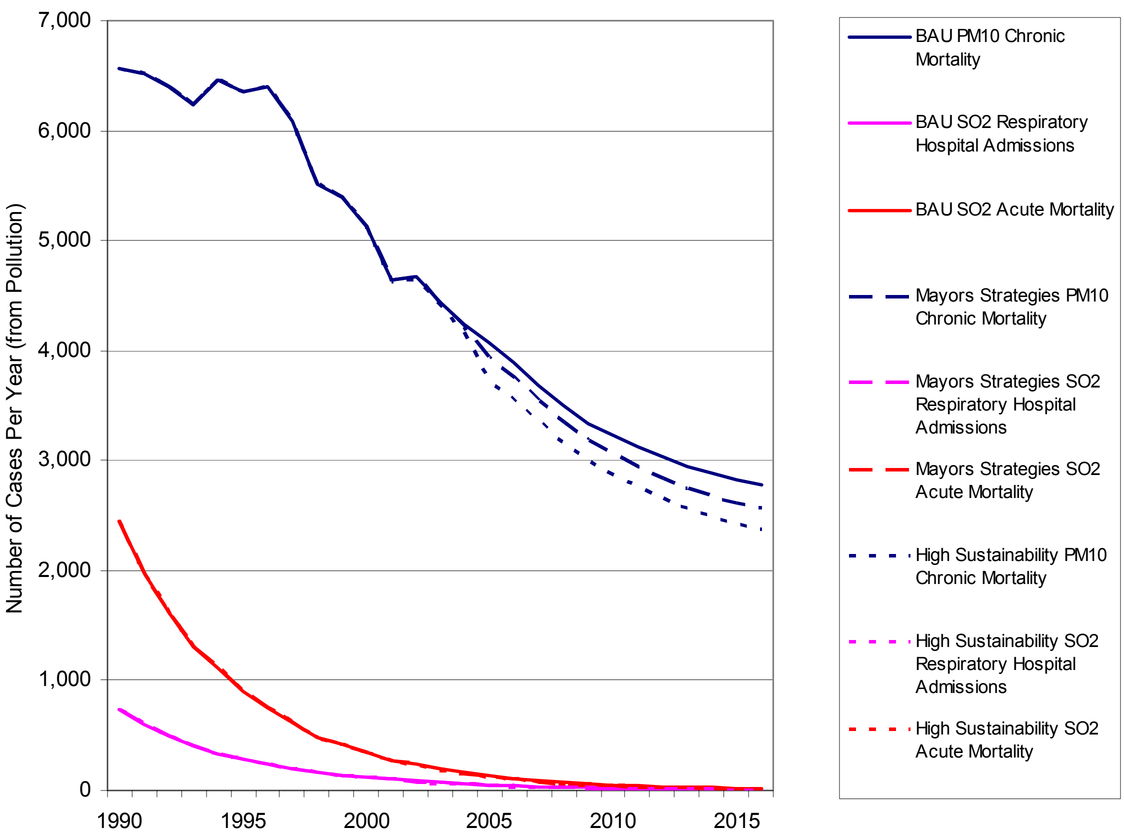


Figure 21 **Health Impacts associated with Total Emissions: SO2 and PM10**



We can see from both of these charts that there is a general downward trend in the health impacts associated with each pollutant. The Mayor's policies do however accelerate this trend as shown in Table 17.

Table 17 Change in Health Impacts compared with the Business as Usual Scenario in 2016

Pollutant	Health Impact	Mayor's Strategies	High Sustainability
PM10	Respiratory hospital admissions	-8%	-15%
PM10	Cerebrovascular hospital admissions	-8%	-15%
PM10	Acute mortality	-8%	-15%
PM10	Chronic mortality	-8%	-15%
SO2	Respiratory hospital admissions	-12%	-19%
SO2	Acute mortality	-12%	-19%
CO	Congestive heart failure - elderly	-15%	-29%
Benzene	Leukaemia	-20%	-37%
1,3-Butadiene	Cancer risk estimates	-3%	-15%

7.4 Waste Arisings and Disposal

We present results for each scenario for both waste arisings and the waste disposal routes. In Figure 22 we show the total waste arisings. These show the impact of halving the rate of growth in waste arisings per head under the Mayor's Strategies scenario, and reducing this growth rate to zero in the High Sustainability scenario.

Figure 22 **Total Waste Arisings**

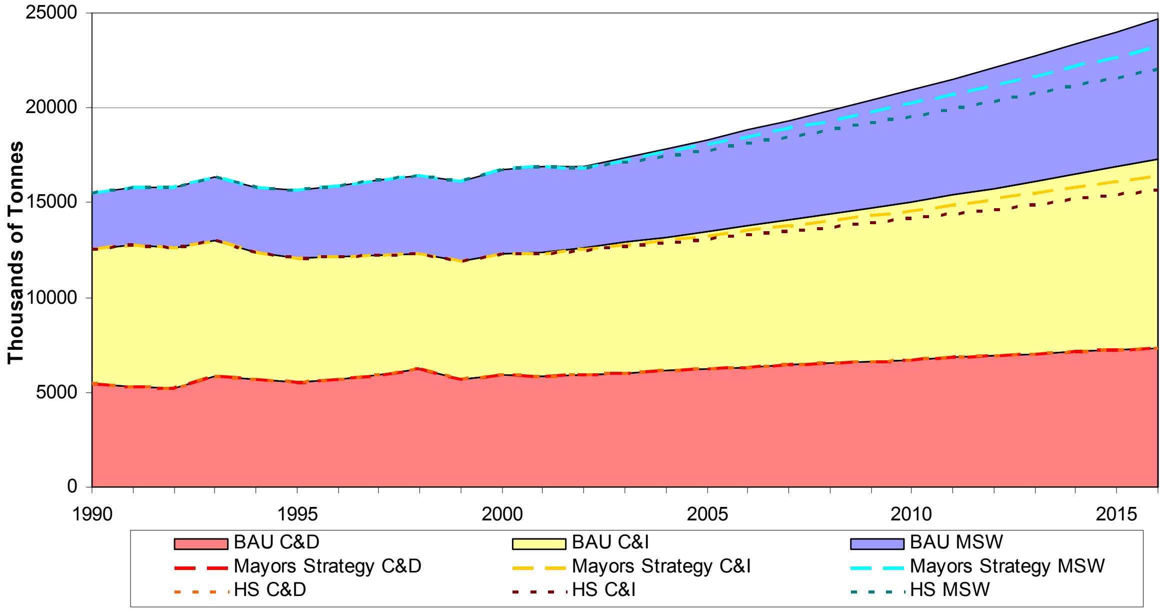


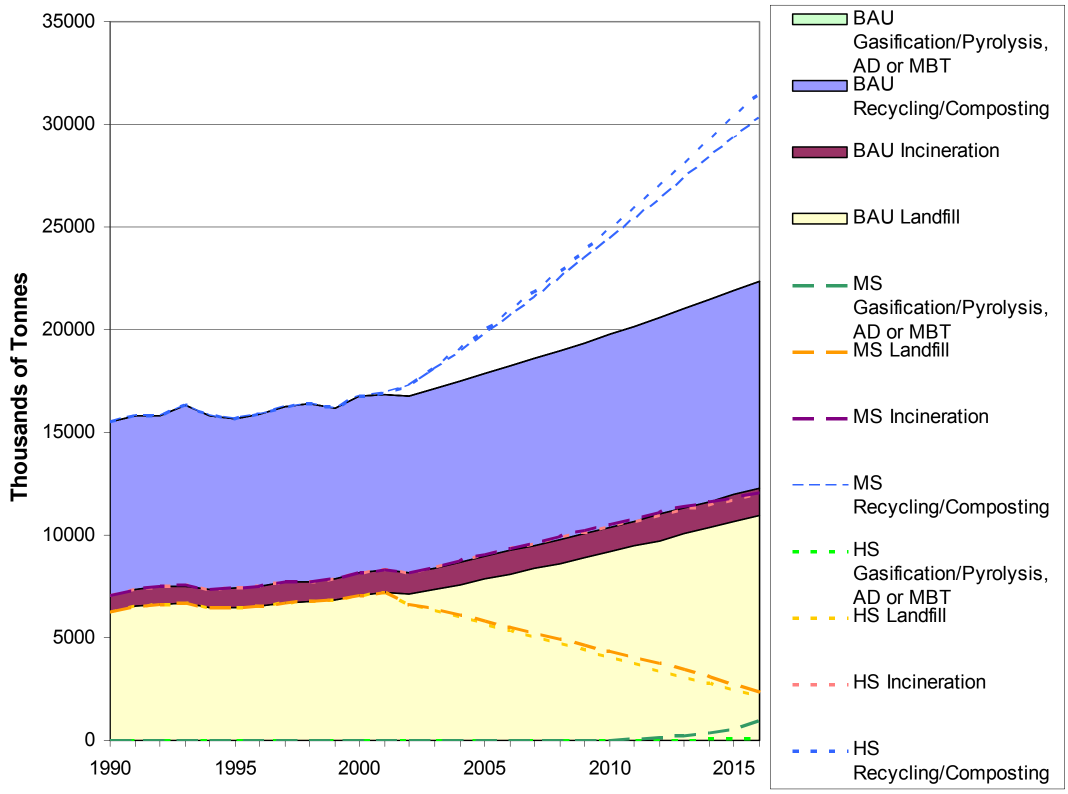
Table 18 shows the expected growth in waste arisings under each scenario. In the business as usual scenario we expect a 3% per year growth rate for MSW and 1% for C&I arisings.

Table 18 Projected Change in Waste Arisings

	Total Arisings in 2000 (mtonnes)	Projected increase in 2016		
		BAU	Mayor's Strategies	High Sustainability
MSW	4.4	66%	34%	7%
C&I	6.4	56%	43%	31%
C&D	5.9	24%	24%	24%

In Figure 23, we show the effect of different choices of disposal routes on arisings as projected in the Mayor's Strategy scenario, described above. These disposal scenarios are taken from modelling undertaken for the Mayor's Waste Strategy.

Figure 23 **Waste Disposal of all waste streams**



The most significant difference in the disposal routes are for the C&I waste stream, where recycling is projected to increase from 39% to 89% in the Mayor's Strategy scenario, and for the MSW waste stream, where recycling and composting is projected to increase from 8% to 43%.

7.5 Water Consumption & Water Emissions

Water consumption projections are presented in Figure 24. This chart, together with Table 19, demonstrates the importance of water leakage in determining overall water consumption.

Figure 24 **Water Consumption Projections**

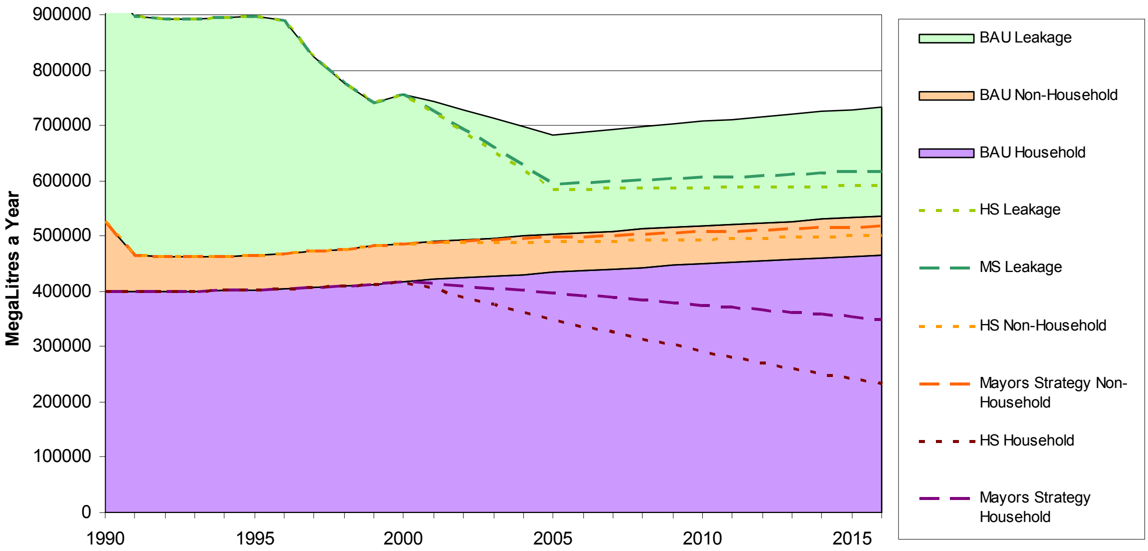


Table 19 Impact of each scenario on water consumption in 2016

Water Consumption	Mayor's Strategies	High Sustainability
Leakage	-59%	-72%
Non-Household	-25%	-50%
Household	-25%	-50%

Water emissions from road run off are not projected to vary significantly as there is little change in the total land area attributed to the surface area of roads.

Similarly emissions from water effluent emissions and sludge disposal routes are currently not covered by policies in the Mayor's Strategies. As a result no difference is expected between each scenario.

7.6 Land-Take Patterns

The projected land consumption patterns are shown in Figure 25. For simplicity this figure has aggregated the ten land uses modelled to six land uses presented here.

Figure 25 **Land-take patterns in London**

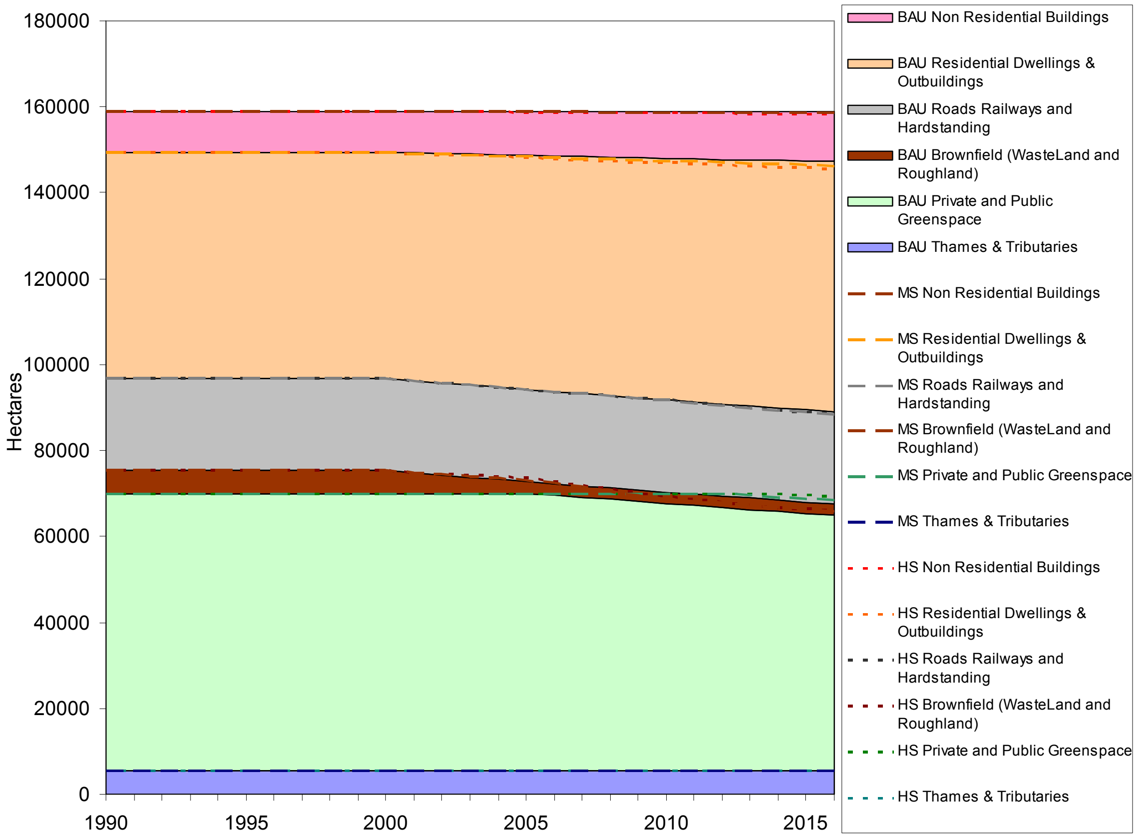


Figure 25 shows the significant impact of each scenario on the amount of green space in London. The share of land-use projected in 2016 is shown in Table 20.

Table 20 Percentage of Land Use in 2016

	Business As Usual	Mayor's Strategies	High Sustainability
Residential Area	7.4%	7.1%	7.0%
Commercial Area	36.7%	36.1%	35.6%
Roads, Railways and Car Parking Areas	13.5%	13.2%	13.2%
Brownfield Area	1.7%	0.7%	0.7%
Private and Public (managed and unmanaged) Green space	37.4%	39.6%	40.2%
Thames & Tributaries	3.4%	3.4%	3.4%

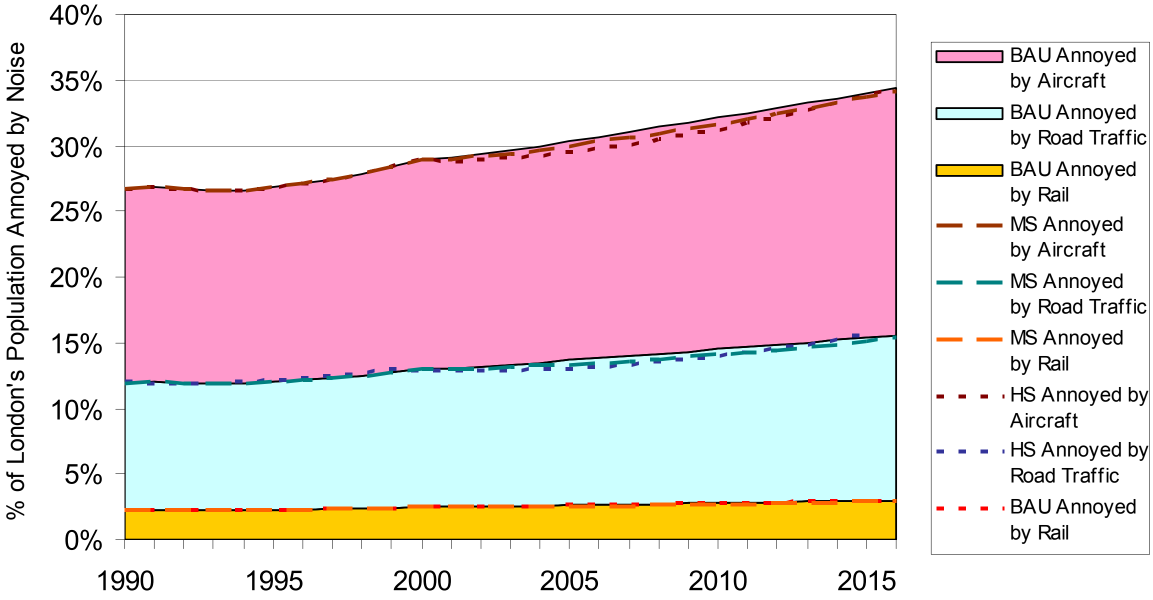
This shows that in 2016 the total amount of green space in London is increased by approximately 2% under the Mayor's Strategy scenario and 3% under the High Sustainability scenario. This is due a strategy of higher building densities being implemented and the reduction in brownfield sites.

7.7 Noise

The results in Figure 26 for noise show the number of people that are expected to be annoyed by transport noise under each scenario.

It should be noted that these are provisional results, and that the differences achieved in each scenario are related to the different choices of transport mode and do not reflect the policies in the noise Strategy.

Figure 26 **Noise Annoyance under each scenario.**



The indicative results of the percentage of people annoyed from each source of noise are given in Table 21.

Table 21 Impact of each scenario on noise annoyance in 2016

Percentage of population annoyed by each source of noise.	Mayor's Strategies	High Sustainability
Aircraft Noise	-0.2%	0.1%
Road Traffic Noise	-0.2%	0.1%
Rail Traffic Noise	-0.1%	0.0%

It should be re-iterated that these results are due to changes in road and rail transport patterns and do not reflect the policies presented in the Mayor's noise strategy.

8. CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The Economy-Environment Model was developed over a period of nine months in 2003 to assist the GLA in understanding the linkages between economic development, the Mayor’s Strategies and the quality of the environment in London and the health of its residents.

The Economy-Environment Model assesses the impact of over 250 policy variables on three key sectors – transport, commercial and domestic – and the resulting impact on six environmental media between 2003 and 2016. Health effects and the monetary values attributed to these effects are explicitly modelled. The monetary values for health take into account the cost of health care, lost earnings and willingness to pay to avoid illness and death.

Other than for health impacts where illnesses are valued in monetary terms, the Economy-Environment Model does not assign monetary values to the environmental outcomes, or indeed inputs. Importantly the model does not determine the costs of implementing the Mayor’s various strategies. This is an obvious area for future development for the model and could add considerable value to the current version.

Where possible the model has been adjusted to be consistent with other GLA data and models, eg energy and waste models. Given the different approaches to the modelling it is not possible to achieve consistency for every year for every environmental media but any differences are largely within the bounds of modelling error. The one exception is the analysis of air quality. For air quality the approach developed in the Economy-Environment Model is only an approximation to the more detailed air quality modelling undertaken by the GLA.

Although the Economy-Environment Model has, as far as possible, been made consistent with these external models, there are currently no direct links. Given that these external models will be more detailed and kept more up to date than the separate receptor components in the Economy-Environment Model, it is likely that the future development of the model will centre around its use as an integrating tool linking currently separate GLA environmental and economic models, rather than as a stand alone model that attempts to replicate these other models.

The outputs of the model shown in section 7 of this report provide a snap shot of the key environmental and health indicators for London given a specific set of input assumptions. Although the outputs need to be treated with caution due to the uncertainty in the assumptions, one conclusion stands out: sustainable growth in London appears difficult to achieve even with the Mayor’s suite of environmentally related strategies. This outcome is driven by the consequences of continued economic and population growth. Specifically, the model shows that whilst the Mayor’s policies are expected to significantly reduce London’s environmental impact they generally reduce the rate of growth of the impact rather than reverse the overall trend.

The real benefit of the model however is not in the snap shot results presented in this report, but as a dynamic tool that can show the sensitivity of environmental and health impacts to changes in the shape of London’s economy and the intervention strategies available to the Mayor.

Although there are clearly aspects of the model that need to be developed in more detail, in summary we believe that the model as it stands has demonstrated the viability of an Economy-Environment Model specific to London.

8.2 Recommendations

Following on from above, there are a number of ways in which this model could be enhanced and developed. These are categorised under “model scope and objectives” and “technical developments”.

Model Scope and Objectives

- Having effectively demonstrated the viability of an Economy-Environment Model, the objectives of the model could be developed to allow the GLA to:

  1. assess the environmental and health impacts of different patterns of economic and population growth and intervention by the Mayor (current functionality);

  2. assess the interactions between different Mayoral strategies (current functionality but can be improved);

  3. understand the optimal sustainability development potential of London –this will require:

     - a quantification of the cost of achieving different levels of environmental quality in London. This will require the development of environmental improvement cost curves for London; and

     - an expansion of the monetary valuations (currently applied to health impacts) to other environmental outcomes.

- The model could be more closely integrated with other GLA models. This will effectively require replacing the current dose response functions with links to these external models. This approach will enable the best aspects of economic and environmental modelling in the GLA to be used to create a more complete and detailed analytical tool. Moreover, incorporating into the Economy-Environment model the outputs from the relevant departmental models should provide a more supportive and wider user base for the Economy-Environment model concept within the GLA.

Technical developments

- Disaggregation of the economic sectors to 2-digit SIC codes. This would allow for more effective modelling of the Part A industrial processes and non-energy related emissions.

- Disaggregation by employment types. Currently all employees are treated as full time employees. The work-force is more complex with part-time workers and home-workers, with different resource use patterns.

- Development of cross-sectoral relationships. Currently the model only shows the impact of the economy on the environment through simple input-output relationships. These relationships could be developed further to model more complex interactions between sectors, as well as possible feedback effects of the environment on the economy.

- Inclusion of lifecycle effects. Lifecycle effects estimate the environmental impacts through-out a product's lifecycle from production, distribution, and consumption through to final disposal. To the extent that it is desirable to examine these supply-chain effects within and outside London these can be built into the model.

- General expansion in specific sectors, for example:

    - Linking transport with waste arisings and economic growth of each sector (if coefficients can be established);

    - Development of a waste stream for special waste; and

    - Linking water consumption explicitly with energy consumption in the utility sector.

- Improvement in the application of dose-response functions, especially for health impacts. Currently the model uses ExternE as the main source of reference for this. Research, however, is continually improving the scientific understanding and the Economy-Environment model could be updated in the light of new information on the impact of pollution on human health.

GLOSSARY

Acronym	Definition
ABI	Association of British Industries
AD	Anaerobic Digestion
BAU	Business as Usual
BOD	Biological Oxygen Demand
C&D	Construction and Demolition (Waste)
C&I	Commercial and Industrial (Waste)
CH_4	Methane
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalents
d.r.f.s	Dose-Response Functions (for defining the impact of a pollutant)
DEFRA	Department of Environment Food and Rural Affairs
DMAG	Data Management and Analysis Group
DTI	Department of Trade and Industry
DUKES	Digest of UK Energy Statistics
EBS	Experian Business Strategies
EP 68	Energy Projections 68, Published by the DTI
EU	European Union
Gas/Pyro	Gasification & Pyrolysis
GLA	Greater London Authority
GVA	Gross Value Added
GWP	Global Warming Potential
HIM	Health Impacts Model
HS	High Sustainability (scenario)
LAP	Local Air Pollutants

LTOs	Landing and Take-Off Cycles (for emissions from airports)
MBT	Mechanical Biological Treatment
MS	Mayor's Strategy
MSW	Municipal Solid Waste
NAEI	National Air Emissions Inventory
NETCEN	National Environmental Technology Center
NOx	Oxides of Nitrogen
OFWAT	Office of Water Services
PAHs	Polyaromatic Hydrocarbons
pkm	Passenger Kilometers
PM10	Airborne Particulate Matter (less than 10 micro meters)
SAP	Standard Assessment Procedure (for Energy Rating of Dwellings)
SIC	Sector Industry Classification
SO_2	Sulphur Dioxide
tCO2e	Tonnes of CO2 equivalent
vkm	Vehicle Kilometers
VOCs	Volatile Organic Compounds
WHO	World Health Organisation

APPENDICES

1. DETAILED DESCRIPTION OF PROJECTION VARIABLES

The following appendices provide a detailed description of the projection variables used in the model. They have been separated into seven sub-sections:

A1. Commercial Energy Consumption;

A2. Residential Energy Consumption;

A3. Transport Patterns;

A4. Waste;

A5. Water;

A6. Land Take Patterns; and

A7. Noise Projects.

Each sub-section gives details of the projection variables used, details about the economic sector each projection variable is applied to, the units used, the value used under each scenario and an explanation about how that value was derived.

Where the explanation is consistent for each economic sector, a single cell has been merged across all the relevant projection variables.

There may be rounding errors in the projection variables.

Appendix A1: Commercial Energy Consumption

Commercial energy consumption uses two categories of building type. The first building type category is the twelve economic SIC sectors used through-out the model. The second building type category is the property description category. The property description distinguishes seven building types, as categorised by the Energy Efficiency Best Practice Programme, which are used to determine the composition of each of the twelve economic SIC sectors – for example, manufacturing is comprised of offices, manufacturing and wholesale buildings.

Commercial energy consumption projections use three sets of projection variables.

- Building stock variables. Building stock variables define the rate of change in the commercial building stock for each of the twelve economic SIC sectors. There are two variables used:
  1. Rebuild in Commercial Properties; and
  2. Refurbishment in Commercial Properties.
- Fuel choice variables. Fuel choice variables determine the type of fuel used in each of the seven property description categories. Fuel choices include:
  1. Natural Gas Consumption;
  2. Oil Consumption; and
  3. Renewables.
- Building design variables. The building design variables determine the type and energy efficiency in each of the seven property description variables. These are:
  1. Office Space;
  2. Manufacturing buildings;
  3. Wholesale Buildings;
  4. Hospitals;
  5. Schools;
  6. Hotels; and
  7. Retail.

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Business as Usual Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Mayor's Strategies Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: High Sustainability Explanation

Building Stock Variables:
There are two building stock variables 'Rebuild in Commercial Properties' and 'Refurbishment in Commercial Properties'. The two should be considered together to determine the changes in the building stock. High values for both rebuild and refurbishment will indicate a higher rate of building stock turnover and hence faster uptake of higher energy efficiency standards.

1) Projection Variable: Rebuild in Commercial Properties

Economic Sector	Units	Scenario 1 Value	Scenario 1 Explanation	Scenario 2 Value	Scenario 2 Explanation	Scenario 3 Value	Scenario 3 Explanation
Primary and utilities	% of floor area rebuilt annually	0%	Estimated annual rebuild rates for each commercial sector.	0%	We assume a 25% increase in the annual rate of rebuild due to the Mayor's strategy of developing regional centres.	0%	We assume the annual rate of rebuild is constant with the Mayor's Strategy scenario.
Manufacturing	% of floor area rebuilt annually	0%		0%		0%	
Construction	% of floor area rebuilt annually	2%		3%		3%	
Retail	% of floor area rebuilt annually	3%		4%		4%	
Wholesale	% of floor area rebuilt annually	2%		3%		3%	
Hotels & restaurants	% of floor area rebuilt annually	3%		4%		4%	
Transport & communication	% of floor area rebuilt annually	1%		1%		1%	
Financial services	% of floor area rebuilt annually	3%		4%		4%	
Business services	% of floor area rebuilt annually	3%		4%		4%	
Public administration	% of floor area rebuilt annually	1%		1%		1%	
Health & Education	% of floor area rebuilt annually	1%		1%		1%	
Other services	% of floor area rebuilt annually	3%		4%		4%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	 Explanation	SCENARIO 2: Mayor's Strategies Value	 Explanation	SCENARIO 3: High Sustainability Value	 Explanation
2) Projection Variable: Refurbishment in Commercial Properties							
Primary and utilities	% of floor area refurbished annually	1%	Estimated annual refurbishment rates for each commercial sector.	1%	We assume a 25% increase in the annual rate of refurbishment due to the Mayor's strategy of developing regional centres.	1%	We assume the annual rate of refurbishment is constant with the Mayor's Strategy scenario.
Manufacturing	% of floor area refurbished annually	1%		1%		1%	
Construction	% of floor area refurbished annually	2%		3%		3%	
Retail	% of floor area refurbished annually	5%		6%		6%	
Wholesale	% of floor area refurbished annually	2%		3%		3%	
Hotels & restaurants	% of floor area refurbished annually	5%		6%		6%	
Transport & communication	% of floor area refurbished annually	1%		1%		1%	
Financial services	% of floor area refurbished annually	5%		6%		6%	
Business services	% of floor area refurbished annually	5%		6%		6%	
Public administration	% of floor area refurbished annually	1%		1%		1%	
Health & Education	% of floor area refurbished annually	1%		1%		1%	
Other services	% of floor area refurbished annually	5%		6%		6%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: Explanation

Fuel Choice Variables:
The fuel choice variables are defined for the seven property descriptions and are separated into fossil fuel choices and renewables. The two fossil fuel options, oil and natural gas, cover all non electrical energy used in the building (heating, hot water and appliances) and should sum to 100%. Renewables provides the percentage of total building energy consumption supplied by on-site renewables.

1) Projection Variable: Natural Gas Consumption

Economic Sector	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Business Services	% of fossil fuels used.	100%	Natural gas used in new builds and refurbishments are constant with current day figures.	100%	We expect some fuel switching from oil to natural gas in new builds and refurbishments under the Mayor's Strategies scenario.	100%	We expect a complete fuel switch from oil to natural gas for all new builds and refurbished properties under High Sustainability scenario.
Storage & Distribution	% of fossil fuels used.	90%		100%		100%	
Manufacturing	% of fossil fuels used.	90%		95%		100%	
Hospitals	% of fossil fuels used.	90%		95%		100%	
Schools	% of fossil fuels used.	90%		95%		100%	
Hotels	% of fossil fuels used.	90%		95%		100%	
Retail	% of fossil fuels used.	90%		95%		100%	

2) Projection Variable: Oil Consumption

Economic Sector	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Business Services	% of fossil fuels used.	0%	Oil used in new builds and refurbishments are constant with current day figures.	0%	We expect some fuel switching from oil to natural gas in new builds and refurbishments under the Mayor's Strategies scenario.	0%	We expect a complete fuel switch from oil to natural gas for all new builds and refurbished properties under High Sustainability scenario.
Storage & Distribution	% of fossil fuels used.	10%		0%		0%	
Manufacturing	% of fossil fuels used.	10%		5%		0%	
Hospitals	% of fossil fuels used.	10%		5%		0%	
Schools	% of fossil fuels used.	10%		5%		0%	
Hotels	% of fossil fuels used.	10%		5%		0%	
Retail	% of fossil fuels used.	10%		5%		0%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: Explanation
3) Projection Variable: Renewables Fuel Consumption							
Business Services	% of site energy used	0%	Constant with current day figures.	4%	On site renewables are based on the Mayor's strategy to provide 14% of London's Electricity from renewables, 10% of this is expected to come from the national grid. This is only applied to new builds and refurbishments.	10%	On site renewables are based on the Mayor's strategy to provide 10% of onsite fuel consumption from renewables (including hot-water and heating). This is only applied to new builds and refurbishments.
Storage & Distribution	% of site energy used	0%		4%		10%	
Manufacturing	% of site energy used	0%		4%		10%	
Hospitals	% of site energy used	0%		4%		10%	
Schools	% of site energy used	0%		4%		10%	
Hotels	% of site energy used	0%		4%		10%	
Retail	% of site energy used	0%		4%		10%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	 Explanation	SCENARIO 2: Mayor's Strategies Value	 Explanation	SCENARIO 3: High Sustainability Value	 Explanation

Building Design Variables

Building design variables are described for each of the 7 property descriptions. Each variable is separated into two parts, the energy efficiency of new build and type of property built. These categories are based on the energy efficiency good practice guides.

1) Projection Variable: Office Space

a) Energy Efficiency:

Economic Sector	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Good Practice	quality of new build and refurbishment (% of floor space)	1%	Constant with current day figures.	75%	Achieved through the implementation of the Mayor's Energy hierarchy.	100%	Assumed that all new build & refurbishment office space reaches a high efficiency.
Typical	quality of new build and refurbishment (% of floor space)	99%		25%		0%	

b) Type of Property:

Economic Sector	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Type 1 - Cellular Natural Ventilation	% of floor area built by office type	0%	We assume that no new cellular offices are built	0%	This is constant with the BAU figures, although the Mayor's strategies may discourage air conditioning.	0%	This is constant with the BAU figures, although the Mayor's strategies may discourage air conditioning.
Type 2 - Open Plan Natural Ventilation	% of floor area built by office type	50%		50%		50%	
Type 3 - Air Conditioned Std	% of floor area built by office type	30%		30%		30%	
Type 4 - Air Conditioned Prestige	% of floor area built by office type	20%		20%		20%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Business as Usual Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Mayor's Strategies Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: High Sustainability Explanation
2) Projection Variable: Manufacturing Building							
a) Energy Efficiency:							
New	% of floor space	0%	Constant with current day figures.	75%	Achieved through the implementation of the Mayor's energy hierarchy.	100%	Assumes that all new builds and refurbishment reach the highest efficiency.
Improved	% of floor space	1%		25%		0%	
Typical	% of floor space	99%		0%		0%	
b) Type of Property:							
General Manufacturing	% of floor space	33%	Expected current day figures.	33%	No change in the type of manufacturing building built from BAU.	33%	No change in the type of manufacturing building built from BAU.
Factory Office	% of floor space	33%		33%		33%	
Light Manufacturing	% of floor space	34%		34%		34%	
3) Projection Variable: Wholesale Building							
NB: There is only one type of property considered under wholesale building							
a) Energy Efficiency							
New	% of floor space	0%	Constant with current day figures.	75%	Achieved through the implementation of the Mayor's energy hierarchy.	100%	Assumes that all new builds & refurbishments reach the highest efficiency.
Improved	% of floor space	1%		25%		0%	
Typical	% of floor space	99%		0%		0%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: Explanation
4) Projection Variable: Hospital Building							
a) Energy Efficiency:							
Good Practice	% of floor space	1%	Constant with current day figures.	75%	Achieved through the implementation of the Mayor's energy hierarchy.	100%	Assumes that all new build & refurbishment hospitals reach a high efficiency.
Typical	% of floor space	99%		25%		0%	
b) Type of Property:							
Teaching	% of floor space	10%	Assumed current day figures.	10%	No change in the type of hospital built from the Business as Usual scenario.	10%	No change in the type of hospital built from the Business as Usual scenario.
Acute	% of floor space	20%		20%		20%	
Cottage	% of floor space	20%		20%		20%	
Long Stay	% of floor space	50%		50%		50%	
5) Projection Variable: School Buildings							
a) Energy Efficiency:							
Good Practice	% of floor space	1%	Constant with current day figures.	75%	Achieved through the implementation of the Mayor's energy hierarchy.	100%	Assumes that all new builds and refurbishment reach the highest efficiency.
Typical	% of floor space	54%		25%		0%	
Poor Practice	% of floor space	45%		0%		0%	
b) Type of Property:							
Primary Schools	% of floor space	50%	Assumed current day figures.	50%	No change in the type of school built.	50%	No change in the type of school built.
Secondary (No Pool)	% of floor space	45%		45%		45%	
Secondary (with Pool)	% of floor space	5%		5%		5%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	 Explanation	SCENARIO 2: Mayor's Strategies Value	 Explanation	SCENARIO 3: High Sustainability Value	 Explanation
6) Projection Variable: Hotels							
a) Energy Efficiency:							
Good Practice	% of floor space	1%	Constant with current day figures.	75%	Achieved through the implementation of the Mayors energy hierarchy.	100%	Assumed that all new builds and refurbishment reach the highest efficiency.
Typical	% of floor space	54%		25%		0%	
Poor Practice	% of floor space	45%		0%		0%	
b) Type of Property:							
Luxury Hotel	% of floor space	27%	Constant with current day figures.	27%	No change in the type of hotel built.	27%	No change in the type of hotel built.
Business/Holiday Hotel	% of floor space	38%		38%		38%	
Smaller Hotel	% of floor space	35%		35%		35%	
7) Projection Variable: Retail							
a) Energy Efficiency:							
Good Practice	% of floor space	5%	Constant with current day figures.	75%	Achieved through the implementation of the Mayors energy hierarchy.	100%	Assumed that all new builds and refurbishment reach the highest efficiency.
Typical	% of floor space	50%		25%		0%	
Poor Practice	% of floor space	45%		0%		0%	
b) Type of Property:							
DIY Stores	% of floor space	15%	Constant with current day figures.	15%	No change in the type of retail built.	15%	No change in the type of retail built.
Non-Food Stores	% of floor space	35%		35%		35%	
Department Stores	% of floor space	20%		20%		20%	
Small Food Stores	% of floor space	15%		15%		15%	
Supermarkets	% of floor space	15%		15%		15%	

Appendix A2: Residential Energy Consumption

As there are no economic sectors in residential energy consumption, we have reclassified the first column from economic sectors to projection variables. These have been classified into two groups of variables, heating and hot water demand projections, and cooking and other appliances.

		SCENARIO 1: Business as Usual		SCENARIO 2: Mayor's Strategies		SCENARIO 3: High Sustainability	
Projection Variables	**Units**	**Value**	**Explanation**	**Value**	**Explanation**	**Value**	**Explanation**
Heating and Hot Water Demand Projections: Heating and hot water energy projections are determined by the SAP rating of new properties, refurbished properties and the rate of refurbishment. The details of each are given below.							
Average SAP for New Builds	SAP RATE (Max 120)	80	Current building standards.	95	Improved energy efficiency achieved from the Mayor's energy hierarchy and new build requirements.	110	All new properties have an SAP have a rating of 110 out of a maximum of 120.
% of Buildings refurbished	% Refurbishment Rate	1%	Estimated percentage of housing stock refurbished.	2%	Estimated refurbishment rate required to brings all fuel poor households out of fuel poverty by 2009.	4%	Twice the number of properties with an SAP Rating under 30.
SAP Ratings of Refurbished properties	Average increase in SAP rating	0	We assumed there is no change in the average SAP values of refurbishment.	3	The Mayor's policy of lifting all London properties out of fuel poverty (an SAP rating of 30) requires an average increase in SAP rating of 3.	6	Double the Mayor's Strategies scenario.

Projection Variables	Units	SCENARIO 1: Business as Usual Value	 Explanation	SCENARIO 2: Mayor's Strategies Value	 Explanation	SCENARIO 3: High Sustainability Value	 Explanation
Cooking and Other Appliances Projections: The other source of energy related emissions is from the onsite combustion of fuel and the use of electricity in appliances. These are projected changes in oil, gas and electricity consumption are detailed below.							
Change in Gas Consumption	% Growth Rate	0.0%	Assumed no reduction in gas consumption.	-0.8%	Historical change in consumption.	-0.8%	Assumed to be constant with Mayor's Strategies scenario.
Change in Electricity Consumption	% Growth Rate	0.8%	Assumed continued growth in electricity consumption based on historical mean.	0.8%	Historical change in consumption.	0.8%	Assumed to be constant with Mayor's Strategies scenario.
Change in Oil Consumption	% Growth Rate	0.0%	Assumed no reduction in oil consumption.	-7.3%	Historical change in consumption.	-7.3%	Assumed to be constant with Mayor's Strategies scenario.

Appendix A3: Transport Energy Consumption

As with domestic energy consumption transport is not divided into economic sectors. The first column has again been reclassified from economic sector to projection variables. These projection variables have been classified into eight categories:

- Road Speed;
- Transport mode choice of residents;
- Transport mode choice of non-residents;
- Transport mode choice of tourists;
- Average distance travelled; and
- Air travel.

		SCENARIO 1: Business as Usual		SCENARIO 2: Mayor's Strategies		SCENARIO 3: High Sustainability	
Projection Variables	**Units**	**Value**	**Explanation**	**Value**	**Explanation**	**Value**	**Explanation**
Road Speed: An increase in Road speed reduces the average emissions associated with each kilometre travelled leading to a net environmental benefit (assuming that there is no increase in the vehicle kilometres travelled). There are two variables for traffic speeds considered, the average speed and the year it is introduced.							
Average Traffic Speed expected in future km/hr	Kms / year	28	Constant with current day figures	30	Mayor's strategies are assumed to improve traffic flows in central London.	35	Mayor's strategies are assumed to improve traffic flows in central London.
Year of new traffic speed	Year	2004		2004		2004	

Projection Variables	Units	SCENARIO 1: Business as Usual — Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies — Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability — Value	SCENARIO 3: Explanation
Types of Journeys Undertaken by Residents in 2016: The choice of transport by London residents is divided into eight transports modes (freight is zero rated). The sum of each scenario should equal 100%							
Car	% of journeys	37%	Constant with current day figures	30%	Adjusted for movement to public transport.	25%	Adjusted for movement to public transport.
Motorcycles	% of journeys	1%		1%	Constant with current day figures.	1%	Constant with current day figures.
Taxi	% of journeys	1%		1%		1%	
Freight	% of journeys	0%		0%		0%	
Rail	% of journeys	3%		3%	Suggested increase in rail by 9%.	4%	Assumed 50% increase in capacity due to major infrastructure projects.
Underground	% of journeys	4%		5%	Suggested increase in underground by 15%.	5%	Assumed 25% increase in capacity due to major infrastructure projects.
Bus	% of journeys	11%		15%	Suggested increase in bus transport by 40%.	17%	Assumed 50% increase in capacity.
Passenger, walking or cycling	% of journeys	43%		45%	More cycle lanes and more road space to pedestrians.	47%	More cycle lanes and more road space to pedestrians.

Projection Variables	Units	SCENARIO 1: Business as Usual — Value	SCENARIO 1: Business as Usual — Explanation	SCENARIO 2: Mayor's Strategies — Value	SCENARIO 2: Mayor's Strategies — Explanation	SCENARIO 3: High Sustainability — Value	SCENARIO 3: High Sustainability — Explanation
Proportion of Journeys Undertaken by Non-Residents in 2016: The choice of transport by non-residents represents the travel requirements of UK residents entering into London, again it is divided into eight transports modes (freight is zero rated). The sum of each scenario should equal 100%.							
Car	% of journeys	40%	Constant with current day figures	36%	Adjusted for movement to public transport.	34%	Adjusted for movement to public transport.
Motorcycles	% of journeys	1%		1%	Constant with current day figures.	1%	Constant with current day figures.
Taxi	% of journeys	1%		1%		1%	
Freight	% of journeys	0%		0%		0%	
Rail	% of journeys	3%		3%	Suggested Increase in Rail by 9%.	5%	Assumed 50% increase in capacity due to major infrastructure projects.
Underground	% of journeys	4%		5%	Suggested Increase in underground by 15%.	5%	Assumed 25% increase in capacity due to major infrastructure projects.
Bus	% of journeys	8%		11%	Suggested Increase in bus transport by 40%.	12%	Assumed 50% increase in capacity.
Passenger, walking or cycling	% of journeys	43%		43%	More cycle lanes and more road space to pedestrians.	43%	More cycle lanes and more road space to pedestrians.

Projection Variables	Units	SCENARIO 1: Business as Usual – Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies – Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability – Value	SCENARIO 3: Explanation

Proportion of Journeys Undertaken by Tourists in 2016
The choice of transport by non-residents represents the travel requirements of tourists visiting London, as with non-residents it is divided into eight transports modes (freight is zero rated). Currently the transport mode choice for tourists is assumed to be the same as residents, non-residents due to the lack of any further information, this can be change as new information becomes available.

Projection Variables	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Car	% of journeys	40%	Constant with current day figures	36%	Adjusted for movement to public transport.	34%	Adjusted for movement to public transport.
Motorcycles	% of journeys	1%		1%	Constant with current day figures.	1%	Constant with current day figures.
Taxi	% of journeys	1%		1%		1%	
Freight	% of journeys	0%		0%		0%	
Rail	% of journeys	3%		3%	Suggested Increase in Rail by 9%.	5%	Assumed 50% increase in capacity due to major infrastructure projects.
Underground	% of journeys	4%		5%	Suggested Increase in underground by 15%.	5%	Assumed 25% increase in capacity due to major infrastructure projects.
Bus	% of journeys	8%		11%	Suggested Increase in bus transport by 40%.	12%	Assumed 50% increase in capacity.
Passenger, walking or cycling	% of journeys	43%		43%	More cycle lanes and more road space to pedestrians.	43%	More cycle lanes and more road space to pedestrians.

Projection Variables	Units	SCENARIO 1: Business as Usual – Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies – Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability – Value	SCENARIO 3: Explanation

Average journey length by transport type:
The average journey length of each mode of transport is also introduced as a variable. No impact has been quantified by the strategies, however, it is a key determinant of emissions and has been declared as a variable explicitly.

Projection Variables	Units	SCENARIO 1: Business as Usual – Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies – Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability – Value	SCENARIO 3: Explanation
Car	vkm	7	Constant with current day figures	7	Constant with current day figures	7	Constant with current day figures
Motorcycles	vkm	15		15		15	
Taxi	vkm	5		5		5	
Freight	vkm	12		12		12	
Rail	vkm	30		30		30	
Underground	vkm	19		19		19	
Bus	vkm	37		37		37	
Passenger, walking or cycling	Km	4		4		4	

Projection Variables	Units	SCENARIO 1: Business as Usual – Value	SCENARIO 1: Business as Usual – Explanation	SCENARIO 2: Mayor's Strategies – Value	SCENARIO 2: Mayor's Strategies – Explanation	SCENARIO 3: High Sustainability – Value	SCENARIO 3: High Sustainability – Explanation

Air Travel:
Air travel variables are determined by three different growth rates. For air travel demanded by London's residents is a function of economic growth. For UK residents, outside of London, the growth rate of air travel is determined by national economic growth projections and for international residents there is an assumed annual growth rate.

1) Income Elasticity of Demand for Air Travel for London Residents

Leisure	Rate of Change	2.77	Estimated from UK air travel projections with an assumed 2.5% economic growth rate netted out.	2.77	Assumed constant with Business as Usual scenario.	2.77	Assumed constant with Business as Usual scenario.
Business	Rate of Change	2.42		2.42		2.42	

2) Growth Rate of UK Residents using a GLA Airport

Leisure	% Annual Growth Rate	5.27%	Estimated from UK air travel projections.	5.27%	Assumed constant with Business as Usual scenario.	5.27%	Assumed constant with Business as Usual scenario.
Business	% Annual Growth Rate	4.92%		4.92%		4.92%	

3) Annual Growth Rate of International Residents using a GLA Airport

Leisure	% Annual Growth Rate	5.4%	Estimated from UK air travel projections.	5.4%	Assumed constant with Business as Usual scenario.	5.4%	Assumed constant with Business as Usual scenario.
Business	% Annual Growth Rate	5.4%		5.4%		5.4%	

Appendix A4: Waste Projections

Waste projections are separated into arisings and disposal. The arisings are determined by each economic sectors arising growth rate and disposal is determined by the disposal options available to each waste stream.

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: Explanation
Projection Variable: Waste Arisings The waste arising of each sector are determined by an annual growth rate, a waste productivity factor. For the C&I and C&D waste streams the growth rate is a function of GVA, for the MSW waste stream the growth rate is a function of the number of households.							
Primary and utilities (C&I)	% Annual Growth Rate Per unit of GVA	1.11%	Expected Waste Productivity Factors per unit of GVA to achieve waste arising projections (annual 2% increase).	0.56%	Assumes that waste growth rate per unit of GVA is halved.	0.00%	Assumes a zero growth in waste arisings per unit of GVA.
Manufacturing (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Retail (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Wholesale (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Hotels & restaurants (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Transport & communication (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Financial services (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	

		SCENARIO 1: Business as Usual		SCENARIO 2: Mayor's Strategies		SCENARIO 3: High Sustainability	
Economic Sector	**Units**	**Value**	**Explanation**	**Value**	**Explanation**	**Value**	**Explanation**
Business services (C&I)	% Annual Growth Rate Per unit of GVA	1.11%	Expected Waste Productivity Factors per unit of GVA to achieve waste arising projections (annual 2% increase).	0.56%	Assumes that waste growth rate per unit of GVA is halved.	0.00%	Assumes a zero growth in waste arisings per unit of GVA.
Public administration (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Health & Education (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Other services (C&I)	% Annual Growth Rate Per unit of GVA	1.11%		0.56%		0.00%	
Construction (C&D)	% Annual Growth Rate Per unit of GVA	-1.68%	Expected Waste Productivity Factors per unit of GVA to achieve GLA waste arising projections.	-1.68%	Constant with Business as Usual Scenario.	-1.68%	Constant with Business as Usual Scenario.
Domestic Sector (MSW)	% Annual Growth Rate Per Household	3%	Expected Waste Productivity Factors per household to achieve GLA waste arising projections.	1.5%	Assumes that waste growth rate per household is halved.	0.00%	Assumes a zero growth in waste arisings per household.

Economic Sector	Units	SCENARIO 1: Business as Usual		SCENARIO 2: Mayor's Strategies		SCENARIO 3: High Sustainability	
		Value	Explanation	Value	Explanation	Value	Explanation

Projection Variable: Waste Disposal

The waste disposal projection variable is separated into the three waste streams, C&I, C&D and MSW. Some waste disposal options are only expected to be applied to the MSW waste stream although they are included as waste disposal options for all waste streams. There are rounding errors in these figures as we have not presented any decimal places with percentage changes.

1) C&I Waste Disposal Route in 2016

Economic Sector	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Reuse	% of waste disposed	2%	Disposal Route determined by the business as usual scenario in Waste Modelling Options.	2%	Disposal route is determined by Exceeding EC Proposed Target Option Waste Modelling Options report.	2%	Assumed to remain the same as the Mayor's Strategies scenario.
Recycling	% of waste disposed	39%		89%		89%	
Composting	% of waste disposed	0%		0%		0%	
Incineration	% of waste disposed	3%		2%		2%	
Landfill	% of waste disposed	56%		7%		7%	
Backfill/cover	% of waste disposed	0%		0%		0%	
MBT	% of waste disposed	0%		0%		0%	
AD	% of waste disposed	0%		0%		0%	
Gasification / Pyrolysis	% of waste disposed	0%		0%		0%	

2) C&D Waste Disposal Route in 2016

Economic Sector	Units	S1 Value	S1 Explanation	S2 Value	S2 Explanation	S3 Value	S3 Explanation
Reuse	% of waste disposed	7%	Disposal Route determined by the business as usual scenario in Waste Modelling Options.	7%	Disposal route is determined by Exceeding EC Proposed Target Option Waste Modelling Options report.	7%	Assumed to remain the same as the Mayor's Strategies scenario.
Recycling	% of waste disposed	80%		90%		90%	
Composting	% of waste disposed	0%		0%		0%	
Incineration	% of waste disposed	0%		0%		0%	
Landfill	% of waste disposed	2%		1%		1%	
Backfill/cover	% of waste disposed	10%		2%		2%	
MBT	% of waste disposed	0%		0%		0%	
AD	% of waste disposed	0%		0%		0%	

Economic Sector	Units	SCENARIO 1: Business as Usual — Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies — Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability — Value	SCENARIO 3: Explanation
Gasification / Pyrolysis	% of waste disposed	0%					
Reuse	% of waste disposed	0%	Disposal Route determined by option 1 business as usual scenario in SU Technical Report	0%	Disposal routes are determined by option 5 in SU Technical Report.	0%	Disposal routes are determined by option 3 High Recycling in SU Technical Report.
Recycling	% of waste disposed	5%		28%		37%	
Composting	% of waste disposed	3%		15%		20%	
Incineration	% of waste disposed	16%		15%		15%	
Landfill	% of waste disposed	76%		26%		25%	
Backfill/cover	% of waste disposed	0%		0%		0%	
MBT	% of waste disposed	0%		11%		1%	
AD	% of waste disposed	0%		2%		0%	
Gasification / Pyrolysis	% of waste disposed	0%		4%		0%	

Appendix A5: Water Projections

Water projections are separated into two parts, consumption and disposal. Consumption is determined according to economic sector whilst disposal is considered according to the disposal options and discharge consents.

Economic Sector	Units	SCENARIO 1: Business as Usual – Value	SCENARIO 1: Business as Usual – Explanation	SCENARIO 2: Mayor's Strategies – Value	SCENARIO 2: Mayor's Strategies – Explanation	SCENARIO 3: High Sustainability – Value	SCENARIO 3: High Sustainability – Explanation
Projection Variable: Discharges to the water course in 2016 Four discharges to the water course are considered. These are not varied in each scenario as they are currently considered outside the remit of the Mayor's strategies.							
Ammonia	% Change in emissions per head of population	-25%	Set at a level that will maintain constant absolute emissions until 2016.	-25%	Constant with the Business as Usual Scenario.	-25%	Constant with the Business as Usual Scenario.
Biochemical oxygen demand (BOD)	% Change in emissions per head of population	-24%		-24%		-24%	
Phosphate discharges	% Change in emissions per head of population	-4%		-4%		-4%	
Suspended Solids discharges	% Change in emissions per head of population	-10%		-10%		-10%	
Projection Variables: Disposal of Sewage Sludge in 2005 As with discharges to the water course, the disposal of sewage sludge is considered outside the remit of the Mayor's strategies, although the Mayor's renewable targets may encourage further sludge incineration.							
Agriculture	% of total sludge arisings	71%	Current UK estimates.	71%	Constant with the Business as Usual Scenario.	71%	Constant with the Business as Usual Scenario .
Incineration	% of total sludge arisings	21%		21%		21%	
Landfill	% of total sludge arisings	7%		7%		7%	
Reclamation	% of total sludge arisings	0%		0%		0%	
Other	% of total sludge arisings	1%		1%		1%	
Sea	% of total sludge arisings	0%		0%		0%	

Economic Sector	Units	SCENARIO 1: Business as Usual — Value	SCENARIO 1: Business as Usual — Explanation	SCENARIO 2: Mayor's Strategies — Value	SCENARIO 2: Mayor's Strategies — Explanation	SCENARIO 3: High Sustainability — Value	SCENARIO 3: High Sustainability — Explanation

Projection Variables: Water by Economic Sector in 2016

Water consumption for each economic sector is given as a function of the number of employees with the except for the hotels and restaurant sectors where it is considered a function of the number of restaurant visitors or the type of hotel.

1) Water Consumption per Employee

Economic Sector	Units	SCENARIO 1 Value	SCENARIO 1 Explanation	SCENARIO 2 Value	SCENARIO 2 Explanation	SCENARIO 3 Value	SCENARIO 3 Explanation
Primary and utilities	M3 per employee in 2016	25.22	Assumed to be twice Thames Water's efficiency target.	18.92	Assumed to be a half of high sustainability's maximum water efficiency.	12.61	Based on Thames Water's efficiency target.
Manufacturing	M3 per employee in 2016	25.22		18.92		12.61	
Construction	M3 per employee in 2016	25.22		18.92		12.61	
Retail	M3 per employee in 2016	12.61		9.46		6.31	
Wholesale	M3 per employee in 2016	12.61		9.46		6.31	
Transport & communication	M3 per employee in 2016	25.22		18.92		12.61	
Financial services	M3 per employee in 2016	12.61		9.46		6.31	
Business services	M3 per employee in 2016	12.61		9.46		6.31	
Public administration	M3 per employee in 2016	12.61		9.46		6.31	
Health & Education	M3 per employee in 2016	25.22		18.92		12.61	
Other services	M3 per employee in 2016	25.22		18.92		12.61	

Economic Sector	Units	SCENARIO 1: Business as Usual — Value	Explanation	SCENARIO 2: Mayor's Strategies — Value	Explanation	SCENARIO 3: High Sustainability — Value	Explanation
2) Water Consumption per restaurant in 2016							
Number of Restaurant Visits a day per Tourist	Visits / day	1.00	Assumed current day figures	1.00	Constant with Business as Usual Scenario	1.00	Constant with Business as Usual Scenario
Number of Restaurant Trips A Day Per Resident	Visits / day	0.07		0.07		0.07	
Average Consumption M3 per Customer	M^3 Per Customer Visit	0.012	Constant with current day figures	0.009	Assumed a 25% water saving	0.006	Assumed a 50% water saving
3) Hotel Consumption in 2016							
a) Type of Hotel							
Very High Water Consumption	% of floor area built	40%	Expected water intensity of the hotel industry.	30%	Assumed water intensity of the hotel industry under the Mayor's Strategy scenario	23%	Assumed water intensity of the hotel industry under the High Sustainability scenario.
High Water Consumption	% of floor area built	50%		38%		28%	
Average Water Consumption	% of floor area built	10%		8%		6%	
Low Water Consumption	% of floor area built	0%		0%		0%	
b) Water Intensity							
Luxury Hotel	% of floor area	27%	The same hotel type floor area as are used for energy projections.	27%	The same hotel type floor area as are used for energy projections.	27%	The same hotel type floor area as are used for energy projections.
Business / Holiday Hotel	% of floor area	38%		38%		38%	
Smaller Hotel	% of floor area	35%		35%		35%	

Economic Sector	Units	SCENARIO 1: Business as Usual Value	SCENARIO 1: Business as Usual Explanation	SCENARIO 2: Mayor's Strategies Value	SCENARIO 2: Mayor's Strategies Explanation	SCENARIO 3: High Sustainability Value	SCENARIO 3: High Sustainability Explanation
3) Domestic Water Consumption in 2016							
Consumption Per Head of Population	Litres per head per day in 2016	59.00	Constant with current reported figures.	44.25	Assumes similar proportions to offices.	29.50	Assumes similar proportions to offices.

Projection Variable: Water Leakage
Water leakage rate is given for two different years, 2005 and 2006. Leakage is determined as a percentage of total water supply

Economic Sector	Units	Scenario 1 Value	Scenario 1 Explanation	Scenario 2 Value	Scenario 2 Explanation	Scenario 3 Value	Scenario 3 Explanation
2005	% of total supply that is leaked.	32%	Assumed constant with the minimum Leakage rate so far achieved.	32%	Assumes that OFWAT targets are met and maintained but behind schedule.	18%	Assumes that OFWAT targets are met and maintained according to their schedule.
2016	% of total supply that is leaked.	32%		18%		18%	

Appendix A6: Land Use Projections

In the land use projections we have considered four categories of projection variables:

- Density increases;
- Land use priorities;
- Land use constraints; and
- Land Transfers

Projection Variables	Units	SCENARIO 1: Business as Usual — Value	SCENARIO 1: Business as Usual — Explanation	SCENARIO 2: Mayor's Strategies — Value	SCENARIO 2: Mayor's Strategies — Explanation	SCENARIO 3: High Sustainability — Value	SCENARIO 3: High Sustainability — Explanation
Projection Variable: Population Density in 2016 The population, and employment density, in 2016 determines the number of density of people per plot for new developments. As it is only applied to new properties its impact is linked to the rate of new build considered under the energy scenarios.							
Residential Density Increase of New Developments	Percentage increase in density for new developments	0%	Assumes there is no increase in either employment or residential density.	23%	Density increases to half the high sustainability densities reported in GLA's research.	46%	Density increases to the high sustainability densities reported in GLA's research.
Commercial (Employee) Density Increase of New Developments	Percentage increase in density for new developments	0%		17%		34%	

Projection Variables	Units	SCENARIO 1: Business as Usual		SCENARIO 2: Mayor's Strategies		SCENARIO 3: High Sustainability	
		Value	Explanation	Value	Explanation	Value	Explanation
Projection Variable: Land Use Priority The available land has to be ranked on a scale of 1 to 8 according to the development priority (where 1 is the first land category to be developed).							
Roads & Runways	Development Priority	2	Assumed development priority.	2	Assumed development priority.	2	Assumed development priority.
Railway Lines	Development Priority	3		3		3	
Car parks & Hard Standing	Development Priority	4		4		4	
Brownfield	Development Priority	1		1		1	
Private Green-space	Development Priority	5		5		5	
Public Green-space - Managed	Development Priority	6		6		6	
Public Green-space - Unmanaged	Development Priority	7		7		7	
Thames & Tributaries	Development Priority	8		8		8	

Projection Variables	Units	SCENARIO 1: Business as Usual – Value	SCENARIO 1: Explanation	SCENARIO 2: Mayor's Strategies – Value	SCENARIO 2: Explanation	SCENARIO 3: High Sustainability – Value	SCENARIO 3: Explanation
Projection Variable: Land Use Constraints. The projection variable, land use constraints, determines the percentage of land that is available for redevelopment. This remaining land might be unavailable for development due to logistical, environmental or economic constraints.							
Roads & Runways	% of land available	0%	We assume only a half of brownfield sites would normally be redeveloped, excess demand is met by private green space.	0%	The Mayor's strategy increases the amount of brownfield sites being redeveloped. Some hard surfaces are redeveloped and excess demand is met by private green space.	0%	Remains constant with the Mayor's Strategies scenario.
Railway Lines	% of land available	0%		0%		0%	
Car parks & Hard Standing	% of land available	0%		5%		5%	
Brownfield	% of land available	50%		80%		80%	
Private Green-space	% of land available	50%		50%		50%	
Public Green-space - Managed	% of land available	0%		0%		0%	
Public Green-space - Unmanaged	% of land available	100%		100%		100%	
Thames & Tributaries	% of land available	0%		0%		0%	
Projection Variables: Land Transfers The projection variable, land transfers, allows for land to be transferred between sectors if there is a significant surplus. Currently the residential and domestic sectors are considered for land transfer between the residential and commercial sectors.							
Commercial buildings built on residential land	Annual Percentage	0%	No change in land allocation between commercial and residential.	0%	We assume that 5% of residential buildings are built on land previously considered commercial.	0%	We assume that 5% of residential buildings are built on land previously considered commercial.
Residential buildings built on commercial Land	Annual percentage	0%		5%		5%	

Appendix A6: Noise Projections

We have only considered one variable for noise projections. This is the dominant source of noise experience by the population. This is then used to in the dose response functions to determine the number of people annoyed by each noise source.

Economic Sector	Units	SCENARIO 1: Business as Usual		SCENARIO 2: Mayor's Strategies		SCENARIO 3: High Sustainability	
		Value	Explanation	Value	Explanation	Value	Explanation
Projection Variable: Dominant Noise Source in 2016 The dominant noise source projection variable describes the percentage of London's residents who consider a particular type of noise as dominant in their area. It should always be equal to 100% as the impact of that noise is determined by the average noise level experienced in London.							
Road Traffic	Percentage of the population	45%	Based on current day estimates	36%	Changes in proportion to changes in traffic	31%	Changes in proportion to changes in traffic
Railways	Percentage of the population	21%		24%		29%	
Aircraft	Percentage of the population	34%		40%		41%	