ITRC

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ITRC strategy blueprint: Combining sector headline strategies to generate the ITRC strategy portfolio

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ITRC Strategy Blueprint:
Combining sector headline strategies to generate the ITRC strategy portfolio

Summary

- The ITRC assessment aims to test performance (and robustness) across a range of future conditions (scenarios) of long-term strategies for national infrastructure provision.
- Scenarios are generated from variables exogenous to the analysis: changes to the national and global economy, demographic changes and environmental changes.
- A range of headline infrastructure strategies are proposed, effecting change in infrastructure use and provision across two main dimensions: changes in demand management, and changes in capacity provision (through changes to system efficiencies or infrastructure composition).
- Changes in capacity provision imply a range of different capital investment levels.
- Short-term (to 2030) and long-term (to 2050 and beyond) strategies are combined to give a range of strategy options over time for each sector.
- Two nexuses are considered: Energy-Transport and Energy-Water.
- The sector strategies for these nexuses are combined according to the energy demand implications of each future transport or water strategy (e.g. a particular transport strategy with very high electricity demand expectations can only be combined with energy strategy futures where electricity generation is appropriately high)
- Waste is assumed to be largely independent of other sectors.
- A small number of cross-sector strategy combinations are suggested.

1. Background

ITRC's modelling activity (whereby National Infrastructure is represented as a *system of systems* by capacity and demand models of five different infrastructure sectors – Energy, Transport, Water & Waste Water, and Solid Waste) is aimed at informing decisions regarding planning and investment in national infrastructure (NI) systems by evaluating the (robustness of) performance of NI strategies in providing infrastructure services under a wide range of future conditions.

Decisions that might change the system state are introduced by input variables representing **social and behavioural change** (incorporated as changes in demand), **technological change** (incorporated as changes of efficiencies and technology-cost parameters), and **systemic change** within the physical system of infrastructure assets (incorporated in the configuration and capacity of infrastructure networks).

Changes in exogenous variables that influence the performance of the NI system are represented by scenarios of socio-economic variables, climate variables and other technological variables, which are seen outside the influence of infrastructure planners and investors.

This separation of changes to the system through decisions (or strategies) and external future conditions (or scenarios) enables the evaluation of robustness of infrastructure system performance conditional to the chosen strategy but across a wide range of future conditions.

NI system performance will be evaluated by assessing the various model outputs across a number of metrics. This is a multi-attribute assessment of performance, and the measures to be assessed will include:

- capacity and demand of infrastructure services,
- capacity utilisation and security of supply,
- side effects of service provision (emissions, safety, quality of services),
- costs for service provision and investments.

2. NI Scenario Generation

Three components of the context in which NI operates are taken to be completely exogenous to the analysis: changes to the national economy, demographic changes, and environmental changes.

2.1 Socio-economic change

A range of socio-economic futures will be assessed as part of the ITRC assessment. Outputs from current work (WS1.3 and WS1.4) will include a range of internally consistent socio-economic future trajectories, acknowledging the interaction between prosperity and population growth. Additional outputs from WS1.3, based on possible future global economic conditions, will include the long term effect on fossil-fuel costs.

Demographic change affects demand for infrastructure services. The Office of National Statistics publishes projections of population change across a range of timeframes, and WS1.4 will produce a range of possible future trajectories based on this ONS data[1].

Economic change affects the population's ability to spend on infrastructure services (and hence affects demand), and affects government/NI owners' ability to invest in future changes (affecting change in the composition of the infrastructure system). Historically, growth in GDP has averaged 2.3% pa, and upper and lower bounds are given as outcomes of ITRC WS1.3. One particular implication of economic growth is that higher GDP is likely to result in higher demand for NI, but coupled with higher investments, and ultimately higher capacity.

Global fossil-fuel costs affect both operating costs and transport costs in particular. Some national policy measures may affect these costs, but for ITRC, these are assumed to be exogenous to the models. These costs are outputs of WS1.3 econometrics model.

2.2 Environmental change

Environmental change affects resource for Water, and demand for Energy. For Cycle 2 of the ITRC study, data for future projected UK climate change (seasonal temperatures, rainfall, sea-level rise) are given by UKCP09[2] emissions scenarios (in turn based on the SRES scenario work[3] (IPCC 2000)). Although these projections are likely to be superseded by an equivalent assessment near the end of the ITRC study (based on the on-going work on Representative Concentration Pathways (RCPS) and associated Shared Socioeconomic reference Pathways (SSPs)(Arnell et al. 2011)), it is not envisaged that new climate change scenarios will be available before the end of the project.

[1] To limit the number of scenarios the population growth may be given in terms of different growth bands (similar to the Low, Medium, High used for the FTA, but with a greater number of narrower bands – TO BE CONFIRMED)

[2] http://ukclimateprojections.defra.gov.uk/

[3] In UKCP09, projections are developed under three different emissions scenarios, two of which come from the A1 storyline, and one from the B1 storyline developed by the IPCC Special Report on Emissions Scenarios. Within UKCP09 the emission scenarios are labelled based on their relative greenhouse gas emissions levels - High (SRES A1FI), Medium (SRES A1B) and Low (SRES B1) - and comprise a wide range but not the full set of SRES emissions scenarios.

3. NI Strategy generation

The ITRC guiding hierarchy for strategy generation, presented in Figure 1, consists of high-level policy dimensions, types of changes to the infrastructure system, a portfolio of policy options, and model implementation of these options.

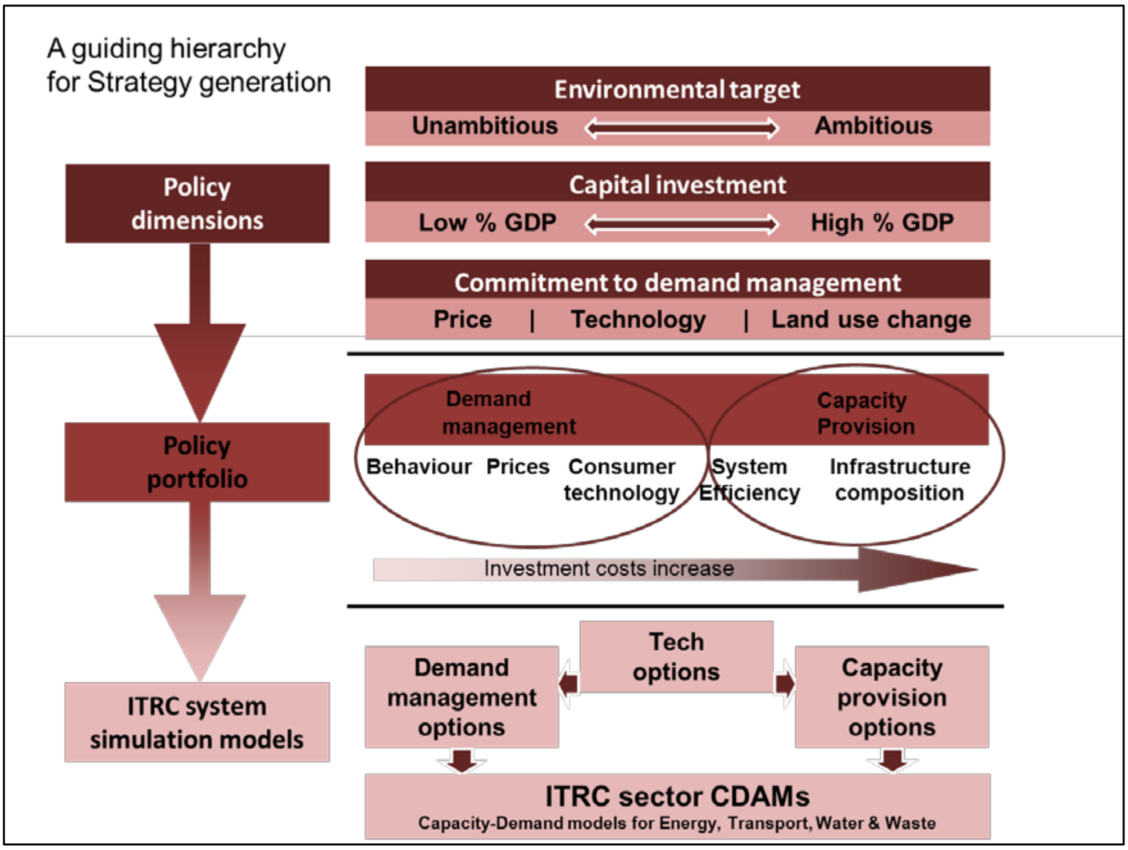

Figure 1: Illustration of the strategy generation process, starting from high-level policy dimensions (Environmental ambition, capital investment level, demand-related policy focus), over the different types of change within the different sectors, down to interpretations of types of change as extent (and timing) of use of single options.

Different strategies will have a range of expected capital investment requirements, and are likely to have different levels of ambition at effecting change in the environmental impact of NI. The strategies will also have different implications for how demand is managed, either through changes in costs to the consumer, changes in technologies (including the rate and diversity of technological innovation), or through levels of decentralisation and other land use factors. However, such high-level policy or strategy dimensions are not easy to implement in the ITRC models. Thus, strategies are considered as decisions which aim to influence changes in demand (through social and behavioural change), and changes in capacity provision (either technologically increasing system efficiencies, or through physical changes to the suite of infrastructure assets). These changes can be more readily ascribed to variables within the models, and are described in greater detail below.

3.1 Strategies for demand management

Influencing user behaviour (with only minor intervention)

User behaviour can be influenced by offering targeted information regarding their use of infrastructure and by other societal pressures. Sector-specific examples include reducing domestic energy use through energy saving schemes, achieving transport modal shift through societal pressure, increasing local levels of grey water recycling by introducing water usage schemes and increased levels of recycling and other resource recovery. However, while attractive in terms of the likelihood of lower overall costs of implementation, we have to be realistic about the level of societal behaviour change which may be achievable through education measures.

Pricing measures
Taxation and financial incentive policies influence demand for infrastructure services. Examples include road user charging measures, or other regulations or taxes designed to reduce fossil fuel use and promote electric vehicles; tax incentives to encourage investment in new technologies; and per volume tariffs for water consumption or waste generation.

Consumer technology
Demand can also be influenced by technological changes to the way a system is used. For example increased energy efficiency in domestic appliances, alongside the national roll-out of smart meters is likely to influence energy demand, and increased use of ICT could result in variations in travel habits.

3.2 Strategies enabling change in capacity provision

System efficiency
Technological advances and different approaches to capacity utilisation can affect the overall efficiency of an infrastructure system. For example, efficiencies in road transport can be achieved through increased fuel economy, optimised route planning or vehicle-to-vehicle interactions.

Infrastructure composition
Changes to the infrastructure system itself will be achieved through new-build (such as new rail links, motorways, power stations or reservoirs), and adaptation of existing infrastructure, replacing out-dated infrastructure with modern materials, or incorporating new technologies. The transition to renewable energy generation is one example of how the physical infrastructure required for distribution of energy may remain relatively unchanged, but the landscape of options for energy generation might change significantly.

The ITRC models take two approaches to how systemic change should be handled:
Energy capacity (supply) and Waste are optimised models (by cost and locality), so provide answers to what systemic change is required to meet different levels of demand – in this case, strategies can be created by altering availabilities and choice of energy generation/treatment technology (e.g. restricting the nuclear option at a certain point in time, or allowing the model to invest in cheaper energy generation technologies relatively early). Thus, strategies for these models need to incorporate varied restrictions on the available technologies.

Models for Transport and Water have systemic change as an input variable – so different strategies need to include information in the model of what is actually expected to be built, given the different levels of tech and investment associated with each strategy. For transport, such systemic change is step-wise in nature (e.g. the number of lanes of a stretch of road cannot increase by a small percentage, which might be the case for behaviour change). In the short term, this can be achieved by assessing current and future spending commitments and applying these (or not) to create future strategies with and without such infrastructure developments. In the longer term, this may be more challenging, since to explicitly state what transport infrastructure will be included in 2050 or 2080 is highly arbitrary.

4. Strategy construction process and examples

A particular scenario/strategy combination will comprise the exogenous assumptions about the socio-economic and environmental context in which national infrastructure is operated, together with high-level assumptions which determine the **overall willingness to invest in** new infrastructure assets, the **environmental ambition**[4] (both in terms of decarbonisation and other environmental impacts of infrastructure operation), and the **level of commitment to demand management** (strong price signals, consumer technology, level of decentralisation).

[4]An ambitious environmental focus would entail building on the current policies aimed at decarbonising the energy and transport system (through reducing energy consumption, improving energy efficiency, emphasis on renewable energy and sequestration of carbon into carbon sinks). Less ambition may entail more focus on future development, resilience and growth regardless of environmental impacts.

4.1 Defining and combining 'headline strategies'

Sector teams have each provided a number of 'headline strategies' which represent a menu of options within each infrastructure sector. These strategies span the range of policy dimensions described above and shown in Figure 1, and are set out below in Boxes 1 to 5. Generally, these sector specific Headline strategies are comprised of combinations of 'atoms of change', sub-strategies focused on changes in demand, infrastructure composition and supply. (Note that Waste strategies tend to focus simultaneously on all aspects of the infrastructure system.)

Each sector has limited the number of strategies to a manageable number (from 4 to 10). This is often more than previous scenario studies, but is still much fewer than the number of conceivable strategies. The emphasis has been put upon developing a reasonably concise set of strategies that spans the range of possibilities.

Some strategies are more likely to be effective in the short term, while others are not likely to become important until later this century. For energy in particular, this offers an opportunity to consider a range of future policy directions which change over time, by considering pairs of headline strategies – those that are likely to occur within the next 30 years, and those which might only be effective beyond then. Table 1 shows a selection of the range of energy strategy pairs which could be considered. Similar strategy pairs are shown for Transport (Table 2), Water (Table 3) and Wastewater (Table 4).

Acknowledging the energy sector's central position in terms of infrastructure systems, we are initially considering the two major cross-sector nexuses where interactions are likely to be greatest: Energy-Transport and Energy-Water. However, in order to limit the number of cross-sector strategies to be tested in the ITRC modelling, we have assumed certain levels of energy demand associated with different transport and water strategies would be paired with energy strategies with similar expectations of demand. For example, a transport strategy which relies on fossil fuels in the longer term would be assessed only in combination with those energy strategies which incorporate fossil fuels as one of the major components of energy generation mix. Similarly, transport strategies in which aim is for large scale electrification of the fleet would only be assessed in combination with similar energy strategies. These pairwise strategy combinations are set out in Table 5 for Energy and Transport. Combining Energy and Water strategies is currently work in progress, but an example is given in Table 6.

Finally, as an example of how a short list of transition strategies might be given, Table 7 shows a range of cross-sector strategy combinations, ranging from S1, the relatively environmentally unambitious 'do nothing' / 'do minimum' / 'continue current trends' strategy, to the highly ambitious strategy S11 – a solar future with high-tech transport connectivity and reduced demand for water. It will hopefully be possible to draw some narratives around these combinations of transition strategies.

We acknowledge that other interesting combinations of strategies will undoubtedly emerge as a result of further discussion and consultation.

Box 1: Energy strategies

Energy headline strategies

	Strategy name	Demand change	Structural change	Capacity/Supply change
EN0	Minimal policy intervention	ED0 – No change	ES0 – No change	EC0 – No change
EN1	Central electric/flexible consumer	ED3 – Demand response	ES0 – No change	EC2a,b,c – High electricity futures
EN2	Solar world	ED2 – Demand reduction	ES3 – High distributed storage	EC4 – High solar
EN3	Local energy and biomass	ED2 – Demand reduction	ES2 – Distributed generation and heat	EC3 – Biofuel nation
EN4	Interconnected world	ED1a,b – Electrification	ES1 – High interconnection	EC2a – High offshore and marine
EN5	Gas world	ED0 – No change	ES0 – No change	EC1 – Dash for gas
EN6	Local hydrogen	ED3 – Demand response	ES4 – Decentralised hydrogen	EC2a – High offshore and marine
EN7	Electrification of heat and transport	ED1a,b – Electrification	ES0 – No change	EC2a – High offshore and marine EC4 – High solar
EN8	Nuclear & gas	ED0 – No change	ES0 – No change	EC1 – Dash for gas EC2c – High nuclear
EN9	All in – diverse low carbon (comparable contribution from listed options)	ED1a,b – Electrification ED3 – Demand response ED2 – Demand reduction	ES3 – High distributed storage ES2 – Distributed generation and heat	EC2a – High offshore and marine EC4 – High solar EC3 – Biofuel nation

Energy strategy components:

DEMAND CHANGE		
ED0	No change	Modest changes in demand
ED1a	Electrification of heat	Electrification of heat
ED1b	Electrification of transport	Electrification of transport
ED2	Demand reduction	Radical demand reduction
ED3	Demand response	Radical demand response
STRUCTURAL CHANGE		
ES0	No change	Little change in networks, no major use of storage or distributed generation
ES1	High interconnection	High interconnection in electricity to European systems
ES2	Distributed generation and heat	Distributed generation, giving reduced use of grid for bulk transmission, with technology mix including CHP and district heating
ES3	High distributed storage	Cheaper, distributed storage becomes normal in households/commercial complexes
ES4	Decentralised hydrogen	Decentralised hydrogen production
CAPACITY/SUPPLY CHANGE		
EC0	No change	Not much change - mixed supply i.e. basically gas for heating, oil for transport and mixed sources for electricity
EC1	Dash for gas	Supply is mostly cheap gas, including for power generation and CNG for transport. Probably more gas interconnection and LNG
EC2a	High offshore and marine	High electricity futures – offshore (including marine)
EC2b	High CCS	High electricity futures – CCS around existing coal and gas sites
EC2c	High nuclear	High electricity futures – nuclear at coastal sites
EC3	Biofuel nation	Biofuels (possibly EC3a for transport and EC3b for CHP with CCS)
EC4	High solar	Solar PV and storage both cheap, so this becomes the dominant energy paradigm

Energy headline strategies – narratives

	Strategy name	**Example narrative**
EN0	Minimal policy intervention	There is no significant strengthening of climate policies and therefore longer term targets are not necessarily met. Concerns about energy security continue and ensure that there is sufficient investment to ensure reasonable levels of energy security. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. Smart meters are rolled out, but there is no need for significant use of demand response. The energy supply sector changes rather slowly, with continued dominance of large scale investments by large companies. There is no significant investment in nuclear or CCS. Renewables investment continues as cost fall, but capacity increases only slowly. Power sector investment continues to rely largely on gas CCGTs with gas supplies from imported, but diverse, sources. Heat remains largely dependent on gas although with continued efficiency improvements. Transport remains fuel supply remains largely oil dependent with some slow penetration of biofuels and electricity.
EN1	Central electric/flexible consumer	There is a continued emphasis on strong climate policies with targets generally met. Concerns about energy security continue and are addressed primarily by large investments in low carbon electricity generation. This ensures that there continues to be a reasonable level of energy security. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. Smart meters are rolled out and increasingly used in demand response programmes in all demand sectors. In particular, new demands for electricity in heating (heat pumps) and transport (electric vehicles) are used to balance supply and demand. The electricity supply sector changes quickly in line with current policy plans. There is very large and rapid investment in a major low carbon power generation technology, with continued dominance of large companies. Within this there are three broad options Option a: High offshore There is early and rapid investment in offshore wind, primarily in the North Sea, followed by wave and tidal flow investment, mainly in the Atlantic, after 2030. Both developments are facilitated by major offshore grid extensions and strengthening of north to south transmission. Option b: High CCS Carbon capture and storage is demonstrated on both coal and gas power stations and rapidly becomes the preferred form of generation investment. There is rapid investment after 2030, largely on existing coal and gas power station sites, so that no significant changes in grid infrastructure are needed. Option a High nuclear There is successful investment in nuclear power before 2020 and a steady growth in investment the next decade, followed by new generation 4 technologies after 2030. Investment is confined to existing coastal nuclear sites, requiring some grid strengthening.
EN2	Solar world	There is a continued emphasis on strong climate policies with targets generally met. Concerns about energy security continue. Both are addressed by increasing amounts of local investment, in both demand reduction technologies and distributed solar PV. Existing long term trends in demand are reduced as upward pressures from population and economic growth are more than offset by improvements in energy efficiency, stimulated by a combination of active policy and rising awareness of energy issues as solar energy deployment becomes mainstream behaviour for companies and households. Smart meters are rolled out and increasingly used in demand response programmes in all demand sectors. New demands for electricity in heating (heat pumps) and transport (electric vehicles) are used to balance supply and demand. The electricity supply sector changes quickly. Initially this is in line with current policy plans, with high investment on onshore and offshore wind. After 2020, solar PV costs fall to below grid parity and a major paradigm shift occurs, with distributed solar becoming the dominant supply option before 2050. This change is facilitated by the availability of much lower cost electricity storage after 2030. Offshore wind remains important for winter power supply and some gas fired generation is retained for load balancing. Both PV and storage investment result in a major switch away from centralised investment and the dominance of large supply companies. Smart distribution grids become the main means of load balancing with the transmission grid of less importance. Lower cost storage assists the market penetration of both heat pumps and electric vehicles after 2030.

	Strategy name	Example narrative
EN3	Local energy and biomass	There is a continued emphasis on strong climate policies with targets generally met. Concerns about energy security continue. Both are addressed by increasing amounts of local investment, similar to solar world. But in this case there are no major technological breakthroughs and local energy plans use a wider range of energy sources, including more aggressive energy demand reduction and local biomass, both as a solid fuel and as biogas through the gas grid. Existing long term trends in demand change, as upward pressures from population and economic growth are more than offset by improvements in energy efficiency, stimulated by a combination of active policy and rising awareness of the need for local energy action. Smart meters are rolled out. In this case there is less emphasis on demand response, but increased emphasis on consumer information and demand reduction, especially in buildings. New demands for electricity in heating and transport are more limited. There is increased investment in heat networks in all large urban areas, using a combination of fuels, but largely biomass CHP. The electricity supply sector changes steadily. Initial investment is largely in wind, but in this case there is greater emphasis on onshore wind with rapid increases in the acceptance of onshore wind turbines, and much increased diversity of ownership, including by community groups, local authorities and cooperatives. These changes have implications for networks. There is increased deployment of distributed generation (although not as quickly or as highly distributed as in solar world), resulting in a more active role for electricity distribution grids. Biogas is increasingly introduced into the gas grid and takes a large share of gas demand, as total heat falls.
EN4	Interconnected world	There is a continued emphasis on strong climate policies with targets generally met. Concerns about energy security continue, not only in the UK but across Europe. As a result there is a planned investment in a European supergrid to ensure energy security. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. Smart meters are rolled out and increasingly used in demand response programmes in all demand sectors. In particular, new demands for electricity in heating (heat pumps) and transport (electric vehicles) are used to balance supply and demand. The electricity supply sector changes quickly. Initially this is in line with current policy plans. There is very large and rapid investment, especially in offshore wind. This plays a key role in kick-starting EU-wide collaboration on interconnection, initially in the North Sea states, but after 2030 to accommodate very large supplies of solar PV in southern Europe. Very large investments are made in electricity transmission, much with EU financial support. This includes new, high capacity, long distance, very high voltage, transboundary lines, but also massive strengthening of north to south transmission within the UK to take wind and marine power from Scotland to the rest of Europe.
EN5	Gas world	There is a weakening of climate policies and longer term targets are abandoned. Concerns about energy security continue and increase in the face of global uncertainties, placing increased emphasis on indigenous fossil fuel production. Shale gas technologies rapidly penetrate European markets, and after 2030 UK shale gas captures a major share of energy demand. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. There is no significant use of demand response or demand reduction. There is no significant investment in nuclear or CCS. Renewables investment declines as shale gas costs fall. Power sector investment after 2020 is entirely in gas CCGTs with gas supplies initially reliant on imported sources. After 2030 UK shale gas is the dominant source. The electricity supply sector changes rather slowly, with continued dominance of large scale investments by large companies. There is little change in grid configuration. The gas grid continues to develop and grow, both to supply new CCGTs, but also, after 2030 to transport very large gas flows from the shale gas fields in NW England to the rest of the UK. Heat remains largely dependent on gas although with continued efficiency improvements. Transport fuel supply remains initially oil dependent. After 2030 there is increased use in CNG vehicles which eventually become dominant.

	Strategy name	Example narrative
EN6	Local hydrogen	There is a continued emphasis on strong climate policies with targets generally met. Concerns about energy security continue and are addressed by large investments in low carbon electricity generation. This ensures that there continues to be a reasonable level of energy security. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. Smart meters are rolled out and increasingly used in demand response programmes in all demand sectors. After 2030, this is increasingly important to manage the integration of power from distributed fuel cell generation. The electricity supply sector changes quickly, initially in line with current policy plans. There is early and rapid investment in offshore wind, primarily in the North Sea. Solar costs also decline and distributed solar PV is widely adopted. As the penetration of intermittent renewables increases, there are increasing problems with grid control at times of high production, mirroring similar trends in other EU countries. Attempts to address these issues through demand response, interconnection and storage fail for a variety of reasons. Electricity costs fall to zero at times of high production, resulting in a localised hydrogen production industry. This begins as a niche supplier of hydrogen for vehicles, but stimulates the growth of a major fuel cell boom for both transport and stationary applications. There are limited changes to the electricity grid, but the gas grid changes after 2030 from methane to using increasing proportions of hydrogen. Heat remains initially dependent on gas, but after 2030 this becomes more hydrogen dependent as local hydrogen production and fuel cell deployment increase. Transport fuel supply remains initially oil dependent. Electric vehicles prove unpopular and as hydrogen becomes increasingly available, fuel cell vehicles become more popular after 2030.
EN7	Electrification of heat and transport	There is a continued emphasis on strong climate policies with targets generally met. Concerns about energy security continue and are addressed by large investments in low carbon electricity generation. This ensures that there continues to be a reasonable level of energy security. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. But the priority on the demand side is increased electrification of demand in heat and transport. Smart meters are rolled out and increasingly used in demand response programmes in all demand sectors. The electricity supply sector changes quickly, initially in line with current policy plans. There is early and rapid investment in offshore wind, primarily in the North Sea. Solar costs also decline and distributed solar PV is widely adopted. As the penetration of intermittent renewables increases, grid control is addressed primarily through demand response. The energy storage capacity of vehicle batteries and building heating systems become critical for the effective management of electricity loads. This provides additional drivers for the deployment of electric vehicles and heat pumps. There are rapid increases in the capacity of electricity grid, especially after 2030. Transmission and distribution networks are strengthened and additional transmission capacity built to bring power from offshore resources. The gas grid falls into decline and large parts are decommissioned between 2030 and 2050.
EN8	Nuclear & gas	There is a declining emphasis on climate policies and long term targets are abandoned. Increased global uncertainty is the dominant driver of energy policy. These are addressed by large investments in indigenous resources and technology, first shale gas and then nuclear power. This ensures high levels of energy security. Existing long term trends in demand continue with upward pressures from population and economic growth offset by improvements in energy efficiency, but only limited improvements in regulatory standards, some tax incentives and limited support programmes. Smart meters are rolled out and increasingly used in demand response programmes in all demand sectors. The electricity supply sector changes, but initially only slowly as gas increases is market share. Low carbon generation options initially make little progress, but after 2030 there is renewed interest in nuclear technology, by which time costs have fallen substantially as a result of developments elsewhere in the world. There is then increased investment in nuclear in the UK. Throughout there is continued dominance of large companies. Electrification of heating and transport is very limited.

	Strategy name	Example narrative
EN9	All in – diverse low carbon	There is a continued emphasis on strong climate policies with targets met. Concerns about energy security continue and are addressed by large investments in demand reduction, low carbon electricity generation and biomass technologies. This ensures that there continues to be excellent energy security. Existing long term trends in demand are reduced as upward pressures from population and economic growth are more than offset by improvements in energy efficiency, stimulated by a combination of active policy and rising awareness of the need for local energy action. Smart meters are rolled out and used effectively for both demand response and demand reduction. New technologies allow efficient use of both biomass derived fuels and electricity in transport. Heating demands fall and are met by a combination of low carbon technologies, including renewable CHP district heating and heat pumps. The electricity supply sector changes quickly in line with current policy plans. There is very large and rapid investment in all of the major low carbon power generation technologies. As a result the UK decarbonises supply very quickly up to 2030. The rapid growth of offshore wind provides a huge resource for the whole of Europe. Declining energy demand allows the UK to become a large exporter, enabled by rapid development of interconnection.

Box 2: Transport strategies

Transport headline strategies – construction

	Strategy name	**Demand change**	**Structural change**	**Capacity (utilisation)/Supply change**
TR0	Decline and decay	TD1 – Uncontrolled decline	TS0 – No change	TC1 – Reduced
TR1	Predict and provide	TD2 – Unconstrained growth	TS1 – Widespread expansion	TC0 – No change
TR2	Cost and constrain	TD3 – Managed decline	TS2 – Minor retrenchment	TC1 – Reduced
TR3	Adapting the fleet	TD0 – No change	TS0 – No change TS4 – Network electrification	TC0 – No change TC3 – Sophisticated vehicles
TR4	Promo-pricing	TD4 – Spatial redistribution	TS0 – No change	TC0 – No change
TR5	Connected grid	TD5 – ICT replacement	TS0 – No change TS4 – Network electrification	TC2 – Increased
TR6	Smarter choices	TD6 – Smarter choices & TD5 – ICT replacement	TS3 – Local enhancements	TC0 – No change TC4 – Sophisticated behaviour management

Transport strategy components

DEMAND CHANGE		
TD0	No change	Current trend continues
TD1	Uncontrolled decline	Mobility, connectivity and motorised transport decline; growth in walking/cycling
TD2	Unconstrained growth	Per capita demand increases, particularly for private modes and air
TD3	Managed decline	Per capita demand for motorised transport reduces; growth in walking/cycling
TD4	Spatial redistribution	No overall change, but spatial and temporal redistribution of demand
TD5	ICT replacement	Per capita demand reduces as ICT provides alternatives to travel.
TD6	Smarter choices	Switch from private to public modes, and from motorised to non-motorised travel.
STRUCTURAL CHANGE		
TS0	No change	Network unchanged
TS1	Widespread expansion	Large scale road building/widening, airport & seaport expansion, additional railway lines
TS2	Minor retrenchment	Network unchanged (possibly some small scale closures)
TS3	Local enhancements	Local enhancements to complement 'soft' interventions
TS4	Network electrification	Widespread electrification, network size maintained.
CAPACITY (UTILISATION)/SUPPLY CHANGE		
TC0	No change	Capacity utilisation per unit remains approximately constant
TC1	Reduced	Capacity utilisation reduces through less efficient use of the network
TC2	Increased	Capacity utilisation increases through more efficient use of the network
TC3	Sophisticated vehicles	Tech-led efficiency improvements in engines, hybrid technology, lighter vehicles
TC4	Sophisticated behaviour management	'Soft' interventions to promote more considerate and sustainable travel

Transport headline strategies – narratives

	Strategy name	Example narrative
TR0	Decline and decay	No replacements are found for fossil fuels, meaning that as reserves run out motorised transport increasingly becomes the preserve of the rich. Mobility reduces, with a growth in the use of slow but fuel-efficient modes (walk and cycle for passengers, canals/coastal shipping for freight) and in public transport (particularly electrically-powered systems. While substitution of travel by ICT interaction occurs, overall levels of connectivity decline.
TR1	Predict and provide	Demand modelling drives infrastructure construction, with large scale road building and widening programmes, airport and seaport expansion, and construction of additional railway lines. Construction determined by benefit-cost ratios, with environmental factors given a low weighting. Early schemes might include postponed road projects from the 1990s, additional runways at Heathrow, Gatwick and Stansted, the Dibden Bay container terminal, HS2 and the East-West rail link. The ongoing release of latent demand would mean that the expansion of transport networks continued throughout the century, although this could to some extent be offset by the phenomena of 'peak travel'.
TR2	Cost and constrain	Environmental, financial and congestion-related imperatives mean that pricing structures are used to suppress demand on congested or sensitive corridors. Measures might include national road pricing to disincentivise travel on congested routes at peak periods, work place parking levies, above inflation increases in rail fares where trains are overcrowded, higher levels of air passenger duty, and a tax on charter flights to free-up capacity for 'higher priority' business travellers. Smartcard technology would permit a high degree of price differentiation alongside these measures to encourage travellers to shift to less-congested routes and time periods and from private to public transport. There would be minimal investment in new infrastructure, with funds focused on maintaining the existing network.
TR3	Adapting the fleet	Rapid technological development allows wide-ranging modernisation of the vehicle stock for all modes. Increased engine efficiencies reduce energy consumption for all types of vehicle. Electrification is extended across the existing rail network and through the development of new tram and trolleybus networks. Extensive deployment of hybrid transmissions and regenerative braking also reduce fuel consumption. Advances in materials science lead to the production of lighter construction materials, reducing vehicle weights and thereby increasing fuel efficiency. These increases in efficiency and reductions in weight allow the operation of faster, longer trains which can carry more passengers per unit of capacity than current rolling stock, and of larger aeroplanes which again reduce fuel consumption per passenger.
TR4	Promo-pricing	A highly differentiated and disaggregated pricing regime is progressively introduced for all modes, to ensure that transport users pay as close as is possible to the exact social cost incurred by their journey. This includes, for example: differential taxation for users of different fuels in road vehicles, with lower emission fuels incurring less tax; differential taxation for users of different modes, depending on their environmental and infrastructure footprints; national road pricing, with highly-congested roads charged at a higher rate than little-used roads; and temporal variations in pricing, with users charged more to travel at busy times. The taxes raised would be earmarked for infrastructure enhancements. Together these measures would aim to optimise capacity utilisation.
TR5	Connected grid	Maximum possible use would be made of ICT to enhance the operation of transport systems, with a high and increasing level of embedded technology. Measures might include: Efficient road vehicle routing, based on real time traffic information enhanced by vehicle positioning systems; automated 'platoons' of vehicles on trunk roads to increase capacity utilisation and potentially increase maximum permitted speeds and the use of hard shoulder running; real time road pricing based on enhanced traffic information; cooperative traffic management systems; flexible pathing and moving block signalling on the railways; and smart logistics systems to optimise freight movements by all modes. Traffic data provided by crowd sourcing from mobile phones and sat navs would be used to optimise system performance. Overall traffic volumes could be progressively reduced as increased use of video-conferencing, 3D printing, ultra-high-speed internet connections and hologram-based communications reduce the need for both passenger and freight transport, fulfilling the hypothesis of 'peak travel'.
TR6	Smarter choices	A national program of measures to influence and alter travel behaviour and freight logistics would use a variety of 'soft' interventions to promote more considerate and sustainable travel. This would use techniques such as workplace travel plans, targeted discounts and promotional material, and awareness-raising to promote and increase cycling, walking, and public transport use, and reduce intra-zonal road congestion. Additional measures for freight transport might include incorporate drop off boxes and consolidation centres. Substitutes for travel, particularly those based on ICT, would also be promoted (see Scenario 5).

Box 3: Water strategies

Water headline strategies

	Strategy name	Demand change	Structural change	Capacity/Supply change
WR0	Current trends	WD0 – No change	WS0 – No change	WC0 – No change
WR1	Local resilience	WD2 – Demand management	WS0 – No change	WC9 – Desal. + effluent recycling
WR2	Closed loops	WD0 – No change	WS0 – No change	WC6 – Effluent recycling
WR3	Local integration	WD0 – No change	WS2 – Local integration	WC0 – No change
WR4	National integration	WD0 – No change	WS3 – National integration	WC0 – No change
WR5	Regional conservation	WD3 – Demand management	WS0 – No change	WC2 – Increased conservation
WR6	National conservation	WD2 – Demand decrease	WS3 – National integration	WC6 – Effluent recycling
WR7	Local crisis	WD1 – Demand increase	WS0 – No change	WC11 – All technologies + conservation
WR8	Uncontrolled demand	WD1 – Demand increase	WS1 – Targeted connectivity	WC12 – All technologies + aggr. conservation

Water strategy components

DEMAND CHANGE		
WD0	No change	Changes in demand follow current trends
WD1	Demand increase	Relaxation of demand management measure; lower environmental conditions
WD2	Demand decrease	Aggressive demand reduction as part of a national water resource strategy
WD3	Demand management	Reduction in demand, targeting zones with outstanding water stress and/or offsetting growth in demand
STRUCTURAL CHANGE		
WS0	No change	Inter-zone connectivity remains unchanged
WS1	Targeted connectivity	Specific deficits are addressed with strategic links from remote water resource zones exhibiting surplus
WS2	Local integration	Improved distribution of existing deployable output within existing operational boundaries
WS3	High connectivity	Large-scale transfer of water resource across existing operational boundaries
CAPACITY/SUPPLY CHANGE		
WC0	No change	No additional sources developed
WC1	Decreased conservation	Abstraction constraints lowered (i.e. greater abstraction permitted)
WC2	Increased conservation	Abstraction constraints raised moderately (i.e. less abstraction permitted)
WC3	Aggressive conservation	Abstraction constraints raised aggressively (i.e. much less abstraction permitted)
WC4	Increase (storage)	Additional storage
WC5	Increase (desal)	Desalination
WC6	Increase (recycling)	Effluent recycling
+ combinations of individual options etc.		
WC7	Increase	WC4 Additional storage + WC5 Desalination
WC8	Increase	WC4 Additional storage + WC6 Effluent recycling
WC9	Increase	WC5 Desalination + WC6 Effluent recycling
WC10	Increase	WC4 Additional storage + WC5 Desalination + WC6 Effluent recycling
+ combinations of individual options etc.		
WC11	Increase supply / conservation	WC4 Additional storage + WC5 Desalination + WC6 Effluent recycling + WC2 Increased conservation
WC12	Increase supply / conservation	WC4 Additional storage + WC5 Desalination + WC6 Effluent recycling + WC3 Aggressive conservation

Water headline strategies – narratives

	Strategy name	Example narrative
WR0	Current trends	Per capita demand for water changes according to the historical trend, while connectivity between regional networks and the provision of water supply infrastructure remain unchanged from the existing configuration.
WR1	Local resilience	Via emphasis on the efficient use of existing water resource at the scale of existing water supply infrastructure networks, measures to reduce per capita demand through are differentially efficacious. Regions are conservative in their attempts to preserve their local water ecosystems, and prefer no further development of freshwater resources. Instead, they tend towards effluent recycling, supported by desalination. Proprietary management of water resource persists, consistent with a trend towards self-sufficiency through technology, with connectivity between regions remaining static.
WR2	Closed loops	Communities become increasingly feudal in their attempts to preserve what water resource is available locally: regional water supply infrastructure networks become closed loops, with per capita demand static or slowly varying about a minimally sufficient level, and no additional connectivity between regions established. The recycling of effluent becomes (or has already become) the primary means of meeting the demand for water, while prioritised investment eliminates all losses from the water supply infrastructure system.
WR3	Local integration	A proprietary model of water supply infrastructure management persists. External pressures prohibit abstraction from the water environment is excess of historic levels; thus, water service providers maximise the integration of strategic resources across their operational areas by enhancing the connectivity between regional water supply infrastructure networks according to existing geopolitical relationships. Prevailing water management practices persist, and per capita demand does not diverge greatly (if at all) from historical trends.
WR4	National integration	The declaration of a national strategy of water provision supersedes pre-existing geopolitical and commercial interests as part of a major effort to maximise the efficiencies in allocating the water resource available across the whole of the UK, subject to stringent efforts to preserve and protect the water environment that curtail the development of water resources and the abstraction of water to historical limits. The result is a targeted programme of connectivity enhancement between water supply infrastructure networks, tending towards a fully interconnected system, but a comparatively unambitious programme of demand management measures that result in changes in the per capita demand for water similar to the historical trend.
WR5	Regional conservation	Efforts to preserve and enhance the water environment aggravate tension between human and non-human consumers of water, as increasingly stringent abstraction controls progressively diminish the quantity of water available for abstraction, and prevailing proprietary interests continue to define the spatial scale of water supply infrastructure networks and constrain the enhancement of connectivity between regional networks. To offset these limitations, programmes of demand management decrease the per capita demand for water.
WR6	National conservation	A national programme of aggressive environmental conservation realised through aggressive investment in new infrastructure. Enhanced connectivity tending towards a national water grid integrates the regional water supply infrastructure networks, while an increased reliance on effluent recycling decrease the need for abstraction from the water environment. Progressive investment in demand management measures reduces the per capita demand for water.
WR7	Local crisis	Increases in the per capita demand for water places increased stress on the water environment. Decision makers emphasise local resilience: no additional transfers between regional networks are constructed. New abstraction and storage infrastructure are permissible; however, the quantity of freshwater available for abstraction is reduced. Therefore, desalination and effluent recycling are preferred.
WR8	Uncontrolled demand	The per capita demand for water increases unabated, escalating the stress placed on an infrastructure network with constrained opportunities to abstract freshwater. In an attempt to preserve the water environment, new freshwater abstractions and reservoirs occur only in hydrological regimes that maximise the reliability of the resource in the context of a national strategy, and aggressive constraints on the quantity of freshwater available for abstraction further constrain the performance of the existing infrastructure system. The primary methods of meeting both the new demand for water and any shortfall occurring as a result of reduced performance of the incumbent system, are desalination and effluent recycling; however, enhanced connectivity between regional water networks is promoted on a case-by-case basis.

Box 4: Wastewater strategies

Wastewater headline strategies

	Strategy name	**Demand change**	**Structural change**	**Capacity/Supply change**
WW0	Current trends	WWD0 – No change	WWS0 – No change	WWC0 – No change
WW1	Low environmental aspirations	WWD1 – Increase in volumetric demand	WWS1 – Increase volumetric capacity	WWC2 – Decrease in serviceability
WW2	Retrofit technologies within existing network	WWD0 –No change	WWS0 – No change	WWC3 – Change technology mix
WW3	Replace WWTW with new technologies	WWD2 – Decrease in volumetric demand	WWS3 – More decentralised	WWC3 – Change technology mix

Wastewater strategy components

DEMAND CHANGE		
WWD0	No change	No change in volumetric demand or chemical demand
WWD1	Increase in volumetric demand	Increased surface runoff
WWD2	Decrease in volumetric demand	Split processing of waste; reduced surface runoff
STRUCTURAL CHANGE (CONNECTIVITY)		
WWS0	No change	No change in network topology
WWS1	Increase volumetric capacity	Increase the hydraulic capacity of the sewer network
WWS2	Decrease volumetric capacity	Decrease the hydraulic capacity of the sewer network
WWS3	More decentralised	Emphasis on more local wastewater treatment
CAPACITY/SUPPLY CHANGE		
WWC0	No change	No increase in serviceability
WWC1	Increase in serviceability	Increase chemical treatment capacity of WWTW
WWC2	Decrease in serviceability	Decrease chemical treatment capacity of WWTW
WWC3	Change technology mix	Modernise treatment technologies

N.B. 'Serviceability' is 'the capacity to treat effluent to a specified quality', so an increase in serviceability implies an increase in the capacity of a wastewater treatment works to discharge treated effluent of a specified quality.

Wastewater headline strategies – narratives

	Strategy name	**Example narrative**
WW0	Current trends	Prevailing wastewater management strategies persist. The per capita volumetric demand for wastewater services, the biological oxygen demand of sewage, and the chemical oxygen demand of sewage remain constant, corresponding to no change in the consumptive behaviour of consumers. Sewerage service providers maintain the existing sewer network, extending and enhancing where necessary to meet the growth in demand in accordance with established behaviour. Efficiency gains follow historical trends.
WW1	Low environmental aspirations	The volumetric demand for wastewater services increases, as people use water inefficiently and expand impermeable areas, and volumetric capacity of wastewater treatment works increases to meet the growth in demand. Concomitant with a less conscientious approach to managing the environment, lowered serviceability targets for treated effluent decrease the cost of treating wastewater at the cost of increasing the hazard to discharging waters.

	Strategy name	Example narrative
WW2	Retrofit technologies within existing network	Wastewater service providers continue to expand the wastewater treatment capacity on a regional basis. An unwillingness to abandon existing wastewater network infrastructure persists: although sewer networks grow to accommodate new demand, they do so in accordance with established practices, and continue to focus on the conveyance of sewage to large, centralised wastewater treatment works. The capacities of wastewater treatment works increase to meet changes in the demand for wastewater services, and new technologies gradually replace those considered obsolete as it becomes cost-effective to do so. These actions do not influence the consumptive behaviour of the population, which follows historical trends.
WW3	Replace WWTW with new technologies	The development of new technologies facilitates a revolution in wastewater treatment. The long-term benefits of aggressively replacing existing wastewater treatment works rapidly exceed the costs of abandonment, albeit within the context of the prevailing arrangement of sewer networks. The possibilities of micro-treatment and effluent recycling at small scales yield a decrease in the volumetric demand for wastewater services.

Box 5: Solid waste strategies

Solid waste headline strategies

	Strategy name	Demand change	Structural change	Capacity/Supply change
WE0	Current trends	SWD0 – partial decoupling	SWS0 – No change	SWC1 - Thermal treatment increase SWC2 - Bio treatment increase SWC3 - Increase in recycling
WE1	High tech	SWD2 – increase in arisings or SWD0 – partial decoupling	SWS0 – No change or SWS1 – National planning	SWC1 - Thermal treatment increase SWC2 - Bio treatment increase SWC3 - Increase in recycling
WE2	Closed loop, zero waste	SWD0 – partial decoupling or SWD1 – full decoupling	SWS1 – National planning and SWS2 - Taxation & targets	SWC3 - Increase in recycling
WE3	Deep green	SWD1 – full decoupling	SWS1 – National planning and SWS2 - Taxation & targets	SWC0 - No change SWC4 - Increase in reuse/recycling
WE4	Maximum energy	SWD0 – partial decoupling or SWD2 – increase in arisings	SWS0 – No change or SWS1 – National planning	SWC1 - Thermal treatment increase SWC2 - Bio treatment increase SWC5 - Reduction in recycling
WE5	National plan	SWD0 – partial decoupling or SWD1 – full decoupling	SWS1 – National planning and SWS2 - Taxation & targets	SWC1 - Thermal treatment increase SWC2 - Bio treatment increase SWC3 - Increase in recycling

Solid waste strategy components

DEMAND CHANGE		
SWD0	Current trends / partial decoupling	Current trend continues with waste in all sectors apart from hazardous reducing. Partial decoupling from economic growth. Per capita arisings reduce but in some scenarios, overall waste arisings may still increase
SWD1	Further reductions / full decoupling	Waste arisings completely decouple from economic growth due to social and cultural changes and significant investment in waste reduction measures
SWD2	Increase in arisings	
STRUCTURAL CHANGE		
SWS0	No change	Current trends continue with Local Authorities responsible for waste collection
SWS1	National planning	The creation of a national waste body allows demand to be considered at regional or national level rather than local.
SWS2	Taxation & targets	Waste treatment strongly determined by combination of taxation and targets.
CAPACITY /SUPPLY CHANGE		
SWC0	No change	No new capacity is constructed
SWC1	Thermal treatment increase	Construction of new thermal treatment plant – EfW and more advanced forms
SWC2	Bio treatment increase	Construction of AD and composting plant to deal with food and green wastes
SWC3	Increase in recycling	Construction of new MRF facilities to separate recyclables
SWC4	Increase in reuse/recycling	Product designed for reuse/repair (D4R); industrial symbiosis; C&I maximises use of reused/recycled material and designs for minimum waste. Increase in leasing rather than purchasing and involvement of third sector in material recovery/reuse.
SWC5	Reduction in recycling	Recycling reduces

Solid Waste headline strategies – narratives

	Strategy name	Example narrative
WE0	Business as usual	Existing waste, reuse and recycling targets for household, commercial & industrial (C&I) and construction & demolition (C&D) wastes are met by continuing the current trends and building new infrastructure, particularly energy from waste (EfW) and anaerobic digestion (AD) plant as required. There is a steady improvement in the performance of the waste sector and the amount of waste being landfilled continues to fall due in part to the continuing increases in landfill tax.
WE1	High tech	Developments in materials separation and recovery technologies mean that wastes require minimum source separation. For householders this means two bins – food & green wastes and everything else. Consumers disengage from concerns about waste & recycling but despite this, rates of recycling and composting/AD continue to rise as does the overall waste production. The materials left over from materials recovery are used for fuels in EfW plant.
WE2	Closed loop, zero waste	There is a significant move to industrial symbiosis with the wastes from one process providing the raw materials for another. Waste is consciously eliminated from all stages by design and products are designed for reuse, refurbishment, repair and recycling (D4R). Landfill and incineration are largely phased out being retained primarily for disposal of hazardous wastes. Producer responsibility is increased. These changes may be supplemented by moves away from consumerism to leasing. Overall waste arisings drop.
WE3	Deep green	There is a move from consumption to leasing with products designed for long life, easy repair and remanufacturing (D4R). Waste arisings are reduced by increasing prices for waste disposal and increasing the involvement of the third sector in refurbishing of unwanted goods. There is little investment in infrastructure and changes are driven by cultural and behavioural change. Although the outcomes may be similar to the closed loop, zero waste scenario, there is much less investment in infrastructure.
WE4	Maximum energy	Landfill gas continues to supply electricity to the grid but in diminishing amounts as the effects of the EU Landfill Directive are felt. Increasing energy is produced by AD and incineration. Combustible materials are banned from landfill. Growth of recycling slows as energy is prioritised.
WE5	National plan	Waste treatment is nationally planned rather than controlled at the LA level. This reduces the risk of construction of excess capacity and means that waste can be processed strategically depending on national needs.

Note from GW: WE5 is new, but as things stand, Alex's model implementation deals with waste arisings on a regional level rather than a local level and so arguably all our strategies are based on a regional plan.

Table 1: Selected Energy strategy pairs (short term → long term)

	Short term – to 2030	Long term – to 2050 (and 2100)
	Energy strategy combination	**Energy strategy combination**
EP01	**EN0** Minimal policy intervention	**EN0** Minimal policy intervention
EP02	**EN0** Minimal policy intervention	**EN4** Interconnected world
EP03	**EN5** Gas world	**EN8** Nuclear and gas
EP04	**EN4** Interconnected world (RAPID)	**EN4** Interconnected world
EP05	**EN1** Central electric / flexible consumer	**EN4** Interconnected world
EP06	**EN7** Electrification heat and transport	**EN2** Solar world
EP07	**EN1** Central electric (mixed generation)	**EN7** Electrification heat and transport
EP08	**EN3** Local energy and biomass	**EN3** Local energy and biomass
EP09	**EN1** Central electric / flexible consumer	**EN1** Central electric (wind)
EP10	**EN9** All-in	**EN8** Nuclear and gas
EP11	**EN9** All-in	**EN9** All-in
EP12	**EN3** Local energy and biomass	**EN6** Local hydrogen
EP13	**EN3** Local energy and biomass	**EN2** Solar world

Table 2: Selected Transport strategy pairs (short term → long term)

	Short term – to 2030	Long term – to 2050 (and 2100)
	Transport strategy combination	**Transport strategy combination**
TP0	**TR1** Predict and provide	**TR0** Decline and decay
TP1	**TR1** Predict and provide	**TR1** Predict and provide
TP2	**TR2** Cost and constrain	**TR2** Cost and constrain
TP3	**TR5** Connected grid	**TR5** Connected grid
TP4	**TR4** Promo-pricing	**TR4** Promo-pricing
TP5	**TR4** Promo-pricing	**TR3** Adapting the fleet
TP6	**TR3** Adapting the fleet	**TR5** Connected grid
TP7	**TR3** Adapting the fleet	**TR6** Smarter choices
TP8	**TR6** Smarter choices	**TR6** Smarter choices

Table 3: Selected Water strategy pairs (short term → long term)

	Short term – to 2030	Long term – to 2050 (and 2100)
	Water strategy combination	**Water strategy combination**
WP0	**WR0** Current trends	**WR0** Current trends
WP1	**WR7** Local crisis	**WR8** Uncontrolled demand
WP2	**WR3** Local integration	**WR4** National integration
WP3	**WR5** Regional conservation	**WR6** National conservation
WP4	**WR2** Closed loops	**WR2** Closed loops
WP5	**WR1** Local resilience	**WR2** Closed loops

Table 4: Selected Wastewater strategy pairs (short term → long term)

	Short term – to 2030	Long term – to 2050 (and 2100)
	Wastewater strategy combination	**Wastewater strategy combination**
WWP0	**WW0** Current trends	**WW0** Current trends
WWP1	**WW0** No change	**WW1** Low environmental aspirations
WWP2	**WW0** No change	**WW2** Retrofit technologies
WWP3	**WW2** Retrofit technologies	**WW3** Replace WWTW with new tech
WWP4	**WW3** Replace WWTW with new tech	**WW3** Replace WWTW with new tech

Table 5: Energy-transport strategy combinations

	Short term – to 2030		Long term – to 2050 (and 2100)	
	Energy strategy combination	**Transport strategy**	**Energy strategy combination**	**Transport strategy**
ET01	**EN0** Minimum policy intervention	**TR0** Decline and decay	**EN0** Minimum policy intervention	**TR0** Decline and decay
ET02	**EN0** Minimum policy intervention	**TR1** Predict and provide	**EN4** Interconnected world	**TR1** Predict and provide
ET03	**EN5** Gas world	**TR1** Predict and provide	**EN8** Nuclear and gas	**TR1** Predict and provide
ET04	**EN4** Interconnected world (RAPID)	**TP5** Predict and provide	**EN4** Interconnected world	**TR3** Adapting the fleet
ET05	**EN1** Central electric / flexible consumer	**TR6** Smarter choices	**EN4** Interconnected world	**TR1** Predict & provide
ET06	**EN7** Electrification heat and transport	**TR5** Adapting the fleet	**EN2** Solar world	**TR5** Connected grid
ET07	**EN1** Central electric (mixed generation)	**TR4** Promo-pricing	**EN7** Electrification heat & transport	**TR3** Adapting the fleet
ET08	**EN3** Local energy and biomass	**TR5** Connected grid (RAPID)	**EN3** Local energy and biomass	**TR5** Connected grid
ET09	**EN1** Central electric / flexible consumer	**TR4** Promo-pricing	**EN1** Central electric (wind)	**TR4** Promo-pricing
ET10	**EN9** All-in	**TR3** Adapting the fleet	**EN8** Nuclear and gas	**TR6** Smarter choices + **TR3** Adapting the fleet
ET11	**EN9** All-in	**TR3** Adapting the fleet	**EN9** All-in	**TR5** Connected grid + **TR3** Adapting the fleet
ET12	**EN3** Local energy and biomass	**TR2** Cost and constrain	**EN6** Local hydrogen	**TR3** Adapting the fleet
ET13	**EN3** Local energy and biomass	**TR2** Cost and constrain	**EN2** Solar world	**TR2** Cost and constrain

Table 6: Energy-water strategy combinations (NOTE: TO BE UPDATED FOLLOWING ENERGY/WATER HARMONISATION)

	Short term – to 2030		Long term – to 2050 (and 2100)	
	Energy strategy combination	**Water strategy**	**Energy strategy combination**	**Water strategy**
EW01	**EN0** Minimum policy intervention	**WR0** Current trends	**EN0** Minimum policy intervention	**WR0** Current trends
EW02	**EN0** Minimum policy intervention	**WR8** Uncontrolled demand	**EN4** Interconnected world	**WR5** National integration
EW03	**EN5** Gas world	**WR7** Local crisis	**EN8** Nuclear and gas	**WR1** Local resilience
EW04	**EN4** Interconnected world (RAPID)	**WR2** Closed loops	**EN4** Interconnected world	**WR2** Closed loops
EW05	**EN1** Central electric / flexible consumer	**WR3** Local integration	**EN4** Interconnected world	**WR2** Closed loops
EW06	**EN7** Electrification heat and transport	**WR4** National integration	**EN2** Solar world	**WR6** National conservation
EW07	**EN1** Central electric (mixed generation)	**WR3** Local integration	**EN7** Electrification heat & transport	**WR4** National integration
EW08	**EN3** Local energy and biomass	**WR5** Regional conservation	**EN3** Local energy and biomass	**WR5** Regional conservation
EW09	**EN1** Central electric / flexible consumer	**WR3** Local integration	**EN1** Central electric (wind)	**WR3** Local integration
EW10	**EN9** All-in	**WR6** National conservation	**EN8** Nuclear and gas	**WR1** Local resilience
EW11	**EN9** All-in	**WR6** National conservation	**EN9** All-in	**WR6** National conservation
EW12	**EN3** Local energy and biomass	**WR5** Regional conservation	**EN6** Local hydrogen	**WR5** Regional conservation
EW13	**EN3** Local energy and biomass	**WR5** Regional conservation	**EN2** Solar world	**WR6** National conservation

Table 7: Example WS1 Transition Strategy Table

Strategy #	Energy /Transport strategy combination	Water strategy combination	Wastewater strategy combination	Waste strategy
S1	**ET01**	**EW01**	**WW0**	**WE0**
S2	**ET02**	**EW02**	**WW0**	**WE0**
S3	**ET03**	**EW03**	**WW1**	**WE0/WE1/WE4**
S4	**ET04**	**EW04**	**WW1**	**WE0/WE1/WE4**
S5	**ET05**	**EW05**	**WW2**	**WE1/WE4**
S6	**ET06**	**EW06**	**WW2**	**WE1/WE4**
S7	**ET07**	**EW07**	**WW3**	**WE1/WE4**
S8	**ET08**	**EW08**	**WW3**	**WE2/WE3**
S9	**ET09**	**EW09**	**WW4**	**WE2/WE3**
S10	**ET10**	**EW10**	**WW4**	**WE2/WE3**
S11	**ET11**	**EW11**	**WW4**	**WE2/WE3**
S12	**ET12**	**EW12**	**WW4**	**WE2/WE3**
S13	**ET13**	**EW13**	**WW4**	**WE2/WE3**

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