Evidence Dossier

1. Context

In CESI, as elsewhere, we use models of how energy systems can be operated and planned help us make sense of the future energy system and to think more clearly about investments in new energy capacity in the UK.

We have also developed some future energy scenarios in narrative form and would like to use these to explore their possible implications for the UK energy sector, using models. In doing so we are researching ways in which qualitative information or narratives are interchanged with quantitative models. This workshop is helping inform this process.

The future is of course uncertain, and while we have good historical data on the inputs to these models, there are many factors that mean extrapolating from the past into the future is not the most suitable thing to do. Examples:

- Energy system structural changes
- Changing political and regulatory arena
- Changing lifestyles
- Social and environmental aspects
- Factors external to the UK

Effective future planning requires insights from a wide range of perspectives to incorporate some of the above factors.

The purpose of this elicitation workshop is to pilot an approach in considering a broader perspective. In this workshop, invited experts will be making judgments about selected quantitative information that would be relevant for two selected narrative scenarios. The information gathered from the experts will be used in a CESI model and resulting outputs compared with the narrative scenarios for consistency. The selected "quantities of interest" we will be seeking expert views on in the workshop are:

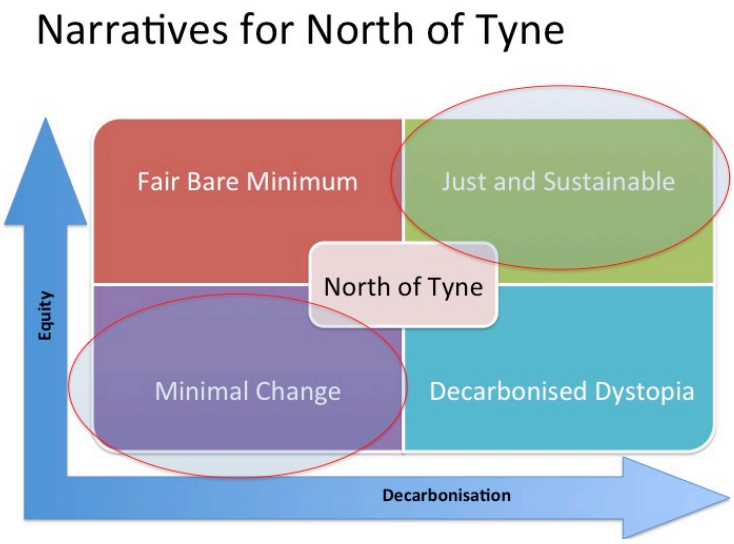
1) future GB annual electricity demand
2) future CO_2 emissions market price
3) future installed capacity of wind, within two possible future energy scenarios.

NB: Note that for this pilot exercise we have had to take a pragmatic approach regarding geographical scale. While the narrative scenarios have been developed at North of Tyne scale the CESI model is at GB scale. The quantitative information we are seeking is therefore at GB scale assuming the North of Tyne scenarios continue to apply.

2. Scenarios

Thinking about the future of a particular system, or problem that needs solving, helps inform planning that is made today. It enables a range of both known and unknown issues or events to be explored in order to take advantages of such changes and mitigate against adverse situations.

CESI recently held a stakeholder workshop to seek views about the future energy system at the North of Tyne geographical scale. Using a particular scenario development approach, two top key drivers for change are identified to form a matrix of 2x2 scenarios, and provisional pathways to 2050 described. These two drivers are; decarbonisation and "equity". This is not to say that other drivers such as financial cost are not also very important, but in terms of how the energy system develops in the future, attendees of the workshop felt that pursuits (or not) of greater equity will be a stronger driver. The drivers give rise to the four scenarios as illustrated below.



Two of these scenarios have been selected for the purposes of this workshop as indicated on the diagram above. These are:

- Just and Sustainable (high decarbonisation and high equity)
- Minimal Change (low decarbonisation and low equity)

It should be stressed that these 2 have not been selected because they are most likely. The approach taken in developing these futures does not assign any judgments as to whether or not a scenario is more or less likely.

An outline of these 2 scenarios is given below followed by a very brief description of the scenarios not applying for this expert elicitation exercise. In this expert elicitation workshop we will be asking for your judgments as to the values of the 'Quantities of Interest' that could apply in these two different visions of the future.

The other two scenarios; “Fair Bare Minimum” where there is high equity but low decarbonisation, and “Decarbonised Dystopia” where there is low equity but high decarbonisation, are not going to be used at this time. Therefore you will not be asked to provide judgments on `Quantities of Interest’ for those scenarios.

Scenario 1: Just and Sustainable

In this scenario the transition of the economy to a decarbonised one, that meets the Paris Agreement by 2050, also prioritises fairness: in other words, more vulnerable members of society are not penalised or left behind in the transition. Policies are developed with all of society in mind to bring about fairness and equity. The egalitarian economy is strongly orientated towards local development and maximising secure employment. Devolved administrations ensure that local communities’ voices are heard in development and are appropriately balanced with financial and environmental pressures. There is an immediate focus and programme of action on education and skills training so that UK communities benefit from employment in the decarbonised economy. There is a surge in community energy projects facilitated and incentivised by the devolved administrations. This features collective community ownership of renewable technologies and minimal corporate ownership except for the largest scale projects such as district heating. Regulations ensure that vulnerable members of communities are also able to partake in the benefits of such schemes. Time of use (TOU) tariffs are tempered by measures to protect those less able to pay. Local banks are established to ensure local issues are incorporated in financial decisions. There is a strong circular economy where as much recycling and repurposing as possible is undertaken locally or at least within GB. Rebalancing of decisions made by corporate entities restores consumers’ levels of trust and they are no longer perceived as only interested in profiteering. This, along with an education programme, enables the decarbonisation path to happen at a faster pace than predicted and the UK is upheld as a model example for the rest of the world to follow in mitigating dangerous climate change.

Appendix 1 provides more details about the pathway to 2050 in this scenario.

Scenario 2: Minimal Changes

In this scenario the current economic paradigm persists and profit incentives drive the economy and the energy sector. Costs and benefits of any change are considered only in monetary terms. Societal, and environmental, costs and benefits are only met if financially advantageous to do so. Any decarbonisation needs strong policy levers and due to the powerful lobbying of corporations there is little appetite for successive governments to implement these. As a result there is only slow progress made in decarbonisation. Any progress in decarbonisation is due to the relative costs of renewable and non-renewable technologies that have largely been developed overseas, as part of the further consolidation of the UK’s post-industrial economy. The local skill base is diminished, leading to the best employment opportunities being given temporarily to workers outside the UK. Employment for locals is low skilled and precarious depending on the profitability of the corporations.

Imports are heavily relied upon not only for the employee skill base but in all areas of day to day life and that includes the energy system. More interconnectors with Europe are planned and this in turn helps to decarbonise the energy system to some extent. Gas is still heavily relied on for heating. Carbon Capture & Storage (CCS) is extremely slow to get of the ground due to a lack of incentive to experiment in the UK – corporations want to be confident they can profit. A shift away from petrol and diesel cars occurs but only because global manufacturers have stopped producing them leading to a need to roll out infrastructure but only where profits can be made for investors. Significant proportion of society cannot afford EVs.

See Appendix 2 for a pathway to 2050 for this scenario.

3. Quantities of Interest (QoI)

Within the two scenarios described above, we consider three specific future years, 2030, 2040 and 2050. There are five quantities of interest for each scenario.

(i) Total Great Britain (GB) electricity demand in Terawatt hours (Twh) for 2030
(ii) Total GB electricity demand (Twh) for 2040
(iii) Average CO_2 emissions market price in pounds per tonne CO_2 (equivalents) (£/tCO_2e) for 2030 applying in GB
(iv) Average CO_2 emissions market price (£/tCO_2e) for 2040 applying in GB
(v) Total GB installed capacity of wind generation in Gigawatts (Gw) for 2050

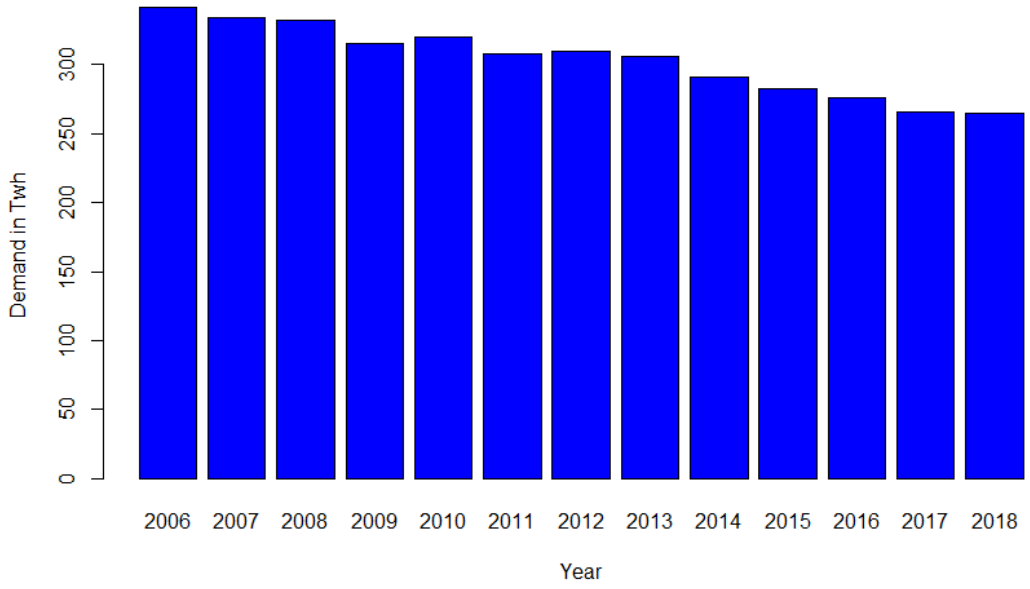
4. Evidence for QoIs

(a) Annual electricity demand

National Grid, on their website, provide data on UK electricity demand for each half-hour period each year. This data, aggregated to annual demand in Terrawatt hours (TWh), for the years 2006-2018, is given below.

Note that the definition applied here is that used by National Grid:

"This is the Great Britain generation requirement and is equivalent to the Initial National Demand Outturn (INDO) and National Demand Forecast as published on BM Reports. National Demand is the sum of metered generation, but excludes generation required to meet station load, pump storage pumping and interconnector exports.



The figures for the most recent ten years are given in the following table.

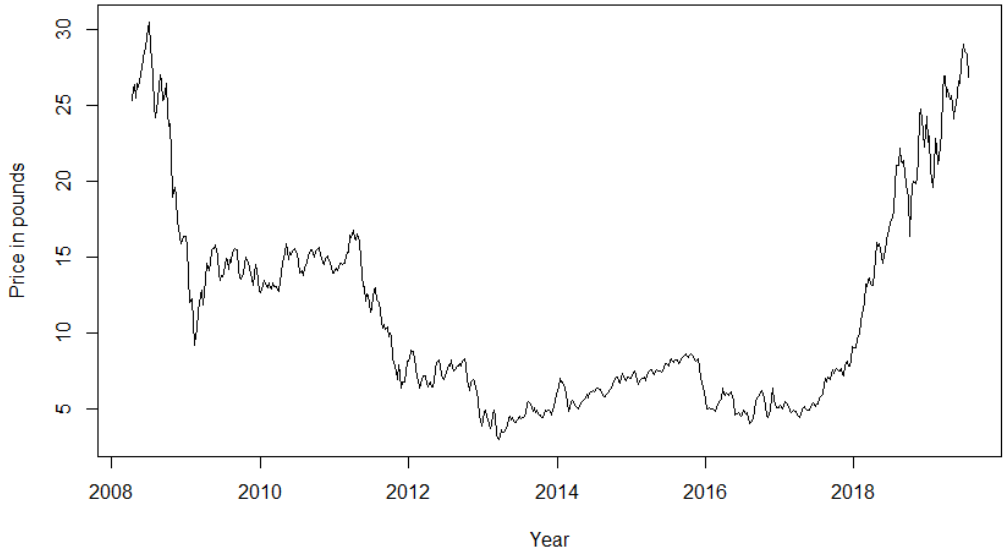
Year	Demand (Mwh)
2009	314,628
2010	320,037
2011	307,854
2012	308,977
2013	305,495
2014	290,484
2015	282,183
2016	275,490
2017	265,922
2018	264,786

(ii) Carbon Price

Incentivising decarbonisation in the UK is currently through participation of the EU Emissions Trading Scheme (ETS). This operates on a "cap and trade" basis whereby a quota of allowable emissions is set and participants then purchase those allowances to emit carbon dioxide (equivalents). The carbon price is a reflection of the

willingness or ability to pay to emit carbon dioxide (equivalents) and when it is high discourages emissions.

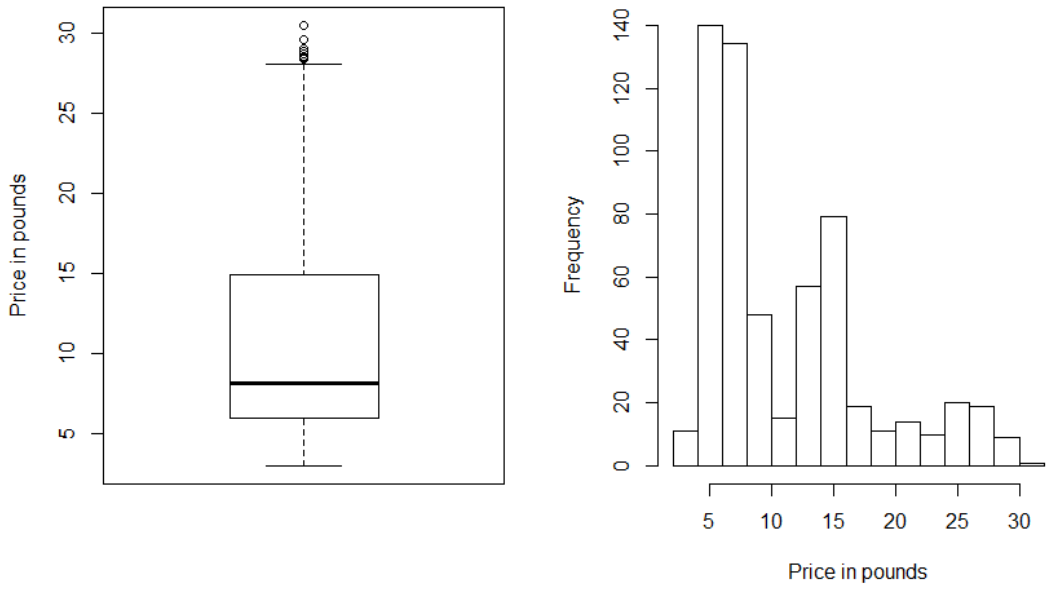
Various sources report the carbon emissions market price. Sandbag for example, is a climate change think tank that provides historical weekly data on the carbon price. Below is a plot of the opening price in pounds per CO_2 (equivalent) between February 2008 and August 2019.



Summary statistics from the same period are given in the table below.

Summary	Value (£'s)
Minimum price	2.97
Lower quartile	5.92
Median	8.13
Upper quartile	14.90
Maximum	30.52

A boxplot and a histogram of the overall distribution of the price are provided below.

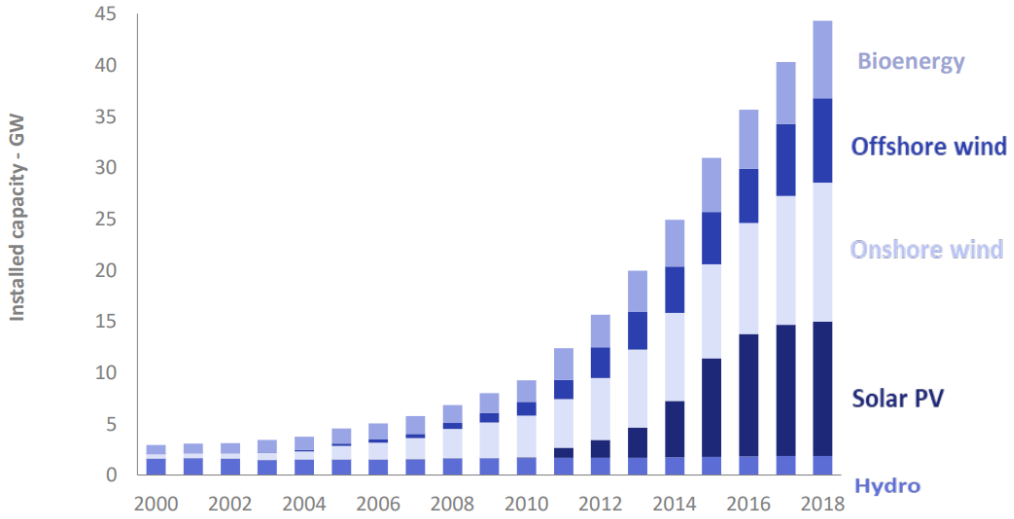


The UK is currently reviewing its options for incentivising decarbonisation on leaving the EU. From recent literature there appears to be a preference for remaining linked with the EU ETS and this would require agreement with the EU. If the UK leaves the EU with "no deal" then the UK may implement a carbon tax on emissions instead. Due to the need to maintain industrial competitiveness it is highly unlikely that the UK will substantially deviate from the carbon price prevailing in the EU ETS. Therefore for the purposes of this workshop we ask the experts to consider the carbon price applicable assuming the current "cap and trade" system.

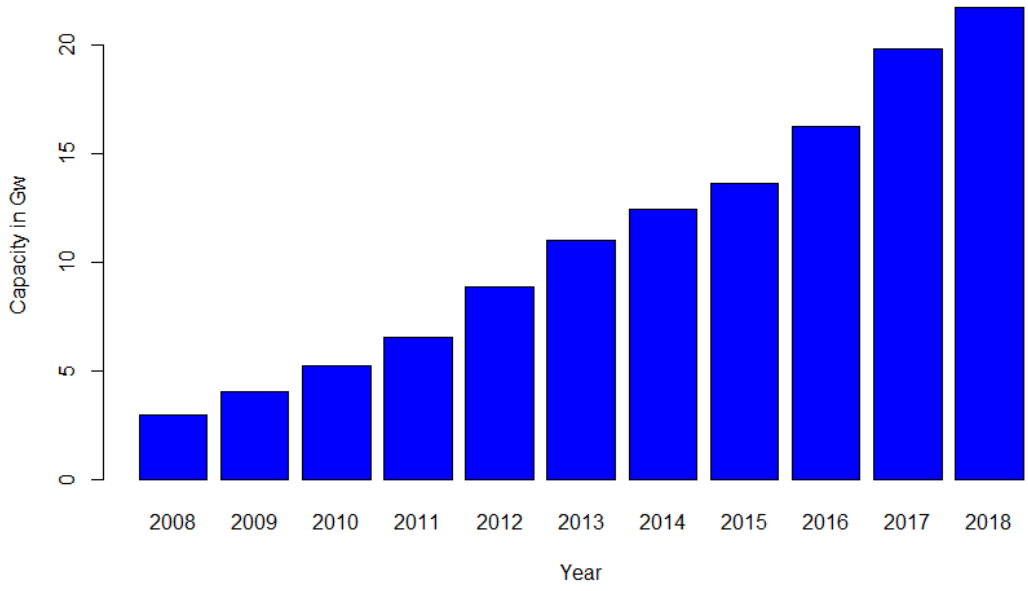
(iii) Total installed capacity of wind

The UK Department of Business, Energy & Industry Strategy produce an annual report titled Digest of UK Energy Statistics (DUKES). Chapter 6 of this report, statistics on energy from renewable sources, details the breakdown of energy capacity, generation and supply in the renewable sector.

The following plot indicates the progression of installed capacity of renewable energy annually over the period 2000-2018. Installed wind capacity would represent the sum of installed capacity by onshore and offshore wind.



Aggregating onshore and offshore wind into a single category, the plot below provides the total capacity of wind in Gigawatts over the period 2008-2018.



The raw values from the above plot are provided below.

Year	Installed capacity (Gw)
2008	3.0
2009	4.1
2010	5.2
2011	6.5
2012	8.9
2013	11.0

2014	12.4
2015	13.6
2016	16.2
2017	19.8
2018	21.7

5. Sources of data

https://www.nationalgrideso.com/balancing-data/data-finder-and-explorer

https://sandbag.org.uk/carbon-price-viewer/

https://www.gov.uk/government/statistics/renewable-sources-of-energy-chapter-6-digest-of-united-kingdom-energy-statistics-dukes

Additional information:

National Grid future energy scenarios

http://fes.nationalgrid.com/media/1410/fes-in-5-2019.pdf

Appendix 1: Just and Sustainable Pathway

Area	2020s	2030s	2040s
Electricity	Community energy schemes, subsidies, incentives, equity R&D	Industry and Transport energy efficiency and automation R&D + Deployment	Deployment. Zero MC generation by 2050
Heating & Cooking	District Heating schemes deployed; industrial / nuclear waste heat and large CHPs	Hydrogen (H_2) blending with natural gas	By 2050 CCS and low carbon fuels
Building Efficiency	Building Regulations become stricter incentivising higher efficiency in both new and existing build	Insulation, PV and retrofit / flexible Schemes to incentivize particularly for landlords	By 2050 thermal efficiency of housing has reduced demand to minimum possible levels
Road & Rail Transport	Road: Infrastructure for electric vehicles (EVs) a priority, along with cycle ways for safe and practical cycling in place of car use. Hydrogen fuel cell buses rolled out. Rail: Refit/extend metro & feasibility study of H_2 trains	Road: Substantial shifts to EVs, public transport and cycling Rail: H_2 trains begin to be rolled out	Road: H_2 buses / electric bikes EV for passenger vehicles, H_2 for freight Rail: all H_2 trains General: Remove stigma of public transport. Make affordable. Essential travel only.
Aviation	Map & understand. Alternative fuels investigated	New usage patterns and strong incentives to switch away from aviation use for recreational purposes	Flights are mainy for business purposes but due to localized economy this also is much reduced.
Shipping	Map & understand. Alternative fuels investigated	Incentivise a shift away from fossil fuels both for domestic shipping and imports	Low carbon technologies apply in shipping and localized economies ensure that imports are minimised
Industry	Import & export complexities need to be understood and accounted for. CCS	Carbon capture and storage (CCS) begins to be implemented. Sensible more local production. Sustainable responsible consumption.	Industrial processes fully decarbonised. Strong circular economy.
Agriculture	Import & export complexities need to be understood and accounted for. Environmental Land Management System (ELMS) complulsory membership.	Renewable energy is implemented in agricultural practices and instead of livestock farming more solar/wind farms and arable crops reflecting dietary changes. Removal of planning barriers. Building efficiency.	Agriculture more arable crops and renewable energy capture/conversion – wind, solar and bioenergy. Minimal livestock.

Area	2020s	2030s	2040s
Land Use	Reforestation and rewilding	Reforestation and rewilding	Reforestation and rewilding
Waste	Waste reduction is incentivised.	Establishment of recycling and repurposing through incentives. Any hard to recycle waste is sent to energy from waste facility used for both electricity and district heating.	Recycling and repurposing becomes commonplace for almost all waste.
Greenhouse Gas Removals	Reforestation/afforestation? Limited. CCS. High capture.	Medium capture. CCS.	Lower capture. Direct air capture and some bioenergy with CCS
Infrastructure	EV charging infrastructure roll out	Infrastructure to maximise energy efficiency all sectors targeted.	"Smart" technologies and grids rolled out everywhere in homes and across cities
Other (specify)	Education. Understanding. R&D. Early devolution. Funding. New Business models. Medium spend.	Partial Circular Economy. Energy system automation. High spend. Medium devolution.	Strong circular economy. High Devolution. CSR. Medium to low spend. Optimised mix. Flexibility. High levels of trust. Reduced funding directed for equity.

Appendix 2: Minimal Changes Pathway

Area	2020s	2030s	2040s
Electricity	The progress towards decarbonisation stalls through lack of investment as overseas develop renewable technologies	Competitive renewable technologies imported from elsewhere but it is patchy	Limited decarbonised electricity mainly due to CCS not getting off the ground fast enough
Heating & Cooking	Lack of policies to incentivise decarbonised heat means little change	In some wealthy areas community district heating projects as gas becomes more expensive due to shrinking markets and need to import	Extensive shale gas exploitation needed to support those areas not able to switch to now more competitive heating systems
Building Efficiency	Improving energy efficiency of housing stock slow and patchy	Only the wealthy can afford to improve energy efficiency	High rates of fuel poverty
Road & Rail Transport	Fuel price increases. End of 2 car family ownership.	Labour force becomes increasing immobile due to cost of travel. Reinforces scaling back of public transport.	Public transport minimal. Most use road transport with often very old and unsafe vehicles due to necessity. Rail travel is attractive to the rich as a result and with ticket prices to match.
Aviation	Reliance on industry to innovate. No significant change.	Fuel efficient planes and practices are imported from implementations overseas as reduces costs for domestic airlines (and therefore increase profits)	Flying tickets unattainable by most.
Shipping	Increase in shipping. Importing more.	Some fuel efficiency drive due to costs	Minimal reduction in total emissions compared with currently
Industry	Investment in clean technologies happening elsewhere – industries look to relocate overseas	Only the dirtiest industries and manufacturing companies remaining	Even those industries remaining struggle to maintain competitiveness
Agriculture	Continue with existing farming methods	Increase consumption of fertiliser and pesticides. New crops and practices. Increased vegan/vegetarians from financial necessity. Meat/poultry/fish for the rich.	Agricultural land suffering yields due to over exploitation. Increased food imports.
Land Use	Some attempts to improve	Expand housing on green	Due to necessity

Area	2020s	2030s	2040s
	efficiency of land use and some reforestation	belt areas because some existing houses uninhabitable. Some reforestation continues.	deforestation takes place to meet some emissions reductions.
Waste	Some improved recycling facilities but lack of investment in the technologies	Due to costs to process waste sent abroad. Some energy from waste facilities.	Increasing energy from waste plants deployed in poorer areas.
Greenhouse Gas Removals	No significant tree planting.	CCS very slow to get off the ground – reliance on development overseas	Minimal GHG removals
Infrastructure	Expand and reinforce but no innovation	Mainly maintenance of existing minimal attempts at efficiency improvements	Patchy deployment of smart technologies
Other (specify)	Slow down in decarbonisation	Dramatic increase in inequality	Civil unrest common place