Technical annex: Energy and fuel bills today and in 2050

July 2018

Introduction

Households pay for many different forms of energy, including electricity, heating, hot water and fuel for driving. There are potential interactions between the different bills; for example, as electric vehicles become widespread, spend on motor fuel will decrease and electricity spend will increase. Projections for population and economic growth also determine the capacity required in all these sectors. Therefore, the predicted future household spend on these energy bills needs to be considered together.

Today, consumers pay an average of £1,850 per year for the energy they use, including electricity, motor fuel, and fuel and equipment for heating and hot water. The Commission's analysis shows that the same services could be delivered at the same cost (in today's prices) in 2050 with a low carbon energy system.[1] This technical annex explains the modelling methodology and assumptions behind this analysis.

The focus throughout this note is the cost of energy to households. Business/industry and the public sector are also major consumers of energy, but cost trends for these sectors are likely to be different and are not considered here.

This note focuses on the steps to derive the energy prices and consumption that are used to compare energy costs today (latest available data, in 2018/19 prices) with those in 2050 (in 2018/19 prices). These calculations draw on analysis undertaken for the Commission, and available on the Commission's website:

- Aurora Energy Research (July 2018), Power sector modelling: system cost impact of renewables
- Energy Systems Catapult (July 2018), Electric vehicle charging cost analysis
- Element Energy (May 2018), Cost analysis of future heat infrastructure options

In some cases, estimates from these reports have been converted into an estimated impact on bills, using a bills model developed by the Commission. The assumptions and methodology for these bills models are explained where relevant.

The calculations set out here are on a different basis to those in table 7.2 of the *National Infrastructure Assessment* ('the impact on bills'). Table 7.2 compares the impact of the Commission's recommendations against the alternative ('counterfactual') where recommendations are not implemented. It does not, therefore, take into account changes to household expenditure between today and 2050 that are not directly related to National Infrastructure Assessment recommendations. Nor does it include effects where recommendations enable, but do not require, consumers to make different choices, such as purchasing electric vehicles instead of internal combustion engine powered vehicles.

Calculations in this technical annex also take a different approach to low carbon heat to that in table 7.2. The calculations in this annex include estimates of the full cost of moving to low carbon heating, based on analysis for the Commission.[2] Table 7.2 includes only those costs related to recommendations in the National Infrastructure Assessment. Uncertainties around cost, technology, and consumer behaviour means that it is difficult to decide now the cheapest way to replace natural gas to meet future Climate Change Act targets. The Commission plans to provide further advice to government on this issue in the next National Infrastructure Assessment, considering parallel strategies in Scotland and Wales.

There is substantial uncertainty about estimates so far in the future. Costs within this annex are rounded to the nearest £10 for individual items and the nearest £50 for totals (totals may not sum due to rounding). However, uncertainty is substantially greater than this. Undue weight should not be given to specific figures.

Scope of the analysis

The Commission's cost estimates:

- assume a typical household, consuming the same quantities of energy services today and in 2050
- include the costs of electric vehicle charging infrastructure and home heating appliances (boilers, heat pumps) as well as the costs of energy and fuel
- exclude potential savings on the cost of cars and car maintenance from the switch to electric vehicles, and the one off costs of energy efficiency measures
- exclude tax – there would be further savings for households from today's tax system (since petrol and diesel are heavily taxed) but these savings would have to be made up elsewhere by the Exchequer
- average the projected costs of predominantly hydrogen and predominantly heat pump scenarios for low carbon heat
- assume continued technology development for existing technologies (eg battery storage) but do not take into account potential new technologies.

Averaging heat costs

There are two potential large scale solutions for low carbon heat, and a range of smaller solutions which may complement one of them. The first option is electrification, using heat pumps to increase the efficiency of using electricity for heating. Alternatively, hydrogen

(which creates only water vapour when burnt) from a zero carbon source could be used as a direct replacement for natural gas, fuelling boilers and appliances.

Calculations in this annex use an unweighted average of two alternative heat solutions:

- one predominantly based on using heat pumps, with other fuels for hard to insulate properties where heat pumps are not suitable
- one predominantly based on using hydrogen, with biomass for off grid properties.

Full details are in *Cost analysis of future heat infrastructure options*.[3]

Both solutions assume deployment of cost effective energy efficiency measures in households. The one off costs of these measures are not included in the analysis in this annex.

Results

Tables 1 to 3 show the results of the energy bills comparison between today and 2050. Table 1 gives the headline comparison including the fixed costs of infrastructure for each household which are not expected to vary by the amount of energy consumed. Tables 2 and 3 disaggregate the variable costs into a price per unit of energy and the amount of energy consumed annually per household, for today and 2050 respectively.

Average annual household bill (£, 2018/19 prices)	**Average bill today**	**Average bill in 2050**	**Difference between average bills in 2017 and 2050**
All energy and fuel	**£1,850**	**£1,850**	**£0**
Power (domestic appliances and lighting, but excluding electricity for heat and driving)	£540	£460	**-£90**
Driving: fuel/electricity costs	£410	£220	**-£190**
Driving: fixed costs	N/A*****	£140	**+£140**
Heat: fuel/electricity costs	£750	£590	**-£160**
Heat: fixed costs	£140	£430	**+£290**

Table 1: Average household annual energy bills today (latest data) and 2050, by component
***** fixed costs of petrol/diesel infrastructure are covered in the cost of fuel
Totals may not sum due to rounding

Average annual household bill (£, 2018/19 prices)	Consumption, today	Unit cost, today	Total, today
Power (domestic appliances and lighting, but excluding electricity for heat and driving)	3,400 kWh	15.8 p/kWh	£540
Driving: fuel/electricity costs	13,900 km	3.0 p/km	£410
Heat: fuel/electricity costs	14,300 kWh	5.2 p/kWh	£750

Table 2: Unit costs, consumption and energy bills, today (latest data)
Totals may not sum due to rounding

Average annual household bill (£, 2018/19 prices)	Consumption, 2050	Unit cost, 2050	Total, 2050
Power (domestic appliances and lighting, but excluding electricity for heat and driving)	3,400 kWh	13.3 p/kWh	£460
Driving: fuel/electricity costs	13,900 km	1.6 p/kWh	£220
Heat: fuel/electricity costs	7,000 kWh*	8.4 p/kWh	£590

Table 3: Unit costs, consumption and energy bills, 2050 constant consumption comparison
Totals may not sum due to rounding
***** 2050 energy consumption required to generate the same level of heat as today is lower due to energy efficiency and greater technological efficiency, especially of heat pumps

The rest of this note explains how the energy costs above were estimated, in particular the sources for base year bills and the methodology and assumptions for projected bills in 2050.

Electricity for domestic appliances and lighting

This section covers consumption of electricity for domestic appliances and lighting, but excludes electricity for heating, hot water and electric vehicles.

Cost and consumption of electricity in 2017

1. The unit price of electricity for the residential sector in 2017 is taken directly from *Energy and emissions projections*[4], inflated from 2017 to 2018/19 prices using the GDP deflator from the Office for Budget Responsibility's *March 2018 Economic and Fiscal Outlook*[5], with 5 per cent VAT deducted: **15.8 pence per kilowatt hour (p/kWh).**

2. Total electricity generation in 2017 is calculated by summing electricity supplied across the four quarters of 2017 in *Energy Trends June 2018*: 339 terawatt hours (TWh).[6]

3. Total generation is scaled down by the proportion of electricity generation used by the household sector in 2017, 37 per cent, from *Energy and emissions projections*.[7]

4. Electricity generation used by households is divided by the number of households in Great Britain in 2017.[8] The result is 4.5 megawatt hours (MWh) of electricity used per household in 2017. To avoid double counting, electricity used for heating (see below) needs to be removed from this, giving a figure of **3.4 MWh** of electricity used per household for domestic appliances and lighting in 2017.

Cost of electricity in 2050

1. The cost of electricity relies on power modelling produced for the Commission by Aurora Energy Research.[9] The model estimates the unit prices of electricity for the two heat scenarios. Based on a low carbon power sector with 70 per cent of generation from renewable sources in 2050, the unit price of electricity is estimated to be 13.9 p/kWh in the hydrogen + biomass heating scenario, and 11.7 p/kWh in the heat pumps heating scenario. This gives an average unit price of electricity in 2050 of 12.8 p/kWh.

2. Electric vehicles are assumed to use smart charging to consume electricity at a 10 per cent discount from the average price (see next section). The price of electricity for other uses must therefore be higher for the total electricity price to average out at 12.8 p/kWh. It is assumed that on average between the two heating scenarios, domestic appliances and lighting consume 3.4 MWh of electricity in 2050, heating consumes 1.6 MWh and electric vehicles consume 1.9 MWh (see below). The price of electricity for domestic and heating purposes is adjusted upwards based on its consumption relative to electric vehicles to **13.3 p/kWh**, in 2018/19 prices excluding VAT.

3. Consumption for domestic appliances and lighting in 2050 is assumed constant at today's levels, to give a like for like comparison to today's bills. In practice, the same level of services (appliance outputs, such as washing or cleaning, and light levels) will require less electrical input in 2050, since appliances and lighting become more efficient over time. People may also choose to consume different quantities of electricity, as incomes and relative prices change, and as new electrically powered devices become available.[10] However, this does not affect the cost of today's level of consumption in 2050.

Driving

The costs of driving considered here include the cost of petrol or diesel today and electricity in 2050, and the cost of fuelling infrastructure (petrol stations and electric vehicle charging points). The cost of fuelling infrastructure is currently included in the pump price of petrol and diesel. Electric vehicle drivers will face a range of costs for different types of infrastructure, from off street slow chargers in homes to rapid chargers at motorway service stations, as well as on street and workplace charge points.

All the costs of this charging infrastructure are shown as fixed costs. This reflects the largely fixed cost nature of the infrastructure network, although in reality some costs would be recovered through the price of electricity at charging points.

The costs of purchasing and maintaining vehicles is not included here.

Cost of driving in 2017

1. Vehicles driven by households in 2017 are assumed to be cars and are all assumed to be internal combustion engine vehicles, fuelled by petrol or diesel.

2. The average fuel price paid at the pump is taken from *Energy and emissions projections*[11], inflated from 2017 to 2018/19 prices using the GDP deflator from the Office for Budget Responsibility's *March 2018 Economic and Fiscal Outlook*[12]. This gives pump prices of 117 pence per litre (p/litre) for petrol and 121 p/litre for diesel.

3. VAT at 20 per cent is deducted from the pump price. Fuel duty in 2018 of 57.95 p/litre is used as the most recent value.[13] This fuel duty is deducted from the pre VAT pump price to give fuel prices excluding VAT and duty of 40 p/litre for petrol and 43 p/litre for diesel.

4. Vehicle efficiency data is published for new cars, but not the average across the entire current vehicle stock. Average internal combustion engine car efficiency in 2017 is taken from estimates produced by the Energy Systems Catapult for the Commission: 13.1 kilometres per litre (km/litre) for petrol cars and 15.1 km/litre for diesel cars.[14] This is equivalent to 37.1 and 42.5 miles per gallon respectively.

5. Dividing the p/litre price by the km/litre efficiency gives driving costs in pence per kilometre (p/km) of 3.0 p/km for petrol vehicles and 2.9 p/km for diesel vehicles in 2017.

6. Weighting the two prices by mileage for petrol and diesel cars assumed by the Energy Systems Catapult and the Commission, 60 per cent petrol and 40 per cent diesel,

gives an average price per kilometre driven of **3.0 p/km** in 2017, in 2018/19 prices excluding VAT and fuel duty.

7. The relevant consumption measure is kilometres driven per household. Data for 2017 is not available from public sources, but average miles per car in 2016 is taken from the *National Travel Survey* at 7,200 miles for commuting and private use, excluding business use.[15]

8. The number of cars per household is 1.2 in 2016, also from the *National Travel Survey*.[16] Converting average miles driven per car to kilometres and multiplying by the average number of cars per household gives **13,900 km** driven per household.

Cost of driving in 2050

1. Vehicles driven by households in 2050 are assumed to be battery electric vehicle cars.

2. The price of electricity in 2050 is taken from the power modelling described in the previous section, 12.8 p/kWh.

3. It is assumed that with smart charging at times of lower demand for electricity, EVs will be able to charge at 90 per cent of the average electricity price: 11.5 p/kWh. This discount is based on a comparison of current night time wholesale electricity prices to the daily average using electricity market data.[17]

4. Projected electric vehicle car efficiency in 2050 is taken from estimates produced by the Energy Systems Catapult for the Commission: 7.4 kilometres per kilowatt hour (km/kWh).[18]

5. Dividing the average charging price by average efficiency gives an average cost per kilometre of battery electric cars in 2050 of **1.6 p/km**, in 2018/19 prices excluding VAT.

6. To ensure a like for like comparison, the same driving distance is assumed in 2050 and today. A range of factors, including incomes, relative prices and congestion are likely to affect actual distances in future, but these do not affect the cost of today's consumption in 2050.[19]

7. The annual fixed cost of charging infrastructure per household in 2050 is based on modelling by the Energy Systems Catapult for the Commission, and Commission calculations.[20] The Energy Systems Catapult modelled the charging infrastructure needed to support electric vehicle rollout, and estimate the capital and operational expenditure associated with this infrastructure, disaggregated by different charger types.

8. The capital cost of off street home chargers is assumed to be paid for by households directly in the year they are installed. For all other charger types including on street, rapid and workplace, the capital cost is assumed to be recovered over time, as they are expected to be funded through the price of electricity drawn from them for charging.

9. The cost recovery framework combines straight line depreciation of the capital expenditure over a 20 year asset life, and a Weighted Average Cost of Capital (WACC) of 7 per cent applied to the remaining value of charging assets. A retail margin of 3 per cent is added. The recovered cost of these chargers is then allocated between households and businesses based on the proportion of electricity they are projected to use for electric vehicle charging in the Energy Systems Catapult modelling. Businesses are assumed to drive all vans and 8 per cent of car kilometres.[21]

10. Aggregating the costs of off street home chargers and the costs recovered from households of other charger types results in an average annual cost of electric vehicle charging infrastructure per household of **£140** in 2050, in 2018/19 prices and excluding VAT.

Heating and hot water

Costs for heating and hot water include the costs of fuel and electricity and fixed costs including installation and maintenance of in home equipment such as boilers, heat pumps and connections between the network and the home.

One off costs of energy efficiency (insulation) measures are not included. The *Cost analysis of future heat infrastructure options* analysis undertaken for the Commission assumes that a substantial programme of cost effective energy efficiency measures is undertaken between now and 2050. These reduce the energy required to achieve a given level of home heating (thermal comfort).

These one off costs are assumed to have been met by 2050 and so are not included in this analysis. The costs of these measures will need to be financed. However, they also create very long lived assets. Home insulation appears to be capitalised into house values.[22]

Cost of heat in 2017

1. Domestic heat is provided by a number of different fuel sources. The average weekly household expenditure on heating fuels (not including electricity) and equipment is taken from the *Living Costs and Food survey* for 2016/17,[23] as the sum of the spending categories:

- gas
- other fuels including heating oil

for heating fuels, and

- central heating repairs
- central heating installation

for fixed costs.

2. These costs are converted into annual values and inflated from 2016/17 to 2018/19 prices using the GDP deflator from the Office for Budget Responsibility's *March 2018 Economic and Fiscal Outlook*.[24]

3. VAT at 5 per cent on domestic heating fuel and heating equipment is deducted to give average annual costs of £580 for heating fuels and **£140** for fixed costs.

4. To estimate the unit price of fuel for heat from this annual bill, total energy consumed by all households for space and hot water heating in 2016, excluding electricity, is taken from *Energy consumption in the UK*.[25]

5. The kilotonnes of oil equivalent value is converted into terawatt hours (TWh) and divided by the number of households in the UK in 2016[26], giving 13.2 MWh of energy consumed in 2016 for heating per household, excluding electricity.

6. The average annual cost of £580 is multiplied by the number of households and divided through by total consumption to estimate a price of heating fuel excluding electricity of 4.3 p/kWh, in 2018/19 prices.

7. For the price of heating including electricity, the unit price of electricity (see above) is averaged with the unit price of heating fuel, weighted by the consumption of electric and fuel inputs to domestic heating in 2016. The result is **14.3 MWh** energy consumed in 2016 for heating per household at **5.2 p/kWh**, including electricity.

Cost of heat in 2050

1. The cost of heat in 2050 relies on the heat modelling produced for the Commission by Element Energy.[27]

2. Energy consumption in 2050 differs from that today to achieve the same levels of heating for two reasons. Firstly, energy efficiency measures mean less heat is wasted. Secondly, the technologies vary in their efficiency of converting input energy into heat. Heat pumps, which transfer rather than generate heat, are particularly efficient, reducing the amount of input energy required for the same level of heat.

3. Total annual fuel consumed for heating by fuel type is extracted from the model for the two heat scenarios. The domestic sector proportion of total energy inputs to heat are assumed to be the same as in 2016, 72 per cent. This is sourced from *Energy consumption in the UK*, comparing domestic energy consumption for space heating and hot water with industrial and services consumption.[28]

4. Total annual fuel consumed by type is scaled down by the domestic share and divided through by the Commission's projection of the number of UK households in 2050, which the Element Energy modelling assumes.[29]

5. For the hydrogen + biomass scenario, average fuel consumption per household in 2050 is 10.3 MWh.

6. For the heat pumps scenario, average fuel consumption per household in 2050 is 3.6 MWh, of which 3.2 MWh is electricity and 0.5 MWh is fuel for hard to insulate properties.

7. The whole system cost in the hydrogen + biomass scenario, in 2050, is £37 billion. Capital expenditure for converting the gas grid from natural gas to hydrogen and for new district heating is recovered from customer bills. This uses straight line depreciation of the new assets over their lifetime and a Weighted Average Cost of Capital (WACC) for the heat sector. The WACC is based on RIIO-GD1 and RIIO-GD2 regulatory assumptions, adjusted for expected changes to the risk free rate, and in real terms is assumed to be 3.8 per cent until 2020, 2.8 per cent until 2028, and 3 per cent from 2029 onwards.

8. Operational costs and wholesale fuel costs are recovered directly from bills in year. The Consolidated Segmental Statements are used to estimate the remaining components of average gas bills: fixed costs and the remaining cost of financing legacy network assets, which is assumed to fall to zero over 30 years. [30] Total revenues are divided between households, businesses and the public sector.

9. For households using oil heating or bioenergy, the cost of heating oil and biomass (which include operating costs) is taken from the Element modelling and divided across the number of households using oil or biomass heating. The average annual cost of heating fuel per household in 2050 is estimated as £680 for the hydrogen + biomass scenario.

10. Combining this input cost with the consumption of 10.3 MWh gives a unit cost of 6.6 p/kWh for the hydrogen + biomass scenario.

11. The whole system cost in the heat pumps scenario, in 2050, is £39 billion. The heat modelling was undertaken before the power modelling and therefore does not use a consistent cost of electricity (conversely, the power modelling is consistent with the heat modelling). It is therefore necessary to remove the cost of electricity from the heat modelling and substitute a cost consistent with the power modelling.

12. The residual cost of heating fuel excluding electricity is converted into average annual heating bills using the heating bills modelling described above. The average annual cost of heating fuel per household in 2050 is estimated as £120 for the heat pumps scenario, excluding the cost of electricity.

13. To this is added the cost of electricity for heating: 3.2 MWh on average at a unit cost in the heat pump scenario of 12.0 p/kWh, giving a cost of £380 for electricity and a total cost of £490 per household.

14. Combining this input cost with consumption of 3.6 MWh gives a unit cost of 13.6 p/kWh in the heat pump scenario.

15. Averaging the two scenarios then gives average consumption of **7.0 MWh** of energy consumed in 2050 for heating per household, at a weighted average unit cost of **8.4 p/kWh**.

16. The heat modelling also estimates the fixed cost of building level heating equipment in 2050 in each scenario, which is assumed to be recovered directly from households.

17. In the hydrogen + biomass scenario, building level costs are not significantly increased relative to the status quo. It is assumed that, once produced at scale, hydrogen boilers can be installed for the same cost as a gas boiler. There are some additional costs due to early replacements of gas boilers before their natural end of life, and the higher cost of biomass boilers.[31] A modelled increase to building level costs per household of £80 between 2018 and 2050 is added to the 2017 cost of central heating repairs and installation to give a cost of £220 per household for hydrogen + biomass fixed costs in 2050.

18. The fixed cost of heat pumps is modelled as £640 per household in 2050.[32] The average fixed cost between the two heat scenarios is **£430**, in 2018/19 prices and excluding VAT.

End notes

[1] National Infrastructure Commission (2018), National Infrastructure Assessment Chapter 2: low cost, low carbon
[2] Element Energy (2018), Cost analysis of future heat infrastructure options
[3] Ibid
[4] Department for Business, Energy & Industrial Strategy (2018), Updated Energy and emissions projections 2017, Annex M: Growth assumptions and prices. Assessed at: **https://www.gov.uk/government/publications/updated-energy-and-emissions-projections-2017**
[5] Office for Budget Responsibility (2018), March 2018 Economic and fiscal outlook – supplementary economy tables.
[6] Department for Business, Energy & Industrial Strategy (2018), Energy Trends: June 2018, Table 5.1. Fuel used in electricity generation and electricity supplied, electricity generated. Accessed at: **https://www.gov.uk/government/statistics/energy-trends-june-2018**
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[20] Ibid
[21] Department for Transport (2017), National Travel Survey, Vehicle mileage and occupancy, Table NTS0901 Annual mileage of 4-wheeled cars by ownership and trip purpose. Commission calculations: business mileage as a percentage of total mileage.
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[23] Office for National Statistics (2018), Family spending in the UK: financial year ending 2017. Accessed at: **https://www.ons.gov.uk/peoplepopulationandcommunity/personalandhouseholdfinances/expenditure/bulletins/familyspendingintheuk/financialyearending2017**

[24] Office for Budget Responsibility (2018), March 2018 Economic and fiscal outlook – supplementary economy tables. Accessed at: **http://obr.uk/download/march-2018-economic-and-fiscal-outlook-supplementary-economy-tables/**
[25] Department for Business, Energy & Industrial Strategy (2018), Energy consumption in the UK, Table 3.02 domestic energy consumption by end use and fuel 1990 to 2016. Accessed at: **https://www.gov.uk/government/statistics/energy-consumption-in-the-uk**
[26] National Infrastructure Commission (2017), Congestion, capacity, carbon – modelling annex. Accessed at: **https://www.nic.org.uk/publications/1481/**
[27] Element Energy and E4Tech (2018), Cost analysis of future heat infrastructure options. Accessed at: **https://www.nic.org.uk/publications/cost-analysis-of-future-heat-infrastructure/**
[28] Department for Business, Energy & Industrial Strategy (2018), Energy consumption in the UK, Table 1.03 Non transport energy consumption by end use. Accessed at: **https://www.gov.uk/government/statistics/energy-consumption-in-the-uk**
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