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The UK Energy System in 2050: Centralised or Localised?

A Report on the Construction of the CLUES Scenarios

Lester C Hunt and Scott Milne

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This report outlines work undertaken in 2011 and 2012 as part of the Challenging Lock-in through Urban Energy Systems (CLUES) project funded by the Engineering and Physical Sciences Research Council (EPSRC), grant number EP/1002170/1 under the Sustainable Urban Environments Programme Phase 3. We are grateful to Yvonne Rydin, other CLUES team members, and the technical panel for their review and comment on work described in this report. Nevertheless, the views expressed are those of the authors alone and we are, of course, responsible for all errors and omissions.

The UK Energy System in 2050: Centralised or Localised?

A Report on the Construction of the CLUES Scenarios

Lester C. Hunt* and Scott Milne#

1. Introduction

The relative merits of a centralised verses a decentralised energy system have exercised researchers and policy makers for some time. In the UK, the energy system is predominantly centralised with centrally generated electricity in remote power plants, heating systems generally fired by centrally distributed gas, and transportation fuel refined and distributed through a few large depots. Furthermore, market rules, institutional arrangements, business models and social norms that make the energy system difficult to change reinforce these centralised energy technologies. It is therefore argued in some quarters that the UK is locked-in to this centralised system and is consequently not flexible enough to accommodate the needs of the twin policy challenges of climate change and energy security and this will require a shift to an energy system "located at a range of scales" (Foresight, 2008a; p. 106). In addition, Foresight (2008a) argue that given this lock-in to centralisation, the restructuring the UK's energy system will be central to fulfilling the Government's goal of 80% cuts in emissions.

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,There is therefore arguably potential for challenging this lock-in; through developing and promoting more decentralised systems that are at the urban scale through innovative urban development, the role of local planning systems, targeted subsidies for installation of new technologies, the introduction of feed-in tariffs, and initiatives such as DECC's Low Carbon Communities Challenge and local government responses arising from the Sustainable Communities Act 2007. Such decentralised urban energy systems can cover a range of scales and encompass a variety of ways of possibly achieving carbon reductions, including the deployment of low carbon technologies, new institutional arrangements, social innovation and revised policy frameworks.

This report therefore details the research exploring two scenarios that envisage a 'centralised' and a 'localised' UK energy system in 2050 in both quantitative and qualitative terms (often referred to here as 'central' and 'local' for short).[1] This is research from a work package that was part of the ESPRC funded CLUES[2] project that grew out of the Foresight SEMBE[3] project (Foresight, 2008a and 2008b).

An earlier CLUES work package attempted to fully quantify the four SEMBE scenarios (Foresight, 2008b)[4] based on the Agnolucci, et al. (2009) Tool.[5] This exercise highlighted the limitations in really drawing out the distinction between possible different systems hence, it

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[1] Note that this report details the assumptions and analysis undertaken to produce the CLUES Central and Local scenarios. Summaries of these were presented elsewhere (CLUES, 2012) as 'Greening Centralised Energy' and 'Stretching the Energy Spectrum' respectively.

[2] Challenging Lock-in through Urban Energy Systems.

[3] Sustainable Energy Management and the Built Environment.

[4] It should be noted that there was some 'indicative' quantification in the Foresight (2008a) scenarios, but this was not based on any fully consistent 'model' or 'tool'.

[5] The work for the earlier CLUES work package was undertaken by Jim Watson and his team at Sussex University, but at the time of writing this report no publication detailing their work was available.

was decided within CLUES to focus on two of the quantified SEMBE scenarios (‘Green Growth’ and ‘Sunshine State’) and to re-quantify these to make a clearer distinction between a 'centralised' and a ‘localised' energy system. Moreover, as recognised above, the distinction between centralised and localised is more than just technical; hence, the assumptions were widened beyond the energy system to describe the character of the global economy, i.e. a centralised world of global trade and economic specialisation vs. more localised economies where more primary manufacturing etc. is kept within the UK.

The next section therefore details the methodology adopted for developing the CLUES scenarios, then Section 3 outlines the key assumptions. Section 4 presents the Centralised and Localised scenario outcomes followed by a discussion and summary in Sections 5 and 6.

2. Methodology

Following from the initial quantification by the earlier CLUES work package the Tyndall Centre (Agnolucci, et al., 2009) spreadsheet-based accounting tool for balancing of demand and supply assumptions for the UK energy system was used to significantly re-quantify the SEMBE Green Growth and Sunshine State scenarios. The tool includes four sectors of the UK economy – Households, Industry, Services and Transport – and disaggregates these into 16 sub-sectors as detailed below:

- Households;
- Four Industry Sectors:

- Energy Intensive Industry, Non-Energy Intensive Industry,[6] the Energy Industry, and Construction;

- Four Services Sectors:
  - Public Administration, Commercial, Agriculture, and Miscellaneous;[7]
- Eight Transport sectors
  - Domestic Aviation, International Aviation, Rail, Road Freight, Private Road Passenger, Public Road Passenger, Inland Freight, and International Freight.

For each of the four sectors, a particular identity (i.e. set of assumptions) is used to 'predict' energy demand (explained in more detail in the assumptions section of this report below). The required demand assumptions being the percentage per annum (% p.a.) changes over each decade to 2020, 2030, 2040, and 2050 thus giving a prediction of energy demand for each of the 16 sectors in each decadal year to 2050. With demand determined, assumptions about supply (in absolute units) are required until the cumulative supply contribution matches demand for each decadal year. This is achieved by establishing the grid electricity mix, i.e. the percentage contribution to grid electricity from the following range of fuels/technologies: coal, gas, nuclear, biofuels/waste, renewables, coal co-fired with

[6] Energy intensive industry includes: manufacturing of basic metals; chemicals and man-made fibres; extraction of non-energy materials (includes minerals); non-metallic mineral products. Non-energy intensive industry includes: food, drink and tobacco; textile and textile products; pulp, paper, printing, publishing; electrical and optical equipment; manufacture of transport equipment; leather; wood and wood products; rubber and plastics manufacture; manufacture of machinery and equipment; other manufacturing industries; manufacture of fabricated metal; collection, purification, supply of water.

[7] Commercial services is made up of: retail/trade; hotels and restaurants; transport storage and communication; financial intermediation; financial adjustment; real estate. Public Administration is made up of: public administration and defence; education; health and social work; other social and personal services. Agriculture includes: agriculture, forestry and fishing.

biomass, coal co-fired with biomass with Carbon Capture and Storage (CCS), Coal with CCS, Gas with CCS, imports from other grids.

Then, for each individual sector, various supply assumptions are required as follows:

- share of energy demand met by grid electricity;
- gas Combined Heat and Power (CHP) heat, (electricity contribution then imputed);
- coal CHP heat, (electricity contribution then imputed);
- biofuel CHP heat, (electricity contribution then imputed);
- electricity from onsite renewables;
- non-electrical energy from: onsite renewables, coal, oil, gas, onsite waste & biofuel.

Having balanced supply with demand for each sector in a given decadal year, the same process is repeated for the following decadal year until the entire scenario has been quantified. The rationale for various key demand and supply assumptions in the two scenarios are detailed below.

3 Assumptions

3.1 Households Demand

The energy consumption by Households is given by:

$$E = \frac{E}{CE} \times \frac{CE}{POP} \times \frac{POP}{HH} \times HH$$

where E is energy consumption, E/CE is the energy intensity per unit of economic activity (consumer expenditure), CE/POP is the economic activity (or consumer expenditure) per capita, POP/HH is household size and HH is the number of households in the UK.

Consequently, different assumptions for the Centralised and Localised scenarios are required for the right hand variables of the equation in order to generate the future scenario paths for energy consumption (E) in Million tonnes of oil equivalent (Mtoe). The assumptions for the right hand variables, %p.a. changes for each decadal year up to 2050, are shown in Table 1. Note the assumptions for growth in the number of households (HH) and household size (POP/HH), drawn from ONS 2008-based population projections,[8] are consistent across both Central and Local scenarios.

Table 1: Households - Demand Assumptions

HOUSEHOLDS									
DEMAND									
	2008	2020		2030		2040		2050	
		CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Number of Households (HH)		1.1%		0.9%		1.0%		1.0%	
Household Size (POP/HH)		-0.2%		-0.2%		-0.2%		-0.2%	
Consumer Expenditure (CE/POP)		1.5%	1.5%	2.2%	2.0%	2.2%	2.0%	2.2%	2.0%
Energy Intensity (E/CE)		-2.3%	-2.5%	-2.5%	-2.8%	-2.8%	-3.0%	-2.8%	-3.0%
Energy Consumption (E) (in Mtoe)	45.6	46.1	44.7	47.7	44.2	48.5	43.0	49.3	41.8

[8] www.ons.gov.uk/ons/rel/npp/national-population-projections/2008-based-projections/index.html.

Economic Activity

Economic activity (CE/POP) in the Households sector shows a historical trend in the range of 2.2-3.3% p.a. average on a decadal basis, depending on economic conditions. For the future assumptions, up to 2020, this is lowered to 1.5% in both scenarios to allow for the continuing impact of the financial crisis since 2008. From 2020 onwards, the two scenarios experience different rates of growth in household economic activity, in accordance with the wider storyline of greater economic specialisation and global trade in central, versus re-localisation and more limited trade in Local.

Energy Intensity

Energy intensity is the energy consumption per unit of economic activity (E/ACT). Compared to a historical trend ranging from -1.3 to -3.1% p.a., the two scenarios undergo increasing energy de-intensification over time. In addition, in the Local scenario it is assumed that there is greater demand side management through increased awareness of energy conservation and efficiency issues, due to more direct involvement in energy generation.

Final Energy Consumption

The combined impact of the above assumptions can be seen in the change in energy consumption (E) by households. Compared to a benchmark of 45.6 Mtoe in 2008, the Central scenario sees a small increase in consumption to 49.3 Mtoe (while cleaner energy generation accounts for this sector's contribution towards emissions reductions, see discussion of supply below) and a Local scenario with a slight reduction to 41.8 Mtoe by 2050.

3.2 Industry Demand

The energy consumption for all four industry sectors is expressed by:

$$E = \frac{E}{ACT} \times ACT$$

where E is energy consumption, E/ACT is the energy intensity per unit of economic activity, ACT is the economic activity. Table 2 shows the demand assumptions for each of these sectors in the two scenarios.

Economic Activity

The ***energy intensive industry*** sector shows a historical trend of around 1.75% p.a. For the Central scenario it is assumed that the UK economy focuses largely on services, and sees the offshoring of heavy manufacturing and other energy intensive industry. Meanwhile the Local scenario retains primary manufacturing and energy intensive industry, as part of a world in which the economic geography is one of re-localisation. Hence, in these scenarios, economic activity for this sector diverges in opposite directions from the trend.

Table 2: Industry – Demand Assumptions

INDUSTRY - SECTORAL DISAGGREGATION									
DEMAND									
	2008	2020		2030		2040		2050	
		CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Economic Activity (ACT)		% p.a.							
Non Intensive Industry		0.60%	0.70%	0.55%	0.80%	0.50%	0.90%	0.45%	1.00%
Energy Industry		-2.00%	-1.00%	-2.00%	0.00%	-2.00%	1.00%	-2.00%	2.00%
Intensive Industry		1.50%	1.80%	1.30%	1.90%	1.10%	2.00%	0.90%	2.10%
Construction		2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%
Energy Intensity (E/ACT)		% p.a.							
Non Intensive Industry		-1.50%	-1.20%	-1.50%	-1.20%	-1.50%	-1.20%	-1.50%	-1.20%
Energy Industry		-1.00%	-1.00%	-1.25%	-1.00%	-1.50%	-1.00%	-1.75%	-1.00%
Intensive Industry		-4.35%	-3.50%	-4.50%	-3.50%	-4.50%	-3.50%	-4.50%	-3.50%
Construction		-3.00%	-3.00%	-3.00%	-3.00%	-3.00%	-3.00%	-3.00%	-3.00%
Energy Consumption (E)		Mtoe							
Non Intensive Industry	19.5	17.5	18.4	15.9	17.6	14.4	17.1	12.9	16.7
Energy Industry	13.9	9.7	11.0	7.0	9.9	4.9	9.9	3.4	10.9
Intensive Industry	10.6	7.4	8.5	5.3	7.2	3.8	6.2	2.6	5.3
Construction	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3

A similar story applies in the case of **non-energy intensive industry**, whereby the two scenarios deviate from a historical trend of around 0.75% p.a. The difference between the two scenarios is not as pronounced as in the energy intensive industry sector since it is the heavy manufacturing and other energy intensive activities that are assumed to be offshored more so than the less intensive activities represented in this sector. For ***construction***, which is a relatively insignificant sector in terms of energy consumption at less than 0.5% of the 2008 total, economic activity is held constant at 2% p.a. for the whole period of both scenarios, broadly consistent with the historical trend.

Drawing on historical trends for the ***energy industry*** is more problematic however, as this sector has experienced substantial transformation due to North Sea oil and gas. In more recent years, the sector has slowed, and both scenarios show a decline in the near term. In the Central scenario, which experiences more global trade, the UK is able to rely on imports of electricity, oil and gas to meet on-going energy needs, such that the indigenous energy industry continues its decline in terms of economic activity, while the Local scenario involves greater exploitation of indigenous energy resources.

Energy Intensity

Energy Intensive industry experienced a historical trend of around -4.25% p.a. For the Central scenario energy intensity is therefore assumed to continue to fall but at a slightly faster rate of -4.50% p.a., representing what's possible in a scenario where the most energy intensive activity is gradually offshored, leaving a ‘less’ energy intensive industry sector. For Local however, the sector is assumed to undergo significant innovation in pursuit of energy savings, although the economy does not experience the offshoring of the *most* energy intensive parts of the sector, hence the overall trend is a smaller annual reduction of -3.50%.

Non-energy intensive industry experienced a historical trend of -1.50% p.a. For Central, in a similar pattern to energy intensive industry, the relatively more energy intensive activity in this sector is assumed to be offshored more rapidly, leaving a 'less intensive' non-energy intensive industry sector. In Local, significant innovation is assumed to deliver energy savings, but to the extent that offshoring has made some contribution to the historical trend of falling energy intensity, the reversal of offshoring in this scenario prevents energy intensity from falling as fast. Finally, for the ***Energy industry*** itself, it is assumed that energy intensity falls by 1% p.a. over the whole period in the Local scenario, but for the Central scenario, the decline gathers pace reaching 1.75% p.a. by the end of the period.

For the ***construction*** sector, the past trend for energy intensity has been as high as -6% p.a., depending on the period selected. However, the assumption used here for both scenarios is more conservative at -3% p.a. The growth being held equal across the two scenarios for the reasons given above, so too is the rate of innovation in terms of energy intensity.

3.3 Services Demand

Energy consumption for all four sectors is again given by:

$$E = \frac{E}{ACT} \times ACT$$

where E is energy consumption, E/ACT is the energy intensity per unit of economic activity, ACT is the economic activity. Table 3 shows the demand assumptions used for these sectors in the scenarios.

Table 3: Services - Demand Assumptions

SERVICES - SECTORAL DISAGGREGATION										
DEMAND										
	2008	2020		2030		2040		2050		
		CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC	
Economic Activity (ACT)		% p.a.								
Commercial		2.90%	1.50%	3.30%	2.00%	3.30%	2.00%	3.30%	2.00%	
Public Administration		0.50%	0.50%	1.00%	1.00%	1.50%	1.50%	1.50%	1.50%	
Agriculture		1.50%	2.50%	1.50%	2.50%	1.50%	2.50%	1.50%	2.50%	
Miscellaneous		1.00%	1.00%	2.00%	2.00%	2.00%	2.00%	2.00%	2.00%	
Energy Intensity (E/ACT)		% p.a.								
Commercial		-2.25%	-2.50%	-2.50%	-2.75%	-2.75%	-3.00%	-3.00%	-3.25%	
Public Administration		-2.25%	-2.50%	-2.50%	-2.75%	-2.75%	-3.00%	-3.00%	-3.25%	
Agriculture		-3.25%	-3.25%	-3.25%	-3.25%	-3.25%	-3.25%	-3.25%	-3.25%	
Miscellaneous		-2.97%	-2.97%	-3.92%	-3.92%	-3.92%	-3.92%	-3.92%	-3.92%	
Energy Consumption (E)		Mtoe								
Commercial	10.2	10.9	9.0	11.7	8.3	12.3	7.5	12.5	6.5	
Public Administration	6.9	5.6	5.4	4.8	4.5	4.2	3.9	3.6	3.2	
Agriculture	0.9	0.7	0.8	0.6	0.8	0.5	0.7	0.4	0.7	
Miscellaneous	1.8	1.4	1.4	1.2	1.2	0.9	0.9	0.8	0.8	

Economic Activity

The historical trend for ***commercial services*** economic activity is over 3% p.a. In the Central scenario where industry is offshored in favour of the services sector, growth in economic activity in this sector is assumed to be 2.9% initially, rising to 3.3% from 2030 onwards. In the Local scenario, where there is more of a resurgence in the industrial sectors, growth in commercial services is assumed to be 1.5% p.a. initially, rising to 2% p.a.

The historical trend for economic activity in ***public administration*** is around 1.5% p.a. Since economic activity in this sector is closely related to public policy, and since this study does not set out to tackle the impact on energy demand from such issues e.g. austerity vs stimulus, demand assumptions are held equal across both scenarios. The impact of planned coalition government cuts is shown in a rate of 0.5% p.a. through to 2020, before rising gradually back to the trend.

Economic activity in the ***agriculture*** sector has an historical trend of around 1.6% p.a. In the Central scenario, it is assumed that agriculture grows close to this trend, while in Local agriculture is assumed to be part of the wider narrative of re-localisation of economic activity, so this sector grows at 2.50% p.a. Economic activity in the ***miscellaneous*** sector is, by definition, difficult to tie to a particular scenario narrative, therefore both scenarios experience the same rate of change of 1% p.a. up to 2020, rising to 2% p.a. thereafter.

Energy Intensity

The energy intensity of ***commercial services*** showed a historical trend of around -2%p.a. In the Central scenario the rate of change begins close to the trend, building momentum over time. In Local, a faster rate of change is assumed, consistent with greater demand side measures in this scenario. The energy intensity of ***public administration*** shows a similar historical trend around -2% p.a. As with commercial services, the rate of change begins close to the trend at first before building momentum. For Central this means change in energy intensity ranging from -2.25% p.a. initially to -3.00% p.a. by 2050. In Local, a slightly faster rate of change is assumed, consistent with greater demand side measures.

The energy intensity of the ***agriculture*** sector, has a historical trend of almost -3% p.a. In these scenarios, although there is increased economic activity in Local compared to Central, it is not assumed that the drivers of innovation in terms of energy intensity are any different. For that reason, both scenarios assume the same rate of change.

3.4 Transport Demand

Energy consumption is given by the following equation:

$$E = \frac{E}{MOB} \times MOB$$

where E is energy consumption, E/MOB is energy intensity per unit mobility and MOB is mobility (i.e. passenger kilometres/tonne kilometres). Table 4 shows the demand assumptions used for the transport sectors.

Table 4: Transport - Demand Assumptions

TRANSPORT - SECTORAL DISAGGREGATION									
DEMAND									
	2008	2020		2030		2040		2050	
		CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Mobility (MOB)		% p.a.							
International Aviation		3.50%	2.00%	3.50%	1.50%	3.00%	1.00%	2.50%	0.50%
Domestic Aviation		4.50%	4.00%	4.00%	3.25%	3.50%	2.50%	3.00%	1.75%
Road (Private)		1.00%	0.70%	1.00%	0.25%	0.50%	0.00%	0.50%	-0.25%
Road (Public)		2.00%	1.75%	3.00%	2.75%	4.00%	3.75%	5.00%	4.75%
Road (Freight)		1.00%	0.80%	1.00%	0.80%	1.00%	0.80%	1.00%	0.80%
Rail		2.00%	1.75%	2.00%	1.75%	3.00%	2.75%	3.00%	2.75%
International Shipping		1.50%	1.20%	2.00%	1.00%	2.00%	1.00%	2.00%	1.00%
Domestic Shipping		1.30%	1.20%	1.50%	1.20%	1.60%	1.60%	1.90%	1.70%
Energy Intensity (E/MOB)		% p.a.							
International Aviation		-1.00%	-0.80%	-1.00%	-0.80%	-1.00%	-0.80%	-1.00%	-0.80%
Domestic Aviation		-1.00%	-0.80%	-1.00%	-0.80%	-1.00%	-0.80%	-1.00%	-0.80%
Road (Private)		-1.00%	-0.80%	-1.75%	-1.50%	-2.75%	-2.50%	-3.75%	-3.50%
Road (Public)		-1.50%	-1.25%	-2.50%	-2.25%	-3.50%	-3.25%	-4.50%	-4.25%
Road (Freight)		0.00%	0.00%	-1.00%	-0.75%	-1.50%	-1.25%	-2.00%	-1.75%
Rail		-1.00%	-0.75%	-1.50%	-1.25%	-2.00%	-1.75%	-2.50%	-2.25%
International Shipping		-1.75%	-1.50%	-1.75%	-1.50%	-1.75%	-1.50%	-1.75%	-1.50%
Domestic Shipping		-1.75%	-1.50%	-1.75%	-1.50%	-1.75%	-1.50%	-1.75%	-1.50%
Energy Consumption (E)		Mtoe							
International Aviation	12.5	16.8	14.4	21.4	15.5	26.0	15.8	30.1	15.3
Domestic Aviation	0.9	1.3	1.3	1.8	1.7	2.3	2.0	2.8	2.1
Road (Private)	23.8	23.8	23.5	22.0	20.7	17.5	16.1	12.6	11.0
Road (Public)	1.3	1.3	1.3	1.4	1.4	1.4	1.4	1.5	1.5
Road (Freight)	12.3	14.5	14.2	14.5	14.3	13.8	13.6	12.5	12.4
Rail	1.5	1.7	1.7	1.7	1.7	1.9	1.9	2.0	2.0
International Shipping	13.5	13.5	13.5	13.8	12.8	14.1	12.2	14.4	11.5
Domestic Shipping	1.8	1.6	1.6	1.5	1.5	1.5	1.6	1.5	1.6

Mobility

The historical trend for ***international aviation*** mobility is approximately 5.75% p.a. For both scenarios this growth is curtailed quite considerably in the Local scenario whereas significant growth remains in the Central scenario, consistent with the assumption of greater international trade and mobility. The historical trend for ***domestic aviation*** is lower at around 4.75% p.a. As with international aviation, this trend is curtailed in both scenarios, but more heavily in Local to reflect wider assumptions of a less international travel and trade than in Central.

The growth in mobility of ***private road passenger*** transport has slowed historically (with a trend of 2.4% p.a. from 1970 onwards, down to 1% p.a. from 1990 onwards). This is assumed to slow further in both scenarios, consistent with an assumption of the saturation of road capacity and a modal shift towards public transport. For mobility of ***public road passenger*** transport the historical trend from 1970 shows a decline of -0.65% p.a., while the nearer term trend from 1990 shows a growth of 0.35% p.a. For both scenarios here, significant growth was assumed to reflect modal shift away from private road passenger transport, although less mobility overall in Local is reflected in the lower figures used for that scenario.

Mobility growth historically for ***road freight*** was around 2% p.a. when taken from 1970, slowing to 1% p.a. taken from 1990. Road freight is therefore held at 1.00% and 0.80% p.a. throughout the Central and Local scenarios respectively. The longer term historical trend for mobility in ***rail*** transport is 0.5% p.a. with a shorter term trend of 1.8% p.a. The more recent trend is taken as a starting point for these scenarios, with a modal shift from road to rail transport leading to higher growth in later periods.

The ***international shipping*** category is difficult to quantify since there are competing methodologies for determining the appropriate UK share. The approach adopted here is based on the growth in emissions, estimated by DECC at 8.8 Million Metric Tonnes of Carbon Dioxide Equivalent (MtCO2e) in 1990, and 11.0 MtCO2e in 2008, giving an average annual change of 1.1% per annum, although more accurately: "Since 1990, emissions from UK shipping bunkers have been highly variable. There was an increase of around 18 per cent between 1990 and 1998, followed by a fall of 48 per cent between 1998 and 2002. Emissions then more than doubled between 2002 and 2008, but have since fallen by 20 per cent, and they are now at the same level as in 1990" (DECC, 2012a) . Allowing for some (assumed) improvement in energy intensity over the period, growth in mobility would therefore need to have been higher than the growth in emissions. A figure of 2% p.a. is used in Central to represent a business-as-usual rate of change in a world of continued growth in global trade (allowing for the impact of the global financial crisis in the average rate through to 2020), while in the Local scenario growth in international shipping slows gradually to 1% p.a.

It is further assumed that the mobility of ***inland shipping*** increases over the scenario period in both cases, with domestic waterways used for freight. This growth is marginally higher in Central consistent with the wider assumption of higher growth, trade and mobility.

Energy Intensity

The trend in energy intensity of ***international aviation*** is falling, but also slowing over time to approximately -0.35% p.a. from 1990. The scenarios assume that a focus on energy efficiency in the industry leads to an average of -1% p.a. improvement in efficiency in Central, and – due to less activity and innovation – to 0.8% p.a. in Local. As with international, ***domestic aviation*** energy intensity shows some variability, -2.55% p.a. over the longer term, but -0.25% p.a. since 1990. The same assumptions have been made for domestic that were made for international, i.e. significant effort raises energy efficiency above the recent trend, with some discrepancy between Central and Local consistent with the assumption of greater transport innovation in Central.

For ***road passenger*** transport energy intensity, the trend shifts only from -0.70% to -0.85% p.a. whether 1970 or 1990 is taken as the starting point. Some clarity is required here on what is part of the acceleration of energy efficiency. From the DECC 2050 pathways analysis report: "Efficiency improvements include some engine advances and other vehicle improvements such as light-weighting and downsizing.... ICE cars and vans show an average 54% improvement by 2050; EVs improve by 37%, and PHEVs by 50% by 2050" (DECC 2010a, p. 63). In the assumptions used in this study, from an index where 2008=100, energy intensity falls to 38 in the Central scenario, and to 42 in Local, i.e. a 62% and 58% improvement in overall fleet efficiency.

As for the fuel/technology make up of that fleet (see data tables in later section of this document) the DECC report offers a range of 20% to 60% for electric (see "Proportion of car and van distance travelled by different power sources in 2050"). This study assumes that – in both scenarios - around 40% of total energy consumption for this category comes from electricity, while biofuels account for around 23% of the total.

For ***road public passenger*** transport, reductions in energy intensity accelerate in recent years, with an average of -1.85% p.a. if taken from 1990. It is assumed in both scenarios that a focus on energy efficiency innovation can improve this further. Once more, a smaller rate of reduction in Local reflects less innovation in this scenario generally. ***Road freight*** energy intensity shows an increase historically, of 1.00% p.a. over the long term. Although efforts are made to improve energy efficiency, consistent with the wider scenario narratives, road freight sees more modest improvements than other categories as reflected in the figures.

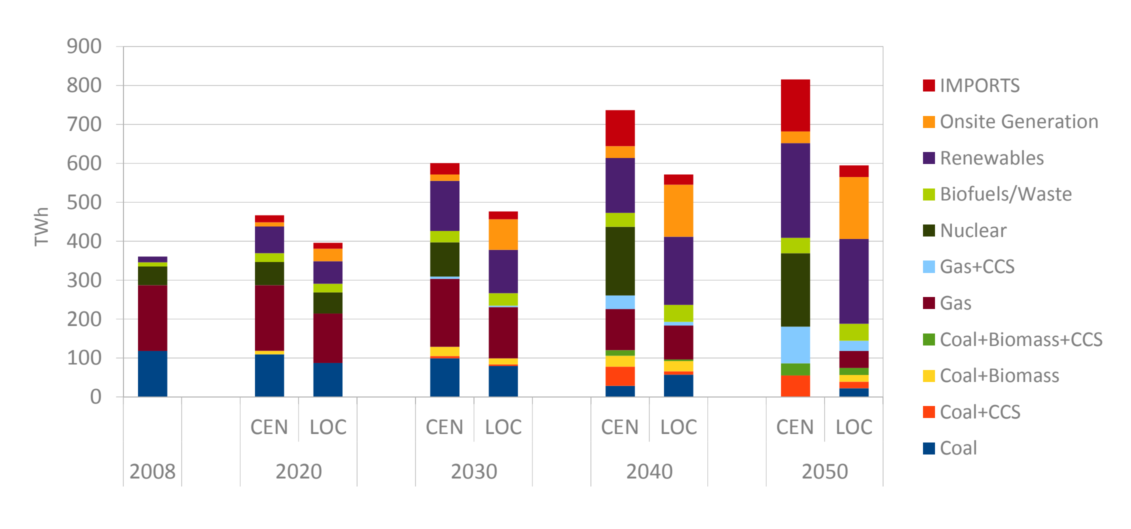
For ***rail*** energy intensity, the more recent historical trend from 1990 has shown a slower reduction of -0.1% p.a. against the longer trend from 1970 of -0.6% p.a. Nevertheless, a focus on energy savings and replacement of rolling stock leads to an increasing rate of energy efficiency improvement over the duration of the scenarios. For ***international and domestic shipping,*** a similar explanation is used for the assumptions to that given under mobility above.

3.5 Grid Electricity Mix

As the two scenarios unfold, they follow divergent pathways in terms of growth in total electricity generation and also the fuel/technology mix. As discussed later in the report, final energy consumption in 2050 is roughly equivalent for the two scenarios (excluding international aviation and shipping). However, the Central scenario sees a greater emphasis on electrification based on large-scale solutions to meet energy needs, while in Local there is a greater emphasis on diversity of both scale and fuel/technology. As a result, Central has a much greater demand for electricity generation in 2050 at 815 625 Terawatt-hours (TWh), against 595 TWh in Local.

This compares with the range of illustrative pathways provided in the DECC 2050 pathways analysis report, with electricity generation in 2050 between 750 TWh and 1000 TWh (DECC 2010) with a reference case at around 500 TWh, a pathway that involves hardly any attempt to decarbonise. However, another scenarios report by UKERC presents a range of between 450 and 625 TWh (UKERC 2009), involving significant demand reduction. The peculiarities of any given scenario pathway allow for significant variation in a variable such as total electricity generation. The assumptions presented here, summarised in Fig, 1, do not appear out of the ordinary against other scenario studies of the UK energy system.

Figure 1: Electricity Mix



In terms of the mix of fuels and technologies contributing to grid electricity, the baseline 2008 composition is shown in Fig. 1. Generation is dominated by gas-fired plant, at 46% of the total, with coal-fired plant at 32% and nuclear at 13%. Waste, biomass and renewables (including hydro) account for the remainder.

Out to 2050, there are several features distinguishing the two scenarios in this study. Firstly, in the Central scenario, a new generation of nuclear power stations makes up a substantial amount of electricity generation in 2050. It is assumed that on-going policy and economic uncertainty in the short term means that rollout of new plant is somewhat delayed, with the first series of new plant merely replacing the old, such that 2030 generation is only marginally greater than 2020. Then, as this period of construction comes to an end in the 2030s, overall generation from nuclear increases substantially to 2040, before stabilising. In Local, nuclear is phased out entirely by 2030.

Carbon capture and storage also has a distinct development pathway in each of the scenarios. In Central, with increased electricity demand, a greater emphasis is placed on securing the necessary technological breakthroughs in CCS to ensure emissions reductions can be met. As a result – and with the necessary breakthroughs assumed to take place – the Central scenario sees a substantial contribution from CCS for both coal and gas by 2040, with the replacement of all unabated fossil fuel plant by 2050. Following a more diverse development pathway, where investment in research and development is spread across a wider portfolio of technologies and solutions, scaling up of CCS in the Local scenario proceeds more slowly so that by 2050 there is a fairly even contribution from each of: coal,

coal with CCS, coal co-fired with biomass, and finally coal co-fired with biomass with CCS. Unabated gas-fired plant is also on the way to being phased out as gas CCS takes hold.

All generation from nuclear and fossil fuels (unabated, co-fired, and CSS), accounts for around 370 TWh in the Central scenario, and only 145 TWh in Local. Notably, the remaining electricity generation in the two scenarios is broadly equivalent in volume, accounting for around 445 TWh in Central and 450 TWh in Local in 2050. Biomass and waste contribute around 40 and 45 TWh in Central and Local respectively.

Imports feature highly in the Central scenario, growing to 135 TWh by 2050 since it assumed that a series of interconnectors are laid between the UK and mainland Europe, allowing for significant intercontinental flow of electricity, including for example concentrated solar power in North Africa. The Local scenario also assumes the laying of interconnectors; however, the diversity of the indigenous supply mix ensures much closer matching between local energy generation and consumption, minimising the need for long distance transmission of this kind.

The remaining two categories are renewables (on a large scale, such as wind farms) and 'onsite generation' which includes electricity from CHP plant as well as building integrated renewables such as solar PV and micro-wind. For the Central scenario, a total of 275 TWh is assumed to be delivered from renewable sources, with the vast majority (90%) coming from large-scale projects such as wind farms (onshore and offshore), wave and tidal energy, including a tidal barrage on the Severn Estuary. In the Local scenario, with less of a contribution from imports, around 375 TWh are required from a renewables source. As a result, it is assumed that technologies at every scale are encouraged (with large-scale projects accounting for 60%).

In summary, the Central scenario involves greater electricity generation in 2050 than the Local scenario with much of the difference accounted for by the significant contribution of electricity imports in Central. While in terms of the indigenous electricity supply mix – with large scale renewables making a comparable contribution in the two scenarios – the distinguishing feature is the contribution of nuclear vs that of small-scale renewable generation in Central and Local respectively.

3.7 Household Energy Supply

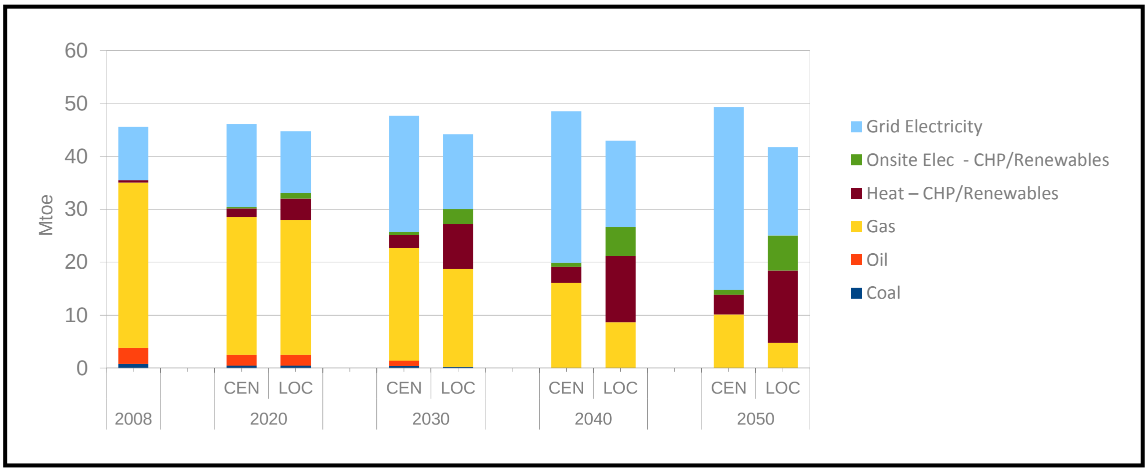
Fig. 2 gives household final consumption by energy source up to 2050 for both scenarios, alongside data for the baseline year of 2008. [9] It can be seen that Gas makes up the largest proportion of energy consumed in 2008 at around 30 Mtoe out of a total of 45 Mtoe. Next to gas is consumption of electricity at around 10 Mtoe, with household consumption of oil at 3 Mtoe and coal at less than1 Mtoe (oil for private transport use is accounted for elsewhere).

Over the course of the scenario period, overall demand in the Central scenario rises to around 49 Mtoe while falling to around 42 Mtoe in the Local scenario (see demand assumptions section of this report for further discussion). Some broad trends are consistent across the two scenarios, with oil and coal dropping out of household energy consumption by 2040, gas consumption falling and electrification of household energy increasing.

[9] Note: i) Final Energy Consumption does not include losses in energy delivery, e.g. from transmission and distribution of grid electricity or oil refining, (for which see section on primary fuel use); and ii) the absolute units used for the supply assumptions can be found in thee fuller tables in the Appendix.

However, there are significant differences in scale within those. For gas, consumption falls to 10 Mtoe in Central and even further to 5 Mtoe in Local. For electricity, overall consumption rises to 35 Mtoe in Central mainly through delivery of grid electricity. In the Local scenario this is lower at 23 Mtoe and from a more diverse mix of grid, onsite and CHP generated electricity. The final category of heat energy (from a combination of renewables, biofuels and CHP), shows some growth in the Central scenario to 4 Mtoe, but enjoys far more significant role in the Local scenario, providing 14 Mtoe of energy consumed by households.

Figure 2: Households Final Consumption by Energy Source



3.8 Industry Energy Supply

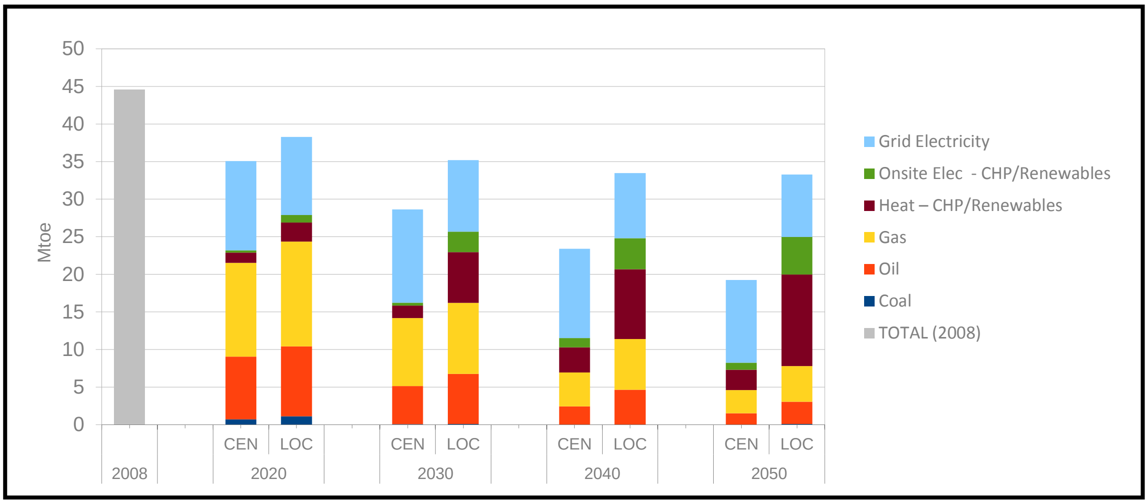
Figure 3 shows final consumption by energy source for the industry sectors through to 2050 (see demand section for a detailed sectoral breakdown).[10] The basic story of the Central scenario is a world of ever greater integration in terms of global trade, with the UK specialising in services at the expense of indigenous industry. As a result, there is a sharp decline in overall energy consumption in that scenario. That decline comes from a reduction in fossil fuel use, while use of electricity and delivered heat remain relatively stable in

[10] Due to data limitations for the energy industry in particular, only the total energy consumption is shown for the 2008 baseline year.

absolute terms. This is essentially the route of decarbonisation through offshoring, and in a world where production is offshored but the goods and services continue to be brought to the UK market; there are obvious implications for energy and emissions from global transportation, as reflected in the transport assumptions in this study. What this study cannot do however, is account for the energy and emissions resulting from the production of goods and services overseas which are then transported to and consumed in the UK.

In the Local scenario, the divergence from the Central pathway is clear, as industry is retained within the UK as part of a trend towards re-localisation of economic activity. With energy consumption by industry declining more slowly then, more effort must be made to provide that energy through low carbon sources. CHP takes on a much stronger role therefore, generating electricity in the process of providing heat for industrial processes. Although gas plays a strong role as a feedstock for CHP, the contribution from biomass sources is marginally higher still.

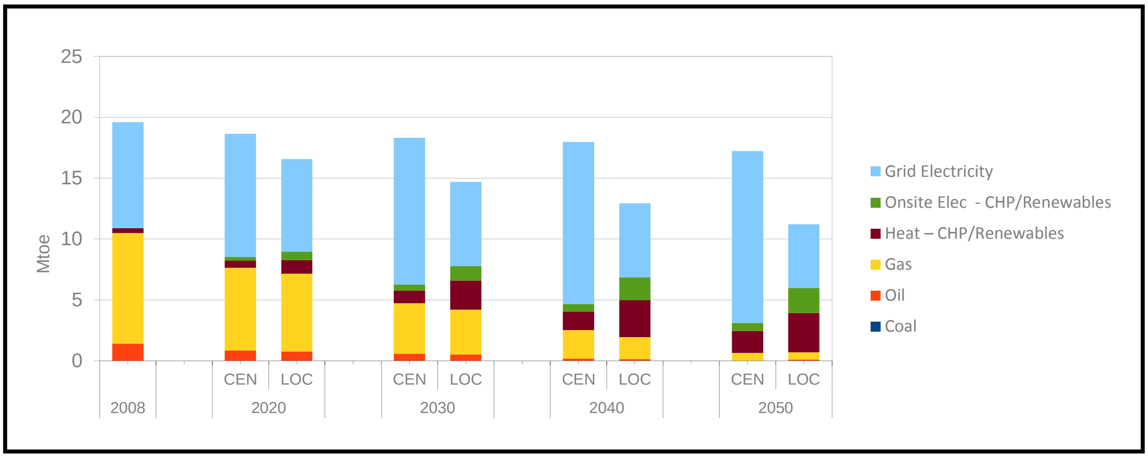
Figure 3: Industrial Final Consumption by Energy Source



3.9 Services Supply

Final consumption by energy source for services through to 2050 can be seen in Figure 4, alongside 2008 baseline data. Of the four services sectors, agriculture and miscellaneous have a relatively small energy footprint, while changes in energy consumption in public administration are subject to politically sensitive assumptions around the size of the public sector. As a result, economic activity for public administration was matched across the two scenarios, while energy intensity came down in both, but at a marginally higher rate in Local to reflect greater engagement in energy efficiency and conservation measures in that scenario.

Figure 4: Services Final Consumption by Energy Source

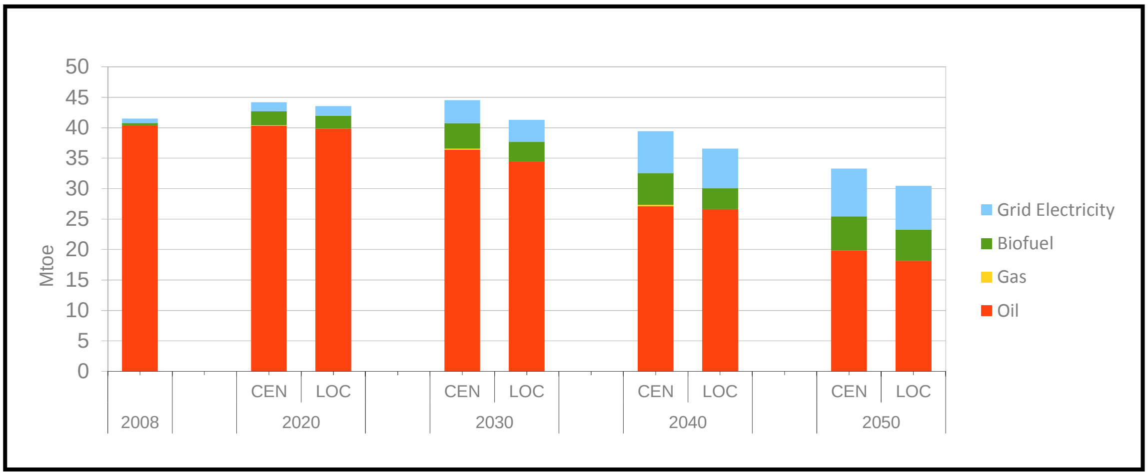


The bulk of the difference between the two scenarios – in terms of final energy consumption by services – is therefore attributable to commercial services, which grows at a far higher rate in Central and enjoys a marginally lower rate of energy de-intensification. This can be seen in the overall energy consumption profiles of the two scenarios. The supply mix for services energy consumption in the Central scenario reflects the wider assumption of electrification, largely through a centralised electricity grid, although onsite generation accounts for some electricity generation in this scenario. In Local, electricity consumption actually falls in absolute terms, and onsite generation accounts for over a quarter of electricity consumed. Gas, which constitutes the largest share of energy consumption in 2008 falls dramatically in both scenarios, although this is partially reintroduced as a feedstock for CHP, especially in the Local scenario.

3.10 Domestic Transport Energy Supply

UK emissions as accounted for under the Kyoto Protocol do not include emissions from international aviation and shipping, therefore those international transport categories have been separated from the domestic categories, which include: domestic aviation, domestic shipping, rail, private road transport, public road transport and road freight. Final consumption by energy source for the domestic transport sectors in the two scenarios through to 2050 are shown in Fig. 5, alongside the 2008 baseline.

Figure 5: Domestic Transport Consumption by Energy Source



Given the evolution of this study from a set of scenarios exploring the built environment, there are no radical differences between the trajectories for energy consumption in domestic transport. Consistent with the wider scenario assumptions, domestic transport in Central consumes more energy as a result of greater mobility. This is true for domestic aviation and shipping as well as for private and public transport use. Nevertheless, the supply breakdown for the two scenarios is similar, with oil continuing to comprise the majority of energy supply, although its share is markedly reduced from the 2008 baseline, with biofuel and electricity each making a growing contribution towards 2050.

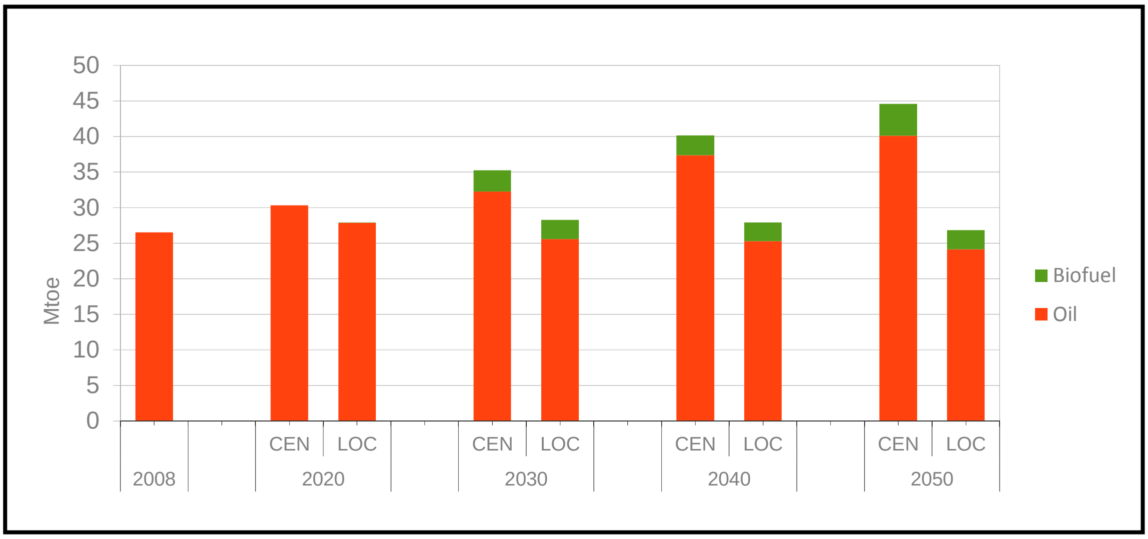
3.11 International Transport Energy Supply

Final consumption by energy source from the UK share of international transport in the two scenarios is shown in Fig. 6, alongside the 2008 baseline. The trajectories clearly reflect the wider scenario assumptions, whereby in Central the UK enjoys increasing trade with the rest of the world, leading to higher energy consumption for international aviation and shipping. Travel and tourism also contributes to this growth. In the Local scenario, where there is a reorientation towards more localised economic activity and a corresponding slowing of global trade, as well as a shift in public attitudes and engagement on emissions from travel and tourism, the energy consumed by international aviation and shipping is held more or less constant. In both scenarios, biofuel makes some contribution to the fuel supply mix, but oil continues to dominate.

3.12 Assumptions Overview

This section has elucidated the detailed assumptions required to build up the Centralised and Localised scenarios. The next section therefore focusses on the scenario outcomes for both scenarios in terms of overall energy supply, consumption, and resultant emissions.

Figure 6: International Transport Consumption by Energy Source



4 Scenario Outcomes

4.1 Aggregate Energy Consumption

Figure 7: Aggregate Energy Consumption by Sector

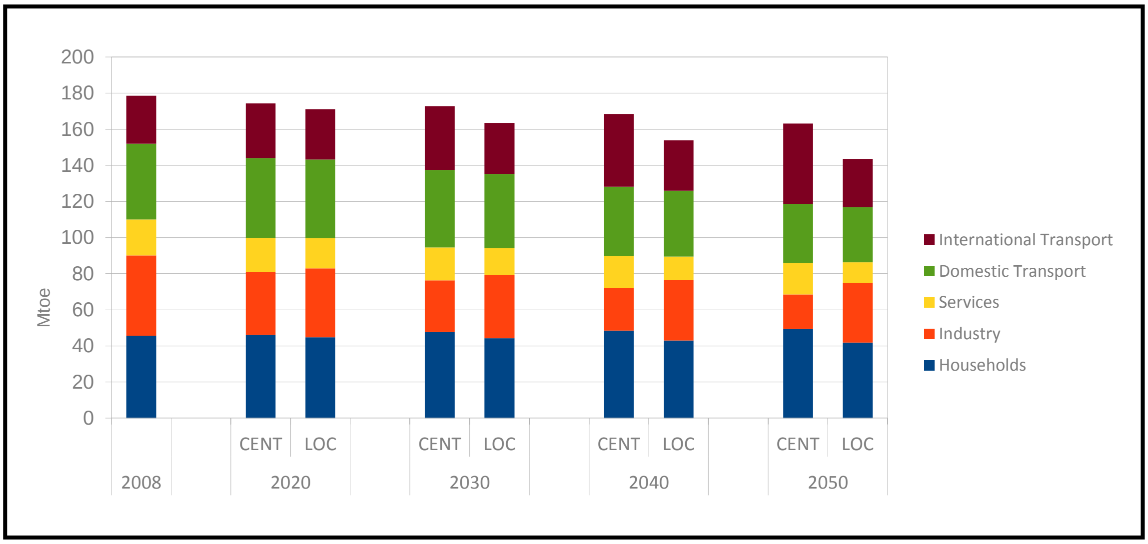
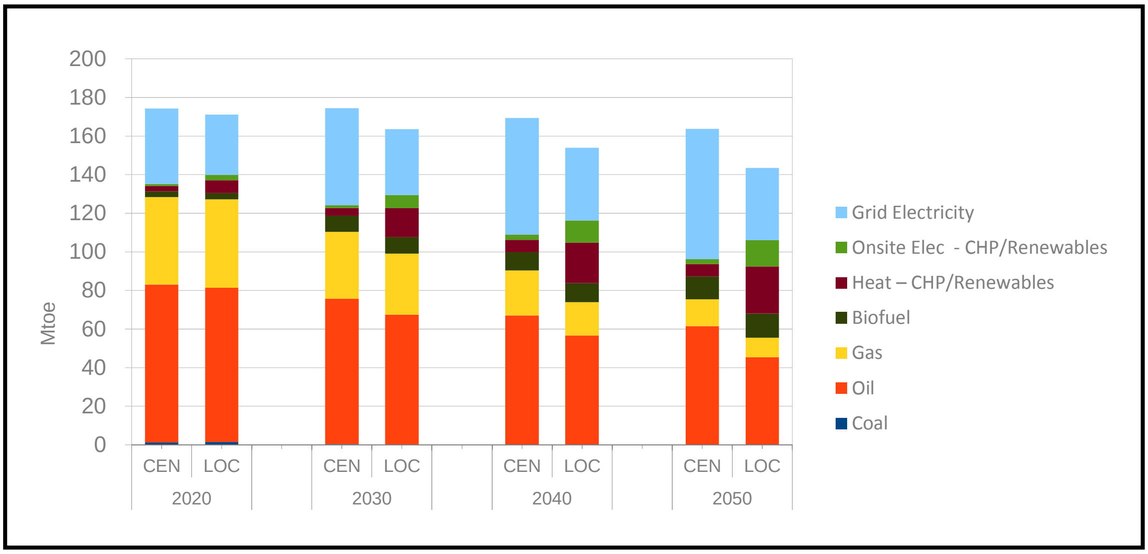


Fig. 7 shows the aggregate final energy consumption for the two scenarios through to 2050, alongside the 2008 baseline. With international transport placed at the top, it is possible to compare the results excluding this category, in which case final energy consumption between the two scenarios is broadly the same. However, the compositions grow more distinct over time. Households in the Central scenario, consume an additional 4 Mtoe by 2050, growth of approximately 0.2% p.a.. Bearing in mind that the number of households is growing at approximately 1% annually, energy consumption *per household* is falling. In the Local scenario though, a combination of lower household income growth and greater efforts at energy efficiency mean that energy consumption falls in absolute terms by around 4 Mtoe.

Other differences in composition have been remarked on already, i.e. the shift away from industry towards services in Central, against a re-localisation of industry and manufacturing in Local. Marginally higher domestic transport energy use in Central reflects marginally higher mobility in that scenario, while the international transport component makes a marked difference in the total energy consumption between the two scenarios. Fig. 8 disaggregates the same final energy consumption by the supply source, rather than by sector.

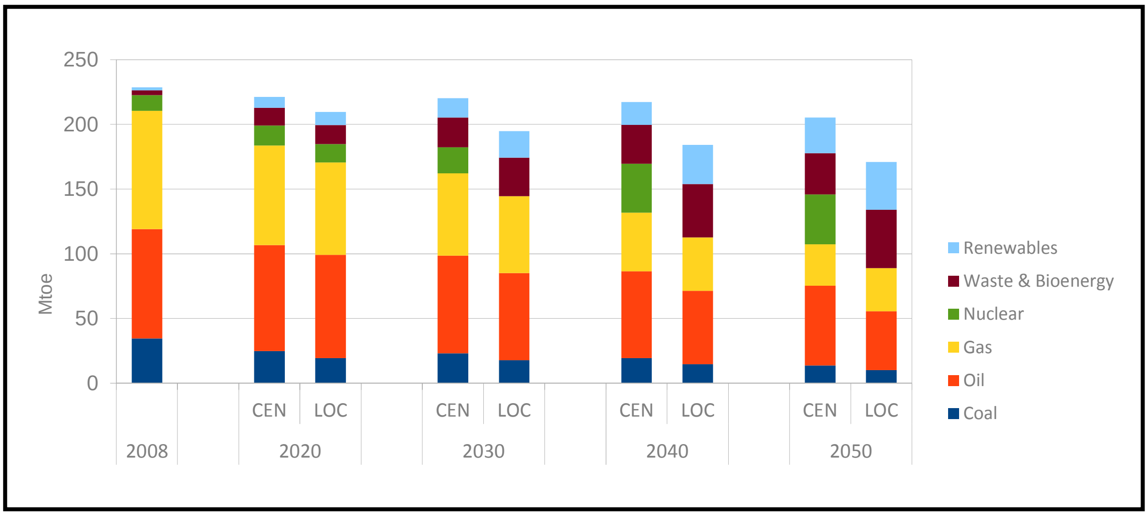
Figure 8: Aggregate Final Consumption by Energy Source



4.2 Primary Energy

Fig. 9 shows the primary energy in Mtoe for the two scenarios out to 2050, alongside the 2008 baseline. Coal, oil and gas all decline in absolute terms in both scenarios. Whereas gas use in 2050 is similar in both scenarios the assumptions around mobility for domestic and particularly international transport mean that the Central scenario involves significantly higher consumption of oil in 2050, at 61 Mtoe compared with 45 Mtoe for Local. Nuclear accounts for 39 Mtoe in the Central scenario in 2050, while it has been phased out entirely by 2030 in Local. Waste and biofuels play a more prominent role in the Local scenario, at 45 Mtoe of primary energy compared with 32 Mtoe in Central, for 2050. Finally, renewables account for 37 Mtoe in Local, and 28 Mtoe in Central. Crucially, the primary energy figures do not include fuel used in the generation of imported electricity.

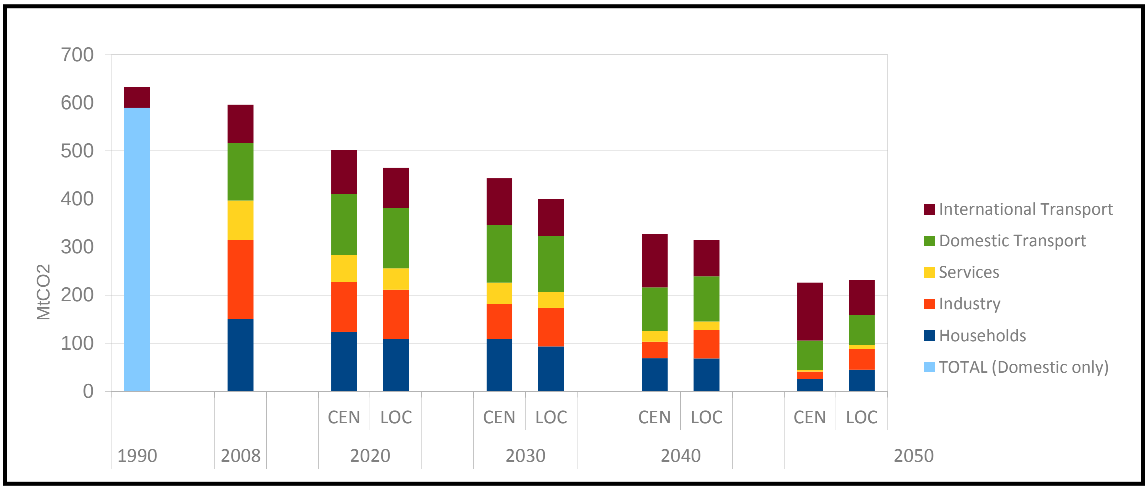
Figure 9: Primary Energy



4.3 Emissions

Fig. 10 shows Carbon emissions in $MtCO_2$ for the two scenarios through to 2050, alongside 1990[11] and 2008 emissions (DECC, 2012a). As discussed above, emissions from international aviation and shipping do not currently form part of the formal Kyoto Protocol emissions accounting; therefore, as with Fig. 7, this category has been placed at the top of each column to make it easier to compare the two scenarios with or without this category. The inclusion of international transport emissions in 2050 is a matter of on-going debate, due to be resolved in 2012. As a result, percentage reductions are given including and excluding international transport (where the baseline emissions are revised up to allow for the inclusion of 1990 international transport emissions), although it is not clear what the eventual decision would be on the adjustment of baseline data. It is worth reiterating that the differing methodologies used in calculating international aviation and shipping emissions affect the baseline data used, meaning that the comparison of CLUES percentage reductions for these categories against DECC or other forecasts will vary.

Figure 10: Carbon Emissions (MtCO2)



[11] The 1990 figure of 590MtCO2 is for Carbon Dioxide only (the component accounted for in this study) and not the full basket of greenhouse gases as accounted under Kyoto. Thus, any comparison against UK 2050 reductions targets (which formally apply to all GHGs) should take account of this.

If international transport is excluded from the accounting, then compared to a 1990 figure of 590 $MtCO_2$, emissions fall by 82% in the Central scenario to 106 $MtCO_2$, and by 73% in the Local scenario to 159 $MtCO_2$. The inclusion of international transport however leads to a much smaller reduction of approximately 64% for both scenarios. In part, the stronger domestic emissions reduction in the Central scenario is made possible through increased offshoring of production, which in turn leads to greater international aviation and shipping. Although the inclusion of that category 'cancels out' any emissions advantage in the Central scenario, it should be noted that the increased transportation of goods to the UK market was only one of the contributors to the demand assumptions outlined earlier, with some increased mobility being attributed to tourism.

4.4 Exploring Scale

Table 5, gives an illustrative breakdown of how grid electricity from each source might be met in terms of scale for the Central scenario in 2050.[12] The Central scenario assumes no unabated fossil fuel plant in the grid electricity mix by 2050. Of the large scale plant, nuclear makes the largest contribution at 189 TWh, achievable through the example breakdown given in Table 5.

For the Central scenario, there are only six coal power plants, all with CCS, and two of those co-firing biofuel, although these operate with a high average load factor to contribute 86

[12] Note, the five rightmost columns are based on simple calculations to illustrate how electricity might be generated, with numbers of units of each technology and average capacities giving total capacity, multiplied by an average load factor to give electricity generated. As this was an illustrative exercise, rounded numbers were used in the assumptions, meaning the resulting generation only approximates the required amount. The actual electricity required (given in the Appendix) are included for comparison. For historical capacity data, see (DECC, 2011).

TWh. By contrast, there are 36 gas power plants with CCS, contributing only marginally more electricity, due to the smaller average capacity and load factors, perhaps reflecting a balancing role for gas plant in light of the large contribution from renewables. The flexibility required of gas plant in this scenario might have important implications for cost, but also for the carbon coefficient of such generation if the associated CCS technology was unable to match the rapid firing up of the plant for electricity generation. This would imply less carbon abatement per unit electricity than would be the case if a higher load factor were applied, although this is not explored in this study. The Central scenario imports 134 TWh of electricity in 2050. Meanwhile electricity from CHP and renewables (grid and onsite) contributes a third of final electricity consumption at 273 TWh (more detailed figures for these sources are discussed shortly).

Table 5: Centralised Scenario in 2050 – Grid Electricity

CENTRAL SCENARIO						
2050 ELECTRICITY GENERATION	Electricity required (TWh)	e.g. number of units	e.g. unit capacity avg (MW)	Total capacity (MW)	Avg load factor	Electricity generated (TWh)
Coal	0	-	-	-	-	-
Gas	0	-	-	-	-	-
Nuclear	**189**	*18*	*1500*	27,000	80%	**189**
Coal with biofuel	0	-	-	-	-	-
Coal with biofuel + CCS	**31**	*2*	*2000*	4,000	90%	**32**
Coal + CCS	**55**	*4*	*2000*	8,000	80%	**56**
Gas + CCS	**94**	*36*	*1000*	36,000	30%	**95**
Biofuel/waste	**39**	*18*	*500*	9,000	50%	**39**
Renewables	**259**					
Electricity from CHP	**14**					
subtotal	***682***					
Plus Imports of	*134*					
Total Grid Electricity	**816**					

Table 6 presents similar information to Table 5, but for the Localised scenario. This illustrates the transition away from unabated fossil fuel plant proceeds more slowly, thus in 2050 there is still a combined generation of 83 TWh from a mixture of coal, gas and coal co-fired with biofuel. Nuclear has been phased out entirely, while the shift to abated fossil fuels has resulted in total generation of 77 TWh for the year. While overall final electricity consumption is much lower here at 595 TWh than in the Central scenario, renewables and CHP nevertheless make a larger contribution in absolute terms at 378 TWh, approaching two thirds of the total.

Tables 5 and 6 describe possible configurations of electricity generating plant at the large scale, whereas Table 7 explores possible configurations for electricity generation in the Central scenario from the remaining categories, i.e.: 'grid' renewables, 'onsite' renewables, gas CHP and biofuel CHP. As with the table exploring large-scale plant, the figure given in the left column is established from the assumptions given in the tool, while the five rightmost columns represent a back of the envelope calculation of how this (approximate) level of generation might be reached.

Table 6: Localised Scenario in 2050 – Grid Electricity

LOCAL SCENARIO						
2050 ELECTRICITY GENERATION	Electricity required (TWh)	e.g. number of units	e.g. unit capacity avg (MW)	Total capacity (MW)	Avg load factor	Electricity generated (TWh)
Coal	22	*2*	*2000*	4,000	62%	22
Gas	44	*8*	*1000*	8,000	60%	42
Nuclear	0	-	-	-	-	-
Coal with biofuel	17	*2*	*2000*	4,000	50%	18
Coal with biofuel + CCS	17	*1*	*2200*	2,200	90%	17
Coal + CCS	17	*1*	*2500*	2,500	80%	18
Gas + CCS	26	*10*	*1000*	10,000	30%	26
Biofuel/waste	44	*20*	*500*	10,000	50%	44
Renewables	296					
Electricity from CHP	82					
subtotal	*565*					
Plus Imports of	*31*					
Total Electricity	595					

Table 7: Centralised Scenario in 2050 – Electricity from Renewables and CHP

CENTRAL SCENARIO						
2050 ELECTRICITY GENERATION	Electricity required (TWh)	e.g. number of units	e.g. unit capacity avg (MW)	Total capacity (MW)	Avg load factor	Electricity generated (TWh)
'Grid' Renewables	244					241
Off-shore wind		10,000	4	40,000	35%	122.6
On-shore wind		10,000	2	20,000	30%	52.6
Tidal stream		1	5000	5,000	40%	17.5
Wave		1	8000	8,000	25%	17.5
Tidal barrage		1	8500	8,500	25%	18.6
Solar PV		100,000	0.03	3,000	10%	2.6
Hydro nat flow (large)		60	30	1,800	35%	5.5
Hydro nat flow (small)		500	3	1,500	34%	4.4
'Onsite' Renewables	15					15
Solar PV		3,000,000	0.003	9,000	10%	7.9
On-site wind (small)		18,000	0.1	1,800	25%	3.9
On-site wind (micro)		200,000	0.006	1,200	20%	2.1
Hydro nat flow (micro)		2,500	0.1	250	54%	1.2
Gas CHP	3					3
District		6	50	300	50%	1.3
Site		200	2	400	50%	1.8
Biofuel CHP	11					11
District		12	50	600	50%	2.6
Site		1,000	2	2,000	50%	8.8

In the Central scenario, where the vast majority of renewable generation comes from comparatively large-scale grid connected systems, only 15 TWh is generated in 2050 from what might be classed as onsite renewables. In this analysis, that generation includes 3 million household PV installations at 3 kilowatts (kW) (peak capacity), 18,000 small-scale wind installations at 100 kW (e.g. industrial sites, community turbine schemes), 200,000 micro-scale wind turbines at 6 kW, and 2,500 micro-hydro installations. Meanwhile CHP deployment is limited in this scenario to 6 gas and 12 biomass schemes at the district level (defined as 50 megawatt electrical (MWe) peak capacity), alongside 200 gas and 1000 biomass schemes at the site level (2 MWe). As the Local scenario sees more ambitious levels of CHP and onsite renewables, the feasibility etc. of the relevant assumptions are below.

In this analysis, electricity generation from large-scale renewables in the Central scenario comes mostly from wind power, with 122 TWh from 10,000 offshore wind turbines (average

4 MW to give 40,000 MW capacity) and 10,000 onshore turbines (average 2 MW to give 20,000 MW capacity). By way of a reference point, data (as of July 2012) from the UK Wind Energy Database[13] indicate a total of 3847 turbines (onshore and offshore) are already operational in the UK. Of those, onshore turbines comprise nearly 5000 MW of current installed capacity. Of the scenarios explored within the DECC 2050 Pathways analysis report (DECC, 2010a), even the Level 2 trajectory sees onshore wind capacity reach 20,000 MW by 2030, before stabilising (while the Level 4 trajectory sees capacity eventually reach 50,000 MW). Compared with this assessment, the 20,000 MW capacity for onshore wind in 2050 in the Central scenario seems uncontroversial.

For offshore wind, where larger turbines are adopted, the 40,000 MW installed capacity by 2050 seems even more modest against trajectories estimated in other studies. The DECC Pathways Analysis report here sees capacity of 60,000 MW at Level 2 (and as much as 140,000 MW at Level 4). Wave and tidal power are assumed to play a significant role by 2050 in the Central scenario. The figures given for tidal barrage technology constitute a single scheme of 8,500 MW peak capacity, with a load factor of 25%, a rounded approximation to the expected output from a large Severn Barrage scheme (DECC, 2010b). For wave and tidal stream it is unclear, at the time of writing, precisely how the technologies will play out, and thus what would constitute a reasonable set of assumptions around number of units and average unit capacity. Nevertheless, total capacity and average load factors are informed by the literature. For simplicity, this analysis assumes 17.5T Wh from each of wave and tidal stream technologies, an annual output well within the range of DECC 2050 pathways, (within level 2 deployment for wave, and level 3 for tidal stream).

[13] www.bwea.com/ukwed/index.asp.

Solar PV installations classed as 'grid' renewables here are those with an average peak capacity of 30 kW, i.e. public sector/commercial building installations. Consistent with DECC assumptions, these size of schemes contribute one quarter of total solar PV generation (DECC 2010a, p.217). For large-scale hydropower, output is not much changed from recent levels (approximately 5 TWh annually), consistent with the assumption that appropriate sites for large scale hydro have already been exploited, while gradual deployment of run of river schemes contributes a similar level of output by 2050.

Clearly, the contribution from nuclear power and other large-scale plant means that renewable generation in this scenario is limited. With less (or no) nuclear, an electricity mix that was still in keeping with the broad assumption of a centralised energy system (i.e. with limited generation at the urban scale) might see far higher levels of onshore and particularly offshore wind. In any case, what this study did not attempt to do is to assess the technical feasibility of each potential mix in terms of load balancing. The role of energy *storage* is not explored in this analysis, but such technologies might be crucial in managing an energy system characterised by such a large contribution from nuclear in the face of variable demand, or alternatively a large proportion of intermittent renewables. Electricity imports/exports may have a significant role to play in this load balancing, but that is a distinct issue from the large *net* imports in this scenario.

Whereas electricity from the renewables/CHP mix in the Central scenario comes overwhelmingly from large-scale wind, Table 8 shows generation in the Local scenario being more evenly spread across different technologies at multiple scales. Unlike the Central scenario, the much reduced role for any regional super-grid in this case means that the UK prioritises a far more diversified electricity mix to ensure resilience. For example, more tidal stream and wave projects are developed than in Central (although large-scale tidal barrage projects are not favoured), and although large-scale hydro again remains steady, smaller scale run of river schemes are developed are far as is feasible. Larger solar PV installations (30 kW) are assumed to make up a large proportion of total generation from solar PV. In this case, approximately 1,500,000 installations provide around 40 TWh a year. At this level of deployment, it is likely that solar PV would expand beyond public/commercial building rooftops to include ground-level installations. The capacity of such schemes would vary considerably, so the averages used below should only be taken as illustrative, it is the notion of grid versus onsite that these calculations are intended to capture.

Table 8: Localised Scenario in 2050 – Electricity from Renewables and CHP

LOCAL SCENARIO						
2050 ELECTRICITY GENERATION	Electricity required (TWh)	e.g. number of units	e.g. unit capacity avg (MW)	Total capacity (MW)	Avg load factor	Electricity generated (TWh)
'Grid' Renewables	**218**					**218.2**
Off-shore wind		*5,000*	*4*	20,000	35%	61.3
On-shore wind		*5,000*	*2*	10,000	30%	26.3
Tidal stream		*1*	*10000*	10,000	40%	35.0
Wave		*1*	*15000*	15,000	25%	32.9
Tidal barrage		*0*	*8500*	0	25%	0.0
Solar PV		*1,500,000*	*0.03*	45,000	10%	39.4
Hydro nat flow (large)		*60*	*30*	1,800	35%	5.5
Hydro nat flow (small)		*2,000*	*3*	6,000	34%	17.8
'Onsite' Renewables	**77**					**76.1**
Solar PV		*20,000,000*	*0.003*	60,000	10%	52.6
On-site wind (small)		*75,000*	*0.1*	7,500	25%	16.4
On-site wind (micro)		*500,000*	*0.006*	3,000	20%	5.3
Hydro nat flow (micro)		*4,000*	*0.1*	400	54%	1.9
Gas CHP	**39.0**					**38.9**
District		*35*	*50*	1,750	50%	7.7
Site		*3,500*	*2*	7,000	50%	30.7
Micro		*100,000*	*0.002*	200	35%	0.6
Biofuel CHP	**42.6**					**42.7**
District		*35*	*50*	1,750	50%	7.7
Site		*4,000*	*2*	8,000	50%	35.0

Renewables classed as ‘onsite’ in this study generate 77 TWh in the Local scenario, compared with only 15 TWh in Central. An illustrative breakdown of onsite generation is provided in the table. Most significantly, this includes over 52 TWh from solar PV installation of an average 3 kW, i.e. at the household scale. Assumptions used here are guided by the DECC 2050 pathways analysis, which in turn draws upon an earlier roadmap for photovoltaic research in the UK (Infield, 2007). According to DECC (2010a), the UKERC analysis (Infield, 2007) suggests there could be 20 million domestic installations by 2050 (although it must be noted that no direct reference to these 2050 installation figures could be located in the source document cited by DECC).

A simple calculation of 20 million installations of 2kW systems does not do justice to the potential diversity in system scale, with the likelihood that ground-based systems would form a necessary part of the mix even for 'onsite' or household level installations, as available rooftop space begins to reach saturation point.

A significant role for small- and micro-scale wind is assumed in the Local scenario, with average peak capacities of 100kW and 6kW respectively. In the case of small-scale wind, there are many different conceivable configurations of turbine size and number of units, so the numbers given serve only as a guide.

Micro-hydro schemes with an average 100 kW peak capacity are also assumed to play a role in the Local scenario at around 400 MW total installed capacity, up from 250 MW in the Central scenario. In the Local scenario, CHP schemes are exploited quite extensively, providing a combined heat output of around 14 Mtoe in 2050. With a heat to electricity ratio of approximately 2:1, this gives around 7 Mtoe, or 81.6 TWh electricity generation.

DECC figures for CHP suggest electricity generation from CHP installations was over 27 TWh in 2011 (up from 25 TWh in 2000, an increase of around 0.7% p.a. average) (DECC, 2012b). The figures assumed for 2050 in the Local scenario therefore represent a factor of four increase (to 2.8% p.a.) in the annual growth of CHP output. A study conducted for the Combined Heat and Power Association in 2010 examined the potential for CHP in the UK in 2050, largely in response to the presumption of an 'all-electric' energy future (Speirs et al., 2010) and in their integrated scenario, electricity from CHP contributes around 50 TWh in 2050. However, an earlier DEFRA report indicated a possible greater role for CHP suggesting an additional potential for just over 80 TWh of electricity generation, largely in relation to industrial needs (DEFRA, 2007). Thus, although the CHP assumptions for the Local scenario may at first seem ambitious, these have to be considered in the context of the industrial renaissance experienced in that case.

5 Discussion

Challenging the lock-in of the current centralised UK energy system is seen in some quarters as being essential to delivering the deep carbon cuts required over the period to 2050 to moderate climate change. Consequently, decentralised energy initiatives are currently being promoted, increasingly within the urban locations where the majority of the population and economic activity is located. This report has therefore detailed the development of the two CLUES scenarios; one predominately centralised and one predominately localised. These illustrate how the UK energy future might look in 2050. These are, of course, not the only possible futures; instead, they have been developed to explore two possible different pathways for the UK and their consequences, and to help policy makers consider possible options for the future. The focus was on developing logically coherent future scenarios consistent with an associated narrative. However, it should be stressed that although the quantification is seen as vital in developing such scenarios the figures do not represent predictions or forecasts; they are simply representations of credible futures.

As for the narratives, ***Centralised*** (or 'Greening Centralised Energy' as it is known in CLUES, 2012) suggests that heavy manufacturing and other energy intensive industry are off-shored with services booming due to increasing global trading and increasing specialisation. Consequently, this scenario envisages a UK reliant on largely electrified services that need large-scale energy systems, such as power plants and large-scale renewables, including noteworthy energy imports from largely abated fossil fuel energy produced in other countries and solar energy farms in the Saharan Desert (Foresight, 2008a and 2008b). Citizens are generally disengaged from the energy system, tending not to be involved in managing and monitoring their energy consumption. Furthermore, this future envisages a world where there is unconstrained international mobility with people and economies dependent upon traveling long distances; thus, resultant energy demand rises fast.

This contrasts to ***Localised*** (or 'Stretching the Energy Spectrum' as it is known in CLUES, 2012) where, due to increased localism, growth remains steady but less than for centralised. However, at the same time it envisages a UK with social transformation at all levels in society with no explicit focus on services, instead an industrial resurgence that retains primary manufacturing and energy intensive industry in the UK – i.e. a world of re-localisation rather than globalisation. Furthermore in localised, in contrast to centralised, the energy system develops at multiple scales with smaller energy imports with some electrification of heating and transport. Moreover, in the localised scenario, the UK depends on a local diversity of energy supply, focuses on smaller-scale renewable, micro-generation and CHP. There is also increased demand side management through increased awareness of energy conservation and energy efficiency given the greater participation of citizens in energy issues and generation. Furthermore, the localised scenario envisages a world where mobility is constrained due to a shift in social values and the creation of international constraints on aviation. In cities, transport is permitted only if it is green and clean, whereas car use is considered to be energy-intensive and therefore restricted with public transport widely used. Aviation still relies on carbon fuels, but it is expensive and international business travel is increasingly substituted by remote teleconferencing. [14]

Interestingly, despite the qualitative differences and the resultant quantitative differences in the two scenarios, both suggest a reasonably high and comparable level of carbon reductions. Both scenarios suggest a 64% reduction in Carbon in 2050 compared to 2008 with international aviation and shipping *included*, however, centralised suggests a reduction of 82% compared to a reduction of 73% for the localised scenario with international aviation and shipping *excluded.*

Thus in summary, despite the very different worlds envisaged for the two scenarios, there are similar outcomes in terms of the key aspect for carbon reductions; nevertheless, the analysis raises many important questions:

[14] A fuller version of the narrative can be found in (CLUES, 2012).

What do the scenarios imply for the energy system?

- For the ***Centralised*** scenario, it is not clear how the UK energy system would cope with the high proportion of large-scale renewables envisaged under this scenario and whether the supply always be sufficient to meet baseline energy needs? If not, perhaps measures would need to be put in place to ration energy at certain times.
- In contrast, the scale of the rollout of decentralised options under the ***Localised*** scenario is astounding; it suggests that in 2050 something like 20 million roofs retrofitted with PVs; over ½ million on-site wind turbines installed; 4,000 small-scale hydro-plants created; and over 100,000 Combined Heat and Power installations delivered. Yet, whether this is plausible and deliverable is very questionable. [15]

What do the scenarios imply for governance?

- For the ***Centralised*** scenario there could be tensions between top-down governance structures and cities, which tend to become competitive, innovative and specialised actors in an increasingly globalised market. Is there a risk that cities' interests and their governance arrangements will conflict with 'centralised' aims and governance structures?
- For the ***Localised*** scenario, there would be a weakening of the lock-in to centralisation, and therefore changes to the governance and economic context. This would imply that local authorities have more control over energy generation then

[15] In fact, in the Localised scenario the combined output of small and micro scale wind is approximately 22 TWh, which is almost three times the maximum feasible output considered in DECC 2010a (p. 215). This is along with what would appear to be towards the feasible upper end of onsite solar and hydro. This highlights how difficult it is to try to foresee how onsite generation might develop given the low base to start from.

they do today, but how would that work exactly and would a more localised system result in locally varying tariffs?

What do the scenarios imply for energy security?

- Electricity imports form a substantial part in the ***Centralised*** scenario, which could arguably reduce the UK's energy security, given the greater reliance on generation some distance overseas and the subsequent transportation.
- Whereas, for the ***Localised*** scenario the greater public engagement and greater localisation would reduce this risk, but would such a localised fragmented decentralised system with minimal central control be as resilient?
- This is important since as IEA (2012) highlights, curbing energy related emissions is not the only energy policy challenge for the UK and "(s)ecurity of supply merits continuous attention" (p. 14). So although the two scenarios envisage similar outcomes in terms of emissions the impact on the different aspects of security of supply do differ somewhat.

What does the Centralised scenario imply for the development of CCS?

- The envisaged grid electricity mix in the ***Centralised*** scenario requires the successful development and deployment of CCS, since without the necessary breakthroughs, the mix of technologies in the Central scenario would add considerably to total emissions in 2050. However, thinking in terms of pathways, it is unlikely that such a non-CCS fossil fuel mix would ever come about given the availability of alternative low carbon technologies. Similar pathways analysis can be applied to all of the technologies considered, and need not be limited to technological considerations. For example, institutional arrangements may be such that negotiating the deployment of district heating networks proves intractable whatever the capabilities of the technologies involved. For a proper consideration of these issues, a more dynamic modelling approach would be required, allowing for substitution between different technologies as these become (un)available. For example, a least-cost optimisation approach, by incorporating capital, fuel, fixed and variable cost assumptions for each technology, would enable an informed assessment of the likely replacement technologies in the absence of another.

What does the Localised scenario imply for behaviour change?

- For the ***Localised*** scenario, the reductions in energy consumption and emissions are envisaged to come about to a large extent from behavioural change; however, it is not clear exactly how this would be achieved and whether the necessary degree of public engagement is really achievable.

What does the analysis and the scenarios imply for the way Carbon is accounted for?

- In keeping with most energy policy analysis, the accounting framework has followed the *production perspective*, taking into account all emissions arising territorially within the UK. By contrast, the *consumption perspective* considers emissions according to the point of final consumption, including those 'embedded' in imports but excluding those in exports.
- In the context of the wider economic profile of the Central and Local scenarios characterised here, this distinction is critical. Whereas the Central scenario in a sense relies on continued economic globalisation to reduce emissions through offshoring of

heavy industry, the Local scenario retains such activity within the UK. Thus, although the headline emissions reductions achieved in each case are comparable, the Local scenario would likely prove more successful in reducing consumption emissions (assuming greater emissions intensity for goods produced overseas and transported globally). This suggests a need for a complementary consumption accounting approach alongside the traditional perspective. For a scenario study that considered UK household emissions from a consumption perspective through to 2030 see Milne (2011).

What lessons can be learnt from the 'quantitative' analysis undertaken?

- On a positive note, the quantification has been useful in considering the narrative that runs with the scenarios. Moreover, it is felt that an iterative process between the quantification and the development of the qualitative analysis is a fruitful way to proceed. Nevertheless, the quantitative tool should arguably be bespoke for the analysis at hand, rather than relying on a tool produced originally for another purpose; however, this would increase the 'cost' somewhat. [16]

[16] See SEG (2012) for a fuller discussion of the lessons learnt from the CLUES quantitative scenario analysis.

6 Summary

This report describes work undertaken in 2011 and 2012 as part of the CLUES project, to re-quantify two earlier scenarios, themselves based on narratives from an earlier scenario study (Foresight, 2008a and 2008b). Within the limitations of the energy-engineering accounting tool adopted, the study illustrates some of the possible defining features of a more ***centralised*** versus a more ***localised*** UK energy system. A more robust analysis would necessarily require the incorporation of other factors, most notably cost, and would benefit from the inclusion of a complementary consumption-based emissions accounting approach. Nevertheless, the quantification and analysis provided gives a flavour of the key issues to be addressed in considering the advantages or disadvantages of a centralised energy system.

Appendix

Table A1: Households

HOUSEHOLDS									
FINAL ENERGY CONSUMPTION									
(in Mtoe)	2008	2020		2030		2040		2050	
		CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Electricity									
Grid Electricity	10.1	**15.7**	**11.6**	**21.9**	**14.1**	**28.6**	**16.3**	**34.5**	**16.7**
Onsite Renewables		**0.2**	**0.5**	**0.4**	**1.4**	**0.5**	**2.5**	**0.6**	**3.1**
CHP-Gas		0.0	0.3	0.0	0.7	0.0	1.5	0.0	1.8
CHP-Coal		0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
CHP-Biomass		0.1	0.3	0.2	0.7	0.3	1.5	0.4	1.8
Non-electrical Energy									
CHP-Gas		**0.0**	**0.8**	**0.0**	**1.8**	**0.0**	**3.0**	**0.0**	**3.5**
CHP-Coal		**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
CHP-Biomass		**0.3**	**0.8**	**0.5**	**1.8**	**0.5**	**3.0**	**0.7**	**3.5**
Renewables		**0.8**	**1.8**	**1.0**	**3.4**	**1.5**	**4.5**	**2.0**	**4.7**
Waste & Biofuel	0.4	**0.6**	**0.7**	**1.0**	**1.5**	**1.0**	**2.0**	**1.0**	**2.0**
Coal	0.8	**0.5**	**0.5**	**0.4**	**0.2**	**0.0**	**0.0**	**0.0**	**0.0**
Oil	3.0	**2.0**	**2.0**	**1.0**	**0.0**	**0.0**	**0.0**	**0.0**	**0.0**
Gas	31.2	**26.0**	**25.5**	**21.3**	**18.5**	**16.2**	**8.7**	**10.2**	**4.8**
TOTAL	45.6	46.1	44.7	47.7	44.2	48.5	43.0	49.3	41.8

Table A2: Industry

ALL INDUSTRY (Intensive, Non Intensive, Energy, Construction)								
FINAL ENERGY CONSUMPTION								
(in Mtoe)	2020		2030		2040		2050	
	CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Electricity								
Grid Electricity	**11.87**	**10.37**	**12.43**	**9.49**	**11.88**	**8.69**	**11.00**	**8.30**
Onsite Renewables	**0.00**	**0.55**	**0.00**	**1.20**	**0.25**	**1.56**	**0.30**	**2.00**
CHP-Gas	0.18	0.22	0.22	0.76	0.30	1.15	0.25	1.45
CHP-Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHP-Biomass	0.12	0.24	0.14	0.76	0.70	1.40	0.40	1.55
Non-electrical Energy								
CHP-Gas	**0.45**	**0.55**	**0.55**	**1.90**	**0.60**	**2.30**	**0.50**	**2.90**
CHP-Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Biomass	**0.30**	**0.60**	**0.35**	**1.90**	**1.40**	**2.80**	**0.80**	**3.10**
Renewables	**0.58**	**1.08**	**0.76**	**2.34**	**1.02**	**2.81**	**1.11**	**4.07**
Waste & Biofuel	**0.02**	**0.30**	**0.02**	**0.62**	**0.31**	**1.39**	**0.27**	**2.11**
Coal	**0.70**	**1.10**	**0.05**	**0.10**	**0.00**	**0.00**	**0.00**	**0.10**
Oil	**8.36**	**9.32**	**5.07**	**6.66**	**2.45**	**4.63**	**1.52**	**2.94**
Gas	**12.47**	**13.94**	**9.06**	**9.45**	**4.50**	**6.75**	**3.10**	**4.75**
TOTAL (mtoe)	35.05	38.27	28.65	35.18	23.41	33.48	19.25	33.27

Table A3: Services

ALL SERVICES (Commercial, Public Administration, Agriculture, Miscellaneous)								
FINAL ENERGY CONSUMPTION								
(in Mtoe)	2020		2030		2040		2050	
	CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Electricity								
Grid Electricity	**10.13**	**7.63**	**12.07**	**6.89**	**13.30**	**6.09**	**14.14**	**5.23**
Onsite Renewables	**0.25**	**0.49**	**0.35**	**0.90**	**0.40**	**1.38**	**0.40**	**1.55**
CHP-Gas	0.00	0.04	0.04	0.12	0.05	0.15	0.01	0.15
CHP-Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHP-Biomass	0.07	0.14	0.10	0.20	0.18	0.35	0.24	0.36
Non-electrical Energy								
CHP-Gas	**0.01**	**0.10**	**0.10**	**0.30**	**0.10**	**0.30**	**0.02**	**0.30**
CHP-Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Biomass	**0.18**	**0.35**	**0.25**	**0.50**	**0.35**	**0.70**	**0.47**	**0.72**
Renewables	**0.29**	**0.57**	**0.49**	**1.09**	**0.88**	**1.58**	**0.82**	**1.60**
Waste & Biofuel	**0.10**	**0.10**	**0.20**	**0.49**	**0.18**	**0.45**	**0.49**	**0.60**
Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Oil	**0.86**	**0.76**	**0.58**	**0.50**	**0.18**	**0.14**	**0.00**	**0.09**
Gas	**6.77**	**6.40**	**4.15**	**3.70**	**2.35**	**1.80**	**0.65**	**0.61**
TOTAL (mtoe)	18.66	16.58	18.33	14.69	17.97	12.94	17.24	11.21

Table A4: Domestic Transport

DOMESTIC TRANSPORT (Rail, Road, Domestic Aviation and Shipping)								
FINAL ENERGY CONSUMPTION								
(in Mtoe)	2020		2030		2040		2050	
	CEN	LOC	CEN	LOC	CEN	LOC	CEN	LOC
Electricity								
Grid Electricity	**1.51**	**1.58**	**3.79**	**3.64**	**6.84**	**6.51**	**7.80**	**7.19**
Onsite Renewables	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHP-Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHP-Biomass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-electrical Energy								
CHP-Gas	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Biomass	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Renewables	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Waste & Biofuel	**2.26**	**2.13**	**4.20**	**3.22**	**5.25**	**3.42**	**5.61**	**5.13**
Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Oil	**40.32**	**39.85**	**36.41**	**34.45**	**27.08**	**26.65**	**19.86**	**18.14**
Gas	**0.10**	**0.00**	**0.15**	**0.00**	**0.25**	**0.00**	**0.00**	**0.00**
TOTAL (mtoe)	44.19	43.56	44.55	41.31	39.42	36.58	33.27	30.46

Table A5: International Transport

INTERNATIONAL TRANSPORT (International Aviation and Shipping)								
FINAL ENERGY CONSUMPTION								
(in Mtoe)	**2020**		**2030**		**2040**		**2050**	
	CEN	**LOC**	**CEN**	**LOC**	**CEN**	**LOC**	**CEN**	**LOC**
Electricity								
Grid Electricity	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Onsite Renewables	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Gas	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHP-Coal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CHP-Biomass	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-electrical Energy								
CHP-Gas	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
CHP-Biomass	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Renewables	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Waste & Biofuel	**0.00**	**0.05**	**2.97**	**2.69**	**2.79**	**2.65**	**4.45**	**2.68**
Coal	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
Oil	**30.33**	**27.86**	**32.27**	**25.57**	**37.37**	**25.27**	**40.12**	**24.15**
Gas	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TOTAL (mtoe)	30.33	27.91	35.24	28.26	40.16	27.92	44.57	26.83

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