Standard Data Inputs and Assumptions for Local Area Energy Planning – Annexe 2

CATAPULT Energy Systems



UK Research and Innovation

LOCAL AREA ENERGY PLANNING



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Introduction

This document accompanies the Guidance on Creating a Local Area Energy Plan and describes how to use input data and the assumptions required when using the data. The purpose is to provide a set of standardised data inputs to use when creating a LAEP, for instances where it is expected that the values should not vary by the region or area covered by the LAEP. The intention in providing these values is to support organisations creating LAEPs and increase the probability of them being comparable to each other and allow insights to be drawn 'summing' multiple plans.

This document starts with an overview to what data has or has not been included, advice on how to handle cost data, and a suggested approach if data different to that in this document is used. It is then followed by a series of sections setting out suggested data sources.

The Guidance discusses how the national datasets could be used in a LAEP, and what datasets should be identified at a more local level.

Inclusion criteria

The following criteria have been considered when selecting the data to be included in this document:

- The data item is likely to have a meaningful impact on the analysis undertaken to create a Local Area Energy Plan
- The data applies nationally, i.e., there are little or no regional differences expected
- A mature and public data source is available for the values, preferably a government source
- The data source does not restrict the model or analysis techniques that can be used, it allows innovation in future LAEP approaches.

List of standardised data items

Following the criteria, the following data items have been selected for inclusion in this document:

- Resource prices
- Resource greenhouse gas emissions
- Generation technologies
- Storage technologies
- Heating system capital costs – domestic
- Heating system capital costs – non-domestic
- Heating system efficiencies – domestic and non-domestic
- Insulation measure costs - domestic
- Insulation measure efficiency improvements

Excluded Data Items

Table 1 provides a list of LAEP data items that were evaluated against the above criteria and were found not to be suitable for inclusion in this document, alongside an explanation of why. It is anticipated that some of these could feature in a future version of the document if new high quality data sources become available.

Table 1: List of data items considered against criteria but not selected for standardisation

Data Item	Exclusion reasons
Heating systems and insulation	
Non-domestic insulation retrofit costs	Likely to be highly variable by building type meaning mature, public dataset not identified.
Heating system lifetimes for domestic and non-domestic	Lack of mature/public data availability, do not want to exclude modelling approaches that model lifetimes in a probabilistic way
Network costs	
Electricity network reinforcement costs	Costs may be broadly similar geographically but can vary by DNO. DNO data should be used where available through engagement with them as a key primary stakeholder in the LAEP process.
Hydrogen networks – new costs and costs to upgrade existing gas networks	Lack of mature/public data availability. Potential to vary by gas network operator and will depend on conditions of pipes in an area. Engagement with gas network operator as primary stakeholder as part of LAEP process.
Heat network costs	Lack of mature/public data available and potential to vary by area. Costings from previous heat network feasibility studies in an area could provide a guide.
Demand profiles	
EV charging	Likely to be particularly impactful on LAEP analysis but there is a lack of mature/public data availability. Difficulty in defining charging profiles where various smart/flexible charging, vehicle to grid, and consumer behaviour patterns could be assumed. Do not want to limit modelling approaches that consider these variations.
Heating requirements	Actual heating demand varies based on local climate and building attributes. Considered standardising the heating requirements for homes i.e., what temperature needs to be achieved and when; but lack of mature/public data available for this and does not reflect wide range of consumer preferences. Some analysis approaches may wish to include interventions that reflect changes in consumer behaviour, so a single profile would not be appropriate.

Choosing to use Different Values

There may be good reasons to not follow this guide for a particular LAEP; for example, an unexpected regional variation, or a new superior data source becoming available. If a data source different to those set out in this document is used then it is helpful to capture this in the LAEP document, with an explanation of what data source was used in its place and the justification for doing so. This will be valuable in any LAEP comparison or scale up process as it highlights reasons for potential differences.

It is envisaged that this document will be updated over time as data sources change and new sources become available. Future versions of this guide will also look to common substitute datasets that LAEPs have frequently used, learning from best practice of LAEPs that have been delivered.

Using cost data

A number of these standardised data items relate to the costs of technologies or products. When using these cost data, a couple of common factors need to be considered:

Inflation

To maintain consistency between different cost values, all costs in a LAEP should be standardised to a common base year. Data sources that represent costs prior or post to that base year should be inflated or deflated respectively, (i.e., if a LAEP has a base year of 2020, then cost data from 2017 should have 2017-2020 inflation applied to it).

The measure of inflation suggested is the Consumer Prices Index (CPI). Data is available from the following source:

- ONS, Consumer price inflation tables. Updated monthly. Available from: https://www.ons.gov.uk/economy/inflationandpriceindices/datasets/consumerpriceinflation

For each set of cost data presented, the year's price level being used is stated. These costs must be brought forwards or backwards to the base year used in the LAEP, if applicable, as described above.

Future costs must also be represented in base year prices (i.e., it may be assumed that the costs of a particular technology reduce over time due to economies of scale or technology improvements, however these future costs must remain in base year £ prices, without the impact of inflation).

VAT and other taxes

A consistent approach to including or excluding tax should be adopted for all costs used in the analysis. It is suggested that excluding tax (e.g., VAT) from the costs used is most sensible. Whether the costs presented are inclusive or exclusive of VAT is indicated in each section and is dependent on the underlying data source, and they may then need to be processed into the format used in that LAEPs analysis.

Format of standardised data sections

The format for each standardised data section is as follows:

- Brief introduction, clarifying the data covered by the section
- Key attributes of the datasets used in this section
- Rationale for data standardisation
- Guidance on use of the data. If possible, the data is clearly presented at the outset of this sub-section. Otherwise, this sub-section contains detailed guidance on how the data should be used for LAEP modelling
- Data sources – a more detailed description of the data source used, and links to the source
- Example data extract from the source
- Appendix – further background information to the data where useful

Data source maturity

The maturity of each data source is shown for each data item. The maturity has been evaluated as follows:

- **High**: Data is from a government source, and:
  - Is based on historical data with a high number of data points or is based on modelling which has drawn from good availability of historic data or is data that is widely accepted by industry.
- **Medium:** Data is from a government source, and does not satisfy other High maturity conditions
- **Low:** Data source does not satisfy any of the above conditions

Item 1
Resource prices

'Resources' here refer to energy resources used but not generated within a local area, e.g., grid electricity, natural gas, and oil. The prices refer to the costs of those resources as they enter the local area and will be a key input into the optimisation process of a LAEP.

1.1 Data Source Summary

Data Source Name	HM Treasury Green Book supplementary guidance
Data Source Link	https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
Data Retrieved	07/04/2022
Data Last Updated	07/10/2021
Expected Update Frequency	Expected to be annual
Data Source Maturity	High

1.2 Rationale for data standardisation

Costs of options is a key input into the LAEP analysis process, with the relative cost of different options having a significant impact on which are taken forward. When assessing the long-term costs of an option it is necessary to have a projection of future energy costs. The recent volatility further supports this case; cost assumptions could otherwise feasibly differ significantly. For a LAEP to be used to justify government investment it needs to be compatible with the Treasury Green Book approach[1], and so it makes sense to use Green Book costs where available.

1.3 How to use the data

The data contains annual prices to the year 2100 expressed in terms of real 2020 p/kWh (i.e., does not include future inflation) for electricity, gas, and oil.

Long Run Variable Costs (LRVC) are the most appropriate for LAEP analysis as they are the recommended measure for valuing net changes in energy use. They include the components of the retail price that represent actual costs to society that vary according to the level of consumption. Retail prices are also provided, which are the final price that consumers pay, and also include all non-variable components and societal transfers.

For each resource, 'Low', 'Central' and 'High' prices are given. While it is encouraged that the Central prices are followed for baseline scenarios, any set of values between Low and High may be used if there is a local justification to stray from the Central values. There can be significant uncertainty in future energy costs and the LAEP may be sensitive to these. Where time and resource allows it is recommended that sensitivity analysis using the low and high bounds it is undertaken. Beyond the baseline scenario more extreme differences may also be tested as part of the analysis.

If possible, within the analysis approach, the relevant values for the Domestic, Commercial/ Public Sector or Industrial costs could be applied to individual energy demands, otherwise a weighted average may by appropriate.

1.4 Example Data Extract

Table 2 shows an extract of the retail electricity prices from the Green Book supplementary guidance. Note this is not the complete data and this table should not be used; the latest full dataset available from the data source link above should be used.

1 As discussed further in the main guidance

Table 2: Long Run Variable Costs of Electricity. BEIS, Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. 2021. Data accessed 07/04/22. Note that these numbers have not yet been updated to reflect the exceptional market conditions in 2021 and 2022

Year	Electricity LRVC (real 2020 p/kWh)								
	Low			Central			High		
	Domestic	Commercial / Public sector	Industrial	Domestic	Commercial / Public sector	Industrial	Domestic	Commercial / Public sector	Industrial
2022	9.6	7.2	7.2	10.9	9.4	8.8	12.4	11.1	10.7
2023	9.6	7.2	7.2	11.0	9.4	8.7	12.4	11.0	10.6
2024	9.6	7.1	7.1	10.9	9.3	8.6	12.3	10.9	10.5
2025	9.8	7.3	7.3	11.1	9.5	8.8	12.6	11.2	10.7
2026	10.3	7.6	7.6	11.6	9.9	9.1	13.0	11.5	11.0
2027	10.3	7.6	7.6	11.6	9.8	9.1	13.0	11.5	11.0
2028	10.2	7.5	7.4	11.5	9.6	8.9	12.9	11.2	10.7
2029	10.2	7.4	7.3	11.5	9.5	8.8	12.8	11.1	10.6
2030	10.6	7.6	7.4	11.9	9.8	8.9	13.3	11.4	10.8
...	...	...	...	...	...	...	...	...	...



Item 2

Resource greenhouse gas emissions

'Resources' here refer to energy resources used but not generated within a local area (e.g., grid electricity, natural gas, and oil), and their emissions represents what should be accounted for if used in a local area (although generated elsewhere).

2.1 Data Source Summary

Data Source Name	HM Treasury Green Book supplementary guidance
Data Source Link	https://www.gov.uk/government/publications/valuation-of-energy-use-and-greenhouse-gas-emissions-for-appraisal
Data Retrieved	07/04/2022
Data Last Updated	07/10/2021
Expected Update Frequency	Expected to be annual
Data Source Maturity	High

2.2 Rationale for data standardisation

The amount of greenhouse gas (GHG) emissions associated with energy brought into a local area may have a significant impact on the future decarbonisation options chosen. A degree of standardisation in a baseline scenario would therefore be beneficial for comparison between LAEPs, and also would allow the analysis to remain compatible with the HM Treasury Green Book guidance. Additional scenarios may explore differences in these values (e.g., more rapid grid decarbonisation).

2.3 How to use the data

The Treasury's Green Book Supplementary Guidance contains GHG emissions for grid electricity, LPG, natural gas, and oil. Electricity GHG emissions include transmission and distribution losses, including significant losses due to power station inefficiency. Annual values in $kgCO_2e/kWh$ are given up to the year 2100. The grid average consumption based values should be used for overall carbon footprinting of an area and depending on the analysis approach separate values for Domestic, Commercial/Public Sector and Industrial emission factors could be used.

For other resources (e.g., oil), single $kgCO_2e$ values are given per unit of final energy demand (in mass, volume, and energy content values).

The analysis may wish to investigate the impact of different resource decarbonisation pathways (e.g., rapid grid electricity decarbonisation) on the LAEP results; in which case, the data provided here should be used as the baseline scenario and can be modified for other scenarios.

2.4 Example Data Extract

Table 2 and Table 3 show extracts of the emission factors from the Green Book supplementary guidance. Note this is not the complete data and these tables should not be used; the latest full dataset available from the data source link above should be used.

Table 3: Electricity Emission factors. BEIS, Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. 2021. Data accessed 07/04/22

Year	Grid average, Consumption-based Emission Factors ($kgCO_2e/kWh$)		
	Domestic	Commercial/ Public sector	Industrial
2022	0.142	0.139	0.136
2023	0.136	0.133	0.131
2024	0.148	0.145	0.143
2025	0.125	0.123	0.121
2026	0.092	0.091	0.089
2027	0.076	0.075	0.074
2028	0.071	0.069	0.068
2029	0.066	0.065	0.064
2030	0.053	0.052	0.051
...	...	...	...

Table 4: Converting fuel types to CO2 and CO2e (emission factors). BEIS, Green Book supplementary guidance: valuation of energy use and greenhouse gas emissions for appraisal. 2021. Data accessed 07/04/22

Fuel	All GHG emissions ($kgCO_2e$ per unit)			
	Tonnes	kWh (Gross CV)	Litres	Therms
LPG	2938.8	0.2	1.6	6.3
Natural Gas	2533.0	0.2	2.0	5.4
Burning Oil	3165.3	0.2	2.5	7.2



Item 3
Generation technologies

3.1 Data Source Summary

'Generation Technologies' here refers to technologies that may be connected to the transmission or distribution electricity or gas grids, or to heat networks.

Data Source Name	BEIS Electricity Generation Costs Key Assumptions
Data Source Link	https://www.gov.uk/government/publications/beis-electricity-generation-costs-2020
Data Retrieved	20/04/22
Data Last Updated	24/08/20
Expected Update Frequency	Irregular (previous update 2016)
Data Source Maturity	High

For costs of small-scale PV only (typically those systems where the majority of energy produced is consumed on site), an alternative data source is available. This data source is suggested because the BEIS data is for a reference plant size of 50MW, which is unlikely to reflect values for small scale systems. This suggested MCS dataset is a survey of many small-scale PV installations.

Data Source Name	Microgeneration Certificate Scheme PV Cost Data
Data Source Link	https://www.gov.uk/government/statistics/solar-pv-cost-data
Data Retrieved	07/03/2022
Data Last Updated	27/05/2021
Expected Update Frequency	Annual
Data Source Maturity	High

3.2 Rationale for data standardisation

New local generation may play a key role in some local area energy plans as it is required to help an area reach net zero, and to support the expected greater demand for low carbon electricity if heat or transport are electrified. The decisions to install are likely to be sensitive to the costs and performance of such generation technologies and as these are not envisaged to vary to a large extent regionally it is sensible to standardise this input data.

3.3 How to use the data

Data for the following technologies are included.

- Closed Cycle Gas Turbine (CCGT) (data for all 3 of: H Class, CHP mode, and with CCS)
- Open Cycle Gas Turbine (OCGT)
- Reciprocating Engines (Diesel & Gas)
- Biomass (Dedicated, CHP, & with CCS)
- Wind (Onshore & Offshore)
- Solar PV (note different sources recommended for large- and small-scale systems)
- Energy from Waste (Dedicated & CHP)
- Anaerobic Digester (Dedicated & CHP)
- Advanced Conversion Technology (Standard, Advanced & CHP)
- Landfill Gas
- Sewage Gas
- Hydro
- Wave

Table 4 shows a complete list of the data included in the source for each generation technology (other than small scale solar). It is suggested that only some of the source's data are standardised data inputs for LAEP analysis. All data is given for the years 2025, 2030, 2035 and 2040 (e.g., showing steady cost reductions between 2025 and 2040) and are given for a generating plant of a reference size (e.g., figures for large-scale Solar PV are given for a 16MW plant size).

Table 5: List of data included in the data source, and enforecment of use in modelling

Data input included in data source	Unit	Input is standardised and should be used for LAEPs (Y/N)	Notes
Average load factor	%	N	Not standardised due to potential regional differences in load factors in some technologies (e.g., wind and solar), however use of given load factor is encouraged when no better data are available
Average fuel efficiency	%	Y	No regional differences envisaged, and important for the calculation of resource usage
Operating lifetime	Years	Y	No regional differences envisaged, site specific factors may impact lifetime and so could be considered if applicable (e.g., a coastal location).
Pre-development costs	£/kW	Y	See costs note (3.1.1)
Pre-development phasing	% in each year	N	Detail may not be required for LAEP analysis
Construction costs	£/kW	Y	See costs note (3.1.1)
Construction phasing	% in each year	Y	Standardised if phasing is supported by the model
Infrastructure costs	£	See note	Infrastructure costs may include those associated with network reinforcement and other connection works. These should be accounted for, but care should be taken to not double count them with any other analysis of network upgrade costs.
Fixed O&M	£/MW /year	Y	See costs note (3.1.1)
Variable O&M	£/MWh /year	Y	See costs note (3.1.1)
Insurance Costs	£/MW /year	Y	See costs note (3.1.1)
Connection and Use of System (UoS) charges	£/MW /year	See note	Connection and UoS charges may vary by region and DNO. Therefore, it is encouraged that where local data is available, the local costs are used. In the absence of local data, the costs given in this data source should be used
Hurdle Rate	%	N	Not likely to be applicable

Small Scale PV

The cost data comes from a separate source and includes PV installation costs for three capacity ranges:

- <4kW: these costs should be used for domestic buildings only
- 4-10kW: costs recommended to be used for smaller non-domestic buildings
- 10-50kW: costs should be used for larger non-domestic buildings only

The data source's capacity ranges have been categorised as above for LAEP modelling to avoid arbitrary jumps in costs from being modelled at 4kW and 10kW system capacities.

For each range, a Lower Confidence interval, Mean, Median and Upper Confidence interval is given. The mean is likely to be the most appropriate value to use in a baseline scenario.

3.4 Example Data Extract

The tables below show extracts from the two datasets.

Table 6: Data extract from electricity generation costs: key data assumptions for generation technologies. BEIS, BEIS Electricity Generation Costs. 2020. Data accessed 20/04/22

Technology			**Energy from Waste (EfW)**			
Commissioning Year			**2025**	**2030**	**2035**	**2040**
Reference plant size		MW	24	24	24	24
Average fuel efficiency		%	22%	22%	22%	22%
Operating lifetime		years	35	35	35	35
Pre-development cost	Low	£/kW	140	140	140	140
	Medium	£/kW	220	220	220	220
	High	£/kW	320	320	320	320
Pre-development period		years	4	4	4	4
Pre-development phasing (% spent in each year)	Year 1	%	23%	23%	23%	23%
	Year 2	%	23%	23%	23%	23%
	Year 3	%	23%	23%	23%	23%
	Year 4	%	32%	32%	32%	32%
Construction cost	Low	£/kW	10800	10700	10600	10600
	Medium	£/kW	13900	13800	13700	13700
	High	£/kW	16600	16400	16300	16300
Construction period		years	3	3	3	3
Construction phasing (% spent in each year)	Year 1	%	34%	34%	34%	34%
	Year 2	%	34%	34%	34%	34%
	Year 3	%	33%	33%	33%	33%
Infrastructure		£'000	6300	6300	6300	6300
Fixed O&M		£/MW/year	157900	155500	154100	154100
Variable O&M		£/MWh	58	57	56	56
Insurance		£/MW/year	88000	86700	85900	85900
Connection and use of system charges		£/MW/year	17200	17000	16800	16800

Table 7: BEIS, Solar Photovoltaic (PV) Cost Data. 2021. Data accessed 07/03/22

Installation Size	BEIS data - Total 2020/21				Suggested Analysis Usage	
	£/kW installed ("variable cost")					
	Median	Mean	Lower 95% Confidence Interval	Upper 95% Confidence Interval	*Use for*	*For fixed+variable cost inputs, match variable costs at:*
0-4kW	1,429	1,628	1,619	1,637	*Domestic buildings*	*4kW*
4-10kW	1,586	1,685	1,668	1,702	*Smaller Non-domestic buildings*	*10kW*
10-50kW	1,000	1,088	1,064	1,112	*Larger Non-domestic buildings*	50kW

Using the numbers above around the 10kW boundary there will be a number of system sizes that are cheaper than smaller systems, for example an 11kW system calculated using the 10-50kW data will show as cheaper than a 10kW system calculated using the 4-10kW data (see Figure 1 for example). This is not desirable and would not make sense in a cost optimised approach. If using systems at sizes around this boundary we suggest that modifications are made to the numbers to avoid this.

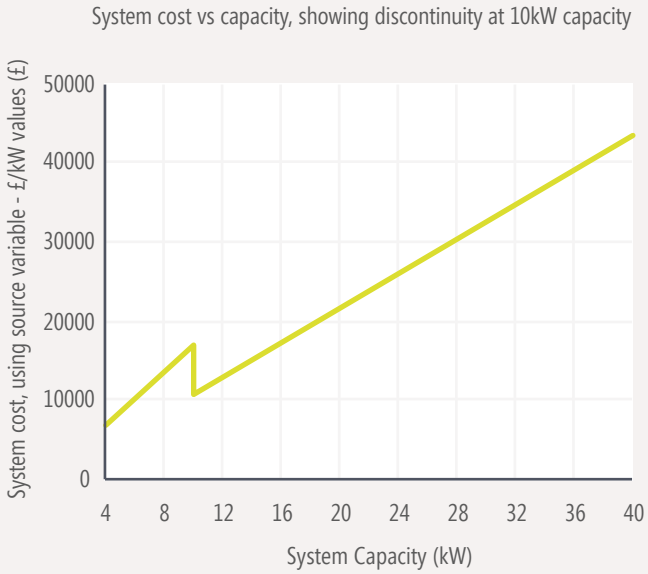

Figure 1: Example of discontinuity at 10kW boundary in system sizes when using source variable £/kW values.



3.4.1 Note on use of cost data

Technologies other than small scale PV

For the report published in 2020, costs are given in real 2018 GBP. Note that inflation should be applied to the figures as explained in the Introduction in order to align with the base year of your LAEP.

CAPEX costs

The CAPEX costs included in the data are Pre-development, Construction, and Infrastructure costs.

Infrastructure costs are costs associated with network reinforcement and other connection works and must be accounted for. It may be better if these costs are accounted for using local DNO cost data, and by considering details such as the connection voltage and distance of connection to substation. If this level of detail is not captured by the LAEP's analysis of the networks, infrastructure costs from this source may be used. Care should be taken not to double count infrastructure costs by taking both approaches.

Pre-development and Construction costs are given in the form of variable (£/kW) costs, and Infrastructure in fixed (£) costs. For a given technology, pre-development and construction costs are therefore easily scaled to plant capacity other than the 'Reference' size given in the data source. It is not possible to deduce from the data how infrastructure cost may scale with plant capacity, however, therefore the fixed value should be used for all plant capacities.

For all costs, users are encouraged to follow the 'Medium' values. If there is justification to deviate from this, any value between the Low and the High bounds may be used.

OPEX costs

The OPEX costs included in the data are: Fixed O&M, Variable O&M, Insurance costs and Connection/Use of System charges. As explained in Table 4, Connection and UoS may vary by DNO, therefore if local data is available, this should be used in place of the data from this data source.

The costs are given in the form of fixed (£/MW/year) or variable (£/MWh/year) costs. Users may use any combination of costs (fixed, variable or both) to suit their own models; this may require converting per MWh costs to per MW costs, or vice versa, using the Load Factor of the technology.

Note, no Low and High bounds are given for the OPEX costs, unlike for CAPEX costs.

Small Scale PV

The data presented here contains cost figures in £/kW (i.e., a variable cost only). Recognising that there are other approaches, the analysis could also use a combination of fixed and variable costs. Solely fixed costs can be used if the costs apply to single discrete PV capacities and are calculated using the source £/kW values.

If costs are modelled using a combination of fixed and variable costs, any fixed and variable cost combination may be used, but it is suggested that the costs are chosen such that the resulting sum of fixed + variable cost falls within the provided data's lower and higher confidence intervals at a given system size (4kW for domestic, 50kW for non-domestic; selected as typical installation sizes).

Potential future cost reductions may be represented if considered appropriate. No data source is stipulated for future costs; however, all reductions must be scaled from the 'current' costs presented here.

Costs from this source include PV and auxiliary equipment costs, cost of installation and connection to the electricity supply, with VAT included (see the Introduction for a discussion on how to handle VAT and other taxes). It should be assumed the costs represent the prices of the year of the data's last update.

Item 4
Storage technologies

4.1 Data Source Summary

Data Source Name	BEIS – Storage Costs and Technical Assumptions
Data Source Link	https://www.gov.uk/government/publications/storage-cost-and-technical-assumptions-for-electricity-storage-technologies
Data Retrieved	02/05/20
Data Last Updated	24/08/20
Expected Update Frequency	Unknown
Data Source Maturity	High

4.2 Rationale for data standardisation

Although the costs and attributes of storage deployed on any one site may be variable, in the absence of site-specific detail it is believed that that the average values will remain consistent across the country. While the costs of some technologies in the present day are well defined, (e.g., Lithium-ion batteries), other less mature technologies are not (e.g., Compressed Air Energy Storage). For all technologies, there is uncertainty around future costs.

4.3 How to use the data

The dataset includes a number of technologies and use cases. The table below sets them out and highlights those likely to be most relevant to a LAEP.

Table 8: Energy storage technologies for each use case included in the data source, and their applicability to LAEP modelling

Use case		Energy Storage Technologies	Applicable for use in LAEP analysis?
Frequency Response (50MW/1hr)		Li-Ion Battery, New Battery[2]	Unlikely to be a key consideration in a LAEP
Peak Lopping (4-6 hours response)	Network Connected (200MW/4hrs)	Pumped Hydro, CAES[3], Thermal, Li-Ion Battery, Zinc-based Battery, Flow Battery, Na-S Battery, New Battery	May be out of scope for a local plan
	Domestic (5kW/4hrs)	Li-Ion Battery, New Battery	Yes
	Co-Located (10MW/4hrs)	Li-Ion Battery, New Battery	Yes
	Distribution (2.5MW/4hrs)	Li-Ion Battery, New Battery	Yes
	Industrial and Commercial (1MW/2.5hrs)	Li-Ion Battery, New Battery	Yes
Long Term Energy Storage (20 hours+)	Weekly Balancing (200MW/4hrs)	Pumped Hydro, CAES, Zinc-based Battery, Flow Battery, Na-S Battery, Thermal	Long term balancing expected to be more applicable to national energy system planning
	Seasonal Balancing (10MW/250hrs)	Hydrogen	

2 New Battery refers to designs included in the report's assessments to allow for 'game changing' new technologies, including experimental new chemistries and compositions of the electrodes. It is considered too speculative to be included in a LAEP.

3 CAES refers to Compressed Air Energy Storage

It is considered that the Peak Lopping use case is likely to be most relevant to LAEPs, and for that the Li-ion battery technology is appropriate for LAEP analysis. The following section focuses on that technology and use case, but others could be selected and used in a LAEP analysis if considered appropriate for that particular use case.

The following attributes are provided by the data source and considered suitable for standardisation:

Source data attributes	Notes
Round trip efficiency	-
Variable Cost	Variable cost is zero for all storage technologies aside from Hydrogen
Construction period	-
Lifetime	-
Useable depth of discharge	-
Construction Period phasing	-
Infrastructure cost	Infrastructure costs (relating to connection works) must be accounted for. If these costs are not already accounted for in the model's network analysis / costs calculations, then the data from this source should be used. See Section cost note for further detail
CAPEX	See below
OPEX	See below

The other attributes provided by the data source are either considered to be a choice in the analysis (e.g., Maximum power) or are at a level of detail not needed for a LAEP (e.g., provision of inertia).

Cost data for LAEP use

The cost data requires processing before being suitable for use in a LAEP. The tables below present a processed set of costs for the Li-Ion technology. The methodology used for processing is explained at the end of this section.

Table 9: Lithium-Ion infrastructure costs per connection type

Lithium-Ion Infrastructure Costs				
Connection type	Suggested to apply to systems of:	Infrastructure cost (£/kW)		
		Low	Medium	High
Domestic	<20kW	13.60	27.30	45.50
Distribution	<50MW	18.20	46.40	83.70
Co-located	<50MW	1.80	4.50	10.90

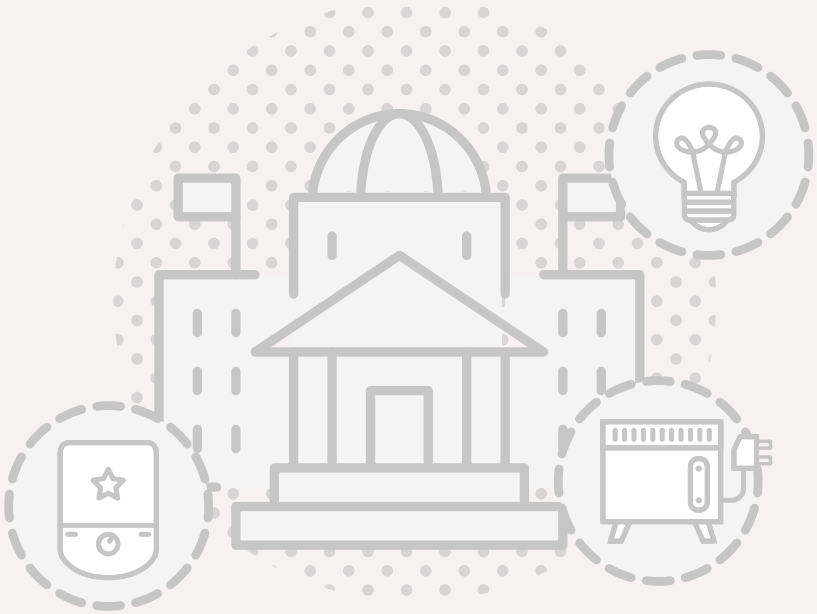

Table 10: Lithium-Ion CAPEX per storage duration

Lithium-Ion CAPEX								
Duration[4] (hours)	2.5				4			
Year	2020	2030	2040	2050	2020	2030	2040	2050
High (£/kWh)	403.40	182.36	120.20	90.44	327.48	169.08	122.88	100.03
Medium (£/kWh)	345.76	156.32	103.00	77.52	280.70	144.93	105.33	85.73
Low (£/kWh)	288.12	130.24	85.84	64.60	233.93	120.78	87.78	71.45

Table 11: Lithium-Ion OPEX per storage application type

Lithium-Ion OPEX					
Year / Storage application		2020	2030	2040	2050
Domestic	High (£/kWh/year)	6.98	3.60	2.63	2.13
	Medium (£/kWh/year)	0.88	0.45	0.33	0.28
	Low (£/kWh/year)	0.00	0.00	0.00	0.00
Non-domestic	High (£/kWh/year)	26.52	12.00	7.88	5.96
	Medium (£/kWh/year)	8.57	4.12	2.85	2.23
	Low (£/kWh/year)	1.78	0.90	0.65	0.55

All costs are given in 2012 prices. Note that inflation should be applied to the figures in order to reach the base year of the LAEP (in accordance with Section A.4). Low, Medium, and High values are presented; it is encouraged that Medium values are used, however if there are local reasons to deviate from this, any values between Low and High may be used.

Infrastructure costs relate to "electrical connection works required to connect the project", must be accounted for. These costs may be accounted for using DNO cost data, and by considering details such as the connection voltage, distance of connection to substation etc., though if this detail is not captured by the LAEP's analysis of the networks, infrastructure costs presented here may be used. Care should be taken not to double count infrastructure costs.

As the cost data in the original data source is given for specific sizes and uses, it is not clear which values to use when wishing to analyse sizes not in the dataset, that may mean there is a risk of inconsistencies. The tables above have been processed into categories for this guidance in an attempt to mitigate this. All processing steps, which are described below, have used data from the data source Summary Document.

Infrastructure costs

For Li-Ion batteries, the infrastructure £/kW costs can be grouped by the type of connection. For example, comparing the medium values, Distribution-connected assets ("Distribution" and "Industrial and Commercial" peak lopping use cases) have the highest £/kW costs, followed by Transmission-connected assets ("Network Connected" peak lopping), then domestic systems, and finally co-located assets have the lowest £/kW costs (as expected due to these sharing an already existing connection).

4 Duration here refers to the time over which the battery fully charges or discharges at the battery's rated power.

In general, £/kW connection costs would in practice differ by connection type considering their differing equipment needs. For this reason, we have consolidated the infrastructure cost data by grouping the use cases into connection types. These are:

- Domestic,
- Distribution,
- and Co-located.

For Domestic and Co-located connection types, the data has been extracted directly from the Domestic Peak Lopping and Co-located Peak Lopping use cases in the data source. For the Distribution connection type, data from two use cases were combined: Distribution Peak Lopping and Industrial and Commercial Peak Lopping. The 'consolidated' Low and High values used are the individual lowest and highest values of these two use cases respectively, and the 'consolidated' Medium value is the average value of the individual Medium values of these two use cases.

CAPEX costs

CAPEX costs in the data source are given in fixed £ and £/kW for each technology size. High, Medium, and Low values are given for each technology and use case, for 2018, '20, '30, '40 and 2050. CAPEX from this source includes project detailed design costs, capital costs, and installation costs.

For Lithium-Ion, the £/kW costs can be grouped by the storage duration. The source's £/kW Li-Ion CAPEX is the same for all 4-hour duration systems and is reduced for 2.5-hour duration systems - and is independent of the system power. This is likely due to cell costs (with number of cells scaling with duration) being the largest contributors to total CAPEX.

For this reason, for purposes of simplifying cost presentation, we have grouped Li-Ion CAPEX costs for use in LAEP modelling according to storage duration. Since CAPEX costs scale primarily with capacity rather than power, we have converted the £/kW values to £/kWh using the capacity values.

OPEX costs

OPEX costs are given in fixed £ and in £/kW for each technology size. High, Medium, and Low values are given for each technology and use case, for 2018, '20, '30, '40 and 2050. OPEX from this source include operation costs, inspection, maintenance, consumables, insurance, and security.

To avoid discontinuities in costs between similar Li-Ion assets, the OPEX data for 'Domestic' and 'Non-Domestic' applications has been consolidated. This is because in the data source there is a large difference in OPEX between the Domestic Peak Lopping Li-Ion batteries and Li-Ion batteries for all other use cases (being Distribution, Industrial and Commercial, and Co-located Peak Lopping). It is recognised that there is also a spread in OPEX within the other use cases, however it is judged that this is the most logical way to group the data.

As with CAPEX costs, £/kW OPEX costs were converted to £/kWh for presentation, as OPEX is expected to scale primarily with capacity. OPEX was then consolidated into 'Domestic' and 'Non-domestic' application types using the method shown in Table 11.

Table 12: OPEX consolidation method

Consolidated application type	Source use cases used	Processing applied for consolidated values		
		Low	Medium	High
Domestic	Domestic Peak Lopping	No processing - Low/Med/High taken directly from source		
Non-domestic	Distribution, Industrial and Commercial, and Co-located Peak Lopping	Lowest value of 3 use cases	Average of 3 use case's Medium values	Highest value of 3 use cases

4.4 Example Data Extract

The table below shows an extract of the data contained in the report other than the costs discussed above.

Table 13: Industrial and Commercial Peak Lopping use case - Lithium-Ion Battery Storage (1MW, 2.5MWh), data extract. BEIS, Storage cost and technical assumptions for electricity storage technologies. 2020. Table 37, p. 65-66. Data accessed 29/04/22

Description of Attribute	Number or Truth Value
Round trip efficiency (%)	85%
Variable Cost (£/MWh)	0
Maximum new builds by plant type each year (MW)	4000
Construction period (Years)	1
Lifetime (Years)	15
Maximum deliverable power (MW)	1
Average availability (%)	95%
Energy Storage (MWh)	4
Self-discharge time (i.e., time elapsed before capacity is reduced to less than 80% by self-discharge) (hours)	1560
Useable depth of discharge (% of energy storage useable)	80%
Response time (s)	0.15
Footprint (m^2)	36.3
Operational environmental, safety limitations/ hazards (Y/N)	N Generally but unsafe if overheated
Provisions of Inertia (Y/N)	N
Cycle Life	5000
Pre-Development Costs (£)	£20,923
Construction Period phasing (% of investment for each year of construction)	100%

Item 5
Heating system capital costs – Domestic

5.1 Data Source Summary

Data Source Name	BEIS - Cost of installing heating measures in domestic properties
Data Source Link	https://www.gov.uk/government/publications/cost-of-installing-heating-measures-in-domestic-properties
Data Retrieved	09/05/2022
Data Last Updated	17/09/2020
Expected Update Frequency	No updates expected
Data Source Maturity	High

For Hydrogen Boilers:

Data Source Name	BEIS - Hydrogen supply chain: evidence base
Data Source Link	https://www.gov.uk/government/publications/hydrogen-supply-chain-evidence-base
Data Retrieved	10/05/2022
Data Last Updated	30/11/2018
Expected Update Frequency	No future updates expected
Data Source Maturity	Medium

5.2 Rationale for data standardisation

Replacement heating system installation costs are likely to be a large contributor to the total cost of decarbonisation for some local areas and are a significant factor when choosing between different systems. It is not expected that equipment and installation costs will vary greatly from region to region.

5.3 How to use the data

The data presented here contains equipment and installation cost data for a range of heating systems, based on a survey of installers. As hydrogen boilers are not commonly installed at this time, a different data source is used.

The heating systems included in this source are listed below:

- Gas boilers (combi and non-combi)
- Oil boilers (combi and non-combi)
- Biomass boilers
- Air to water heat pumps
- Ground to water heat pumps
- Air to air heat pumps
- Electric heating (multiple types)
- Heating control systems

Costs for each technology are divided into various categories. For example, for air to water heat pumps, the costs include costs of the:

- Heat Pump,
- required HP fittings,
- buffer tank and cylinder,
- controls,
- installation labour fees,
- and various types of heat distribution systems including a complete new retrofit and retrofit of existing systems.

For each of these costs, Low, Central and High values are given. For equipment costs, High, Central and Low costs relate to high-end, mid-range and low-end price estimates. For labour costs, the Low and High estimates are generally based on installation complexity. All costs are inclusive of installer margins.

All costs are given as fixed (£) costs. Equipment costs are given for various system sizes (kW). For example, for air to water heat pumps, the cost of HP's is given for 6, 8, 10, 12.5 and 16kW HPs, whereas only one set of Low-High costs are given for fittings, installation costs, heat distribution systems etc. For simplicity, it is recommended that LAEPs use system sizes from those given in the data source – the system sizes are considered representative of systems available on the market according to the data authors, covering approximately 90% of the installed systems. It is encouraged that the Central value is used for equipment costs, however any value within the Low and High ranges may be used if there is local justification to do so.

For costs other than the purchase of the technology itself (e.g., labour, cylinder, fittings, heat distribution system), the analysis should consider which cost value (Low, Central or High) is appropriate, considering the technology size selected, the type and size of dwelling it is likely to be applied to, and any other local factors. For example, when installing a large air to water HP (e.g., 16kW), it is likely that this would be installed to a large house, therefore using the High-cost estimates for labour, cylinder, heat distribution system, etc. would be appropriate. The data source contains useful comments alongside the Low/Central/High which may give a good indication of which estimate is most applicable.

Only current system costs are provided in this data source. It is encouraged that future price reductions are accounted for, since it is expected that technology improvements and improving economies of scale will reduce prices of many low carbon heating systems. No mature data source estimating future cost trajectories for all the considered technologies was identified at the time of writing. There is existing work on future heat pump cost savings produced by Delta EE (e.g. DECC 2016 - Potential Cost Reductions for Air Source Heat Pumps[5] - What is

5 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/498962/150113_Delta-ee_Final_ASHP_report_DECC.pdf and Delta EE 2021

the potential for cutting the cost of an installed heat pump?[6]). Although these are valuable data sources for heat pump cost reductions, ideally the approach should use the same methodology for all considered technologies such that they can be compared equally.". Note that the current prices should still be based on data from the source presented here, and future prices should be scaled from this 'baseline' current price, for example with a year-on-year percentage change.

All prices are stated excluding VAT and are 2017 nominal prices.

For Hydrogen Boilers only

As discussed, this is from a non-survey data source and is expressed as a multiplier over the natural gas boiler costs. The table below sets out how to use the parameters.

Parameter	Value	Notes
Boiler cost (multiplier over NG boiler cost assumption); lower-upper bound	100,000 UPM (Units per manufacturer): 1.5x	The data source authors compared data collected from industry, based on uplift of cost over Natural Gas boiler costs, and later summarises this data into one fixed £ cost for a Hydrogen boiler, based on a NG boiler cost assumption. Since domestic NG boiler cost is standardised for LAEP modelling, the uplift factors presented in the data source are used, as opposed to the fixed (£) Hydrogen boiler cost. The UPM band selected for the cost assumption may be based on the particular scenario being modelled (e.g., low national Hydrogen boiler uptake vs high national Hydrogen boiler uptake).
	1,000,000 UPM: 1x	
Hydrogen ready hybrid boiler	Assume same cost and installation cost as NG boiler, requiring 1hr for switchover	As provided in source Summary table. Domestic NG boiler cost is standardised for LAEP modelling
Boiler and internal gas pipework installation cost (per household; including pipework material cost)	Lower: £925	Sum of "Installation cost" and "Internal gas pipework cost" from source Summary table. Central value added for LAEP use. Using the Central value is encouraged, though if there is reason to deviate from this, any value between the Lower and Upper bound may be used.
	Central: £1,025	
	Upper: £1,125	
Maintenance cost (multiplier over NG boiler cost assumption)	1.5x	As provided in source Summary table. Domestic NG boiler OPEX cost is not standardised, therefore uplift applies to the modeller's own assumptions.

5.4 Example Data Extract

The tables below show an extract of the data for air to water heat pumps. The comments shown in blue text are comments included in the source[7].

6 https://www.delta-ee.com/whitepaper/whitepaper-what-is-the-potential-for-cutting-the-cost-of-an-installed-heat-pump/

7 Note, there are additional useful comments for many of the data items included as "notes" in the Excel spreadsheet. In addition, example cost calculations are provided for each technology which may aid when selecting different costs to sum for the total installation costs.

Table 14: BEIS, Cost of installing heating measures in domestic properties. 2020. Data accessed 09/05/2022

Cost of HP with margin (excl. controls, excl. heat distribution system) - this is the theoretical cost of the HP delivered to the home, with advice on sizing built into the cost						
size (kW)	6	8	10	12.5	16	
Low	£3,150	£3,800	£4,550	£5,500	£5,600	lower end of range (it is possible to get even cheaper - but these systems would not be sold by most installers)
Central	£3,570	£4,150	£4,850	£5,900	£6,400	mid-range
High	£3,950	£4,450	£5,150	£6,300	£7,350	high end / top of the range
Cost of fittings ASHP (elbows, pumps, valves) with margin						
Low	£650	Easy access, HP is close to buffer tank / cylinder				
Central	£800					
High	£950	More complex system, larger associated buffer / cylinder, HP located further away from buffer tank / cylinder				
Cost of buffer tank and cylinder with margin						
Low	£1,500	Smaller tank + cylinder				
Central	£2,500	Larger tank + cylinder				
High	£3,500	Large buffer tank + cylinder				
Controls with margin						
Low	£200	No additional HP controls - only simple room thermostat and timer				
Central	£500					
High	£800	Weather compensated and multi zone thermostats (for larger homes of over 4 bedrooms)				
Labour fee for ASHPs						
Low	£1,400	Simple installation, smaller home				
Central	£1,800					
High	£2,400	More complex installation, larger home of over 4 bedrooms				
Cost of heat distribution system (complete new installation - not retrofit) - Radiators upstairs and downstairs - including TRVs, piping						
Low	£3,500	smaller house				
Central	£4,000	3 bed semi / terraced house				
High	£5,000	Larger house				
Heat distribution system - underfloor downstairs, radiators upstairs, including pipes, using standard radiators with TRVs, (with margin) *(most common distribution system for new builds and some retrofits - when downstairs radiators are replaced with underfloor heating and the upstairs radiators are replaced with low temperature radiators)*						
Low	£6,000	smaller house				
Central	£6,500	3 bed semi / terraced house				
High	£7,500	Larger house				
Heat distribution system - underfloor downstairs and upstairs, including pipes, using standard radiators with TRVs, (with margin) *(more expensive system - often only used in upmarket homes where space saving is key. Is it very expensive and disruptive to retrofit homes with [upstairs] underfloor heating)*						
Low	£9,000	smaller house				
Central	£10,000	3 bed semi / terraced house				
High	£11,500	Larger house				
Cost of heat distribution system (retrofit of existing radiators)						
Low	£500	only a few radiators are replaced				
Central	£1,000					
High	£1,500					

Item 6
Heating system capital costs – Non-domestic

6.1 Data Source Summary

Data Source Name	BEIS - Renewable Heat Incentive statistics
Data Source Link	https://www.gov.uk/government/collections/renewable-heat-incentive-statistics
Data Retrieved	09/05/2022
Data Last Updated	21/04/2022
Expected Update Frequency	Annual
Data Source Maturity	High

For Hydrogen Boilers:

Data Source Name	BEIS - Hydrogen supply chain: evidence base
Data Source Link	https://www.gov.uk/government/publications/hydrogen-supply-chain-evidence-base
Data Retrieved	10/05/2022
Data Last Updated	30/11/2018
Expected Update Frequency	No future updates expected
Data Source Maturity	Medium

6.2 Rationale for data standardisation

Low carbon heating system installation costs are a significant factor when choosing between different systems for a set of buildings. It is not expected that equipment and installation costs will vary greatly from region to region.

6.3 How to use the data

The data presented here contains CAPEX costs for a range of heating systems from a survey of real installations. Hydrogen boiler costs are from a separate source because they are not currently being installed at scale. For the surveyed values, it is assumed that they include installation costs, are exclusive of VAT and are costs representative of the year they were collected, although none of these are explicitly stated in the source.

The following systems are included[8]:

- Solid Biomass Boiler (< 200 kW), (200-1000 kW), (> 1000 kW)
- Small Solar Thermal (< 200 kW)
- Water or Ground Source Heat Pumps (< 100 kW), (>100 kW)
- Air Source Heat Pumps
- Biogas (< 200 kW), (200-1000 kW), (> 1000 kW)
- Air Source Heat Pumps
- Combined Heat and Power

Some technologies are grouped into different capacities, e.g., <100kW and >100kW for water or ground source heat pumps. For each technology and capacity range, fixed costs (£), as well as £/kW costs, are given; as a Median, Lower quartile and Upper quartile. The median £/kW costs are likely to be the most appropriate for this analysis, although the higher and lower range may be useful for sensitivity testing.

As the data source gives different £/kW values for different kW capacity ranges, there are some instances where a slightly larger systems ends up cheaper, such as the discontinuity shown in the blue line below at the 990KW point. When

8 Biomethane has been excluded as no capacity is given in the data source

undertaking the analysis, users should consider if this may be an issue, for example if comparing two systems each side of the category change. If it is then an adjustment may need to be made, for example as shown by the red line. Where possible the difference between original and modified costs should be minimised for the majority of system capacities that are being considered.

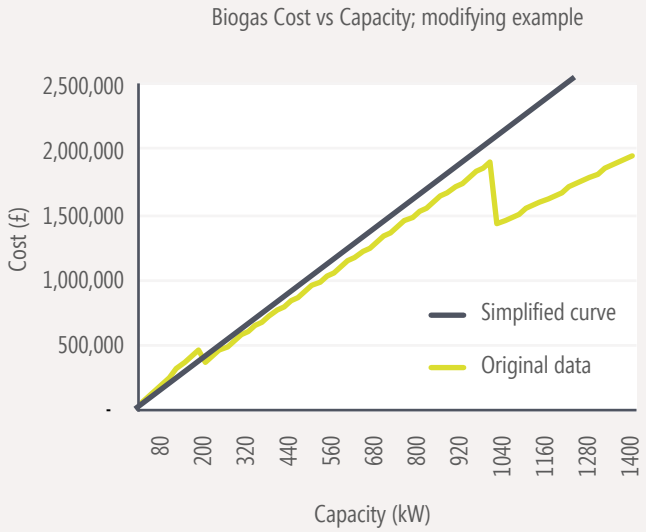

Figure 2: Example of processed data, to remove discontinuities. Suitable example if first discontinuity needs to be removed, and expected that most systems will be of 200-1000kW, some of <200kW and none of >1,000kW.

Only current system costs are provided in this source. It is encouraged that future price reductions are accounted for, since it is expected that technology improvements and improving economies of scale will reduce prices of many low carbon heating systems. No mature data sources estimating future trajectories of cost for these technologies were identified at the time of writing. Current prices should still be based on data from the source presented here, and future prices should be scaled from this 'baseline' current price.



For Hydrogen Boilers only

As discussed above, this is from a non-survey data source and is expressed as a multiplier over the natural gas boiler costs. The table below sets out how to use the parameters.

Parameter	Value	Notes
Boiler cost	1,000 Units per Manufacturer: £53-100/kW	As provided in source Summary table. Based on uplift of ~1.5x on commercial Natural Gas boiler cost range of 35-65 £/kW. Non-domestic NG boiler cost is not a standardised input.
Boiler and internal gas pipework installation cost (including pipework material cost)	100-200kW: £3,250	Sum of "Installation cost" and "Internal gas pipework cost" from source Summary table.
	200-500kW: £4,500	
	>500kW: £8,750	
Maintenance cost	£2-5/kW	As provided in source Summary table. 1.5x uplift on NG maintenance cost

6.4 Example Data Extract

The table below shows a summary of the source's data. Note, the latest available data should be used.

Table 15: BEIS, RHI monthly deployment data: December 2021 (Annual edition), sheet S1.1

	Number of applications contributing	Median Cost per Kilowatt of Capacity (£/kW)	Lower quartile cost per Kilowatt of Capacity (£/kW)	Upper quartile cost per Kilowatt of Capacity (£/kW)
Small Solid Biomass Boiler (< 200 kW)	13,224	590	430	790
Medium Solid Biomass Boiler (200-1000 kW)	4,096	370	240	550
Large Solid Biomass Boiler (> 1000 kW)	188	440	280	820
Small Solar Thermal (< 200 kW)	342	1,390	960	2,000
Small Water or Ground Source Heat Pumps (< 100 kW)	2,124	2,160	1,450	3,780
Large Water or Ground Source Heat Pumps (>100 kW)	594	1,160	650	1,530
Small Biogas (< 200 kW)	408	2,580	620	4,090
Medium Biogas (200-1000 kW)	316	1,900	450	6,070
Large Biogas (> 1000 kW)	57	1,400	440	5,770
Air Source Heat Pumps	924	970	770	1,710
CHP	97	880	570	1,530

Item 7

Heating system efficiencies – Domestic and Non-Domestic

7.1 Data Source Summary

Data Source Name	Department for Levelling Up, Housing and Communities and Ministry of Housing, Communities & Local Government, Conservation of fuel and power
Data Source Link	https://www.gov.uk/government/publications/conservation-of-fuel-and-power-approved-document-l - Table 1 from the Domestic Building Services Compliance Guide and Table 1 from the Non-domestic Building Services Compliance Guide
Data Retrieved	12/05/2022
Data Last Updated	25/02/2022
Expected Update Frequency	Irregular / no updates to efficiency data expected
Data Source Maturity	High

For Hydrogen Boilers

Data Source Name	BEIS - Hydrogen supply chain: evidence base
Data Source Link	https://www.gov.uk/government/publications/hydrogen-supply-chain-evidence-base
Data Retrieved	10/05/2022
Data Last Updated	30/11/2018
Expected Update Frequency	No future updates expected
Data Source Maturity	Medium

For Heat Pumps – COP vs temperature curves (here referred to as "BEIS COP")

Data Source Name	BEIS - Evidence gathering - High temperature heat pumps, hybrid heat pumps and gas driven heat pumps
Data Source Link	https://www.gov.uk/government/publications/evidence-gathering-high-temperature-heat-pumps-hybrid-heat-pumps-and-gas-driven-heat-pumps
Data Retrieved	11/05/2022
Data Last Updated	16/11/2016
Expected Update Frequency	No future updates expected
Data Source Maturity	Medium

For Heat Pumps – Seasonal Performance Factors (here referred to as "DECC SPF")

Data Source Name	DECC - Detailed analysis of data from heat pumps installed via the Renewable Heat Premium Payment Scheme (RHPP)
Data Source Link	https://www.gov.uk/government/publications/detailed-analysis-of-data-from-heat-pumps-installed-via-the-renewable-heat-premium-payment-scheme-rhpp
Data Retrieved	07/06/2022
Data Last Updated	07/04/2017
Expected Update Frequency	No future updates expected
Data Source Maturity	Medium

7.2 Rationale for data standardisation

The choice of heating systems is a key output of LAEP modelling and is naturally sensitive to their efficiency assumptions. Efficiencies are standardised as there is little regional influence (aside from for heat pumps, discussed separately).

7.3 How to use the data

The majority of data used has been sourced from statutory guidance as to the standards for the energy performance of new and existing buildings.

The data suggested for use in LAEP analysis has been consolidated into the table below.

Table 16: Heating system efficiencies for LAEP model input

Heating System	Efficiency	Source data used
Domestic Buildings		
Gas boilers	88%	SEDBUK 2009[9] seasonal efficiency for condensing boilers in new dwellings
LPG boilers	80%	SEDBUK 2009[1] seasonal efficiency for non-condensing boilers
Oil boilers	86%	SEDBUK 2009[1] seasonal efficiency for condensing combination boilers
Biomass boilers	70%	Part load, gross efficiency[10]
Electric heating	100%	
Hydrogen boilers	88%	Hydrogen Supply Chain
Heat pumps	-	See discussion below
Non-domestic buildings		
Gas boilers	82%	Existing buildings, seasonal efficiency (gross, actual[11])
LPG boilers	83%	
Oil boilers	84%	
Biomass boilers	75%	Existing buildings, seasonal efficiency (gross, effective[3])
Electric heating	100%	
Hydrogen boilers	91%	Hydrogen Supply Chain
Heat pumps	-	See discussion below

9 Mixture of SEDBUK 2005 and ErP values also given in data source for gas, LPG, and oil boilers. SEDBUK 2009 values used as LAEP inputs for consistency.

10 Seasonal efficiency not given in data source. Part load efficiency used as likely the more common operating mode versus nominal load.

11 Actual refers to the boiler seasonal efficiency, Effective refers to the boiler seasonal efficiency plus applicable efficiency credits. Actual efficiency is not given by data source for biomass boilers, therefore effective used.

For Heat Pumps only

Table 17: Heat pump efficiencies for LAEP model input

Modelling Requirement	HP type	Efficiency	Efficiency Measure	Source data used
Minimum	ASHP	2.44	SPFH4	DECC SPF, source Table 0-2
	GSHP	2.71		
Going further	ASHP	See graphs	COP-temperature curves	BEIS COP, source Figures 12 and 13
	GSHP	See graphs		

Heat pump efficiencies would benefit from different data sources as the regulation only gives a single value under test conditions – which is unlikely to represent a year's temperature profile. There is no further source identified for this without limitations. However, it is considered an important input into a LAEP analysis and so appropriate for standardisation. This section is likely to be updated in the future if better quality data becomes available (e.g., from current electrification of heat trials). The current data sources do not provide different values for non-domestic heat pumps.

The minimum modelling requirement is to model HP efficiencies with a single 'flat' annual efficiency value. For these, Seasonal Performance Factors (SPF) should be used. Specifically, SPFH4 has been identified as the most relevant measure for LAEP use, as it accounts for all electricity input to the heat pump and all heat output. Here, the DECC SPF source is used, which presents efficiency results from in-situ measurements from heat pumps, with data collected from October 2013 to March 2015. For LAEP use, the median estimated SPFH4 values for ASHPs and GSHPs, presented in Table 16 are used.

It should be noted that by using SPF values, the electrical heating demands on the coldest day of the analysis year will be under-represented. Care should be taken to mitigate this effect.

'Going further' beyond the minimum requirements entails using a variable Coefficient of Performance (COP) related to temperature or times of year, to better represent peak demands. Here, the BEIS COP source is used. Only data is provided for fully electric HPs in this source. Therefore, hybrid HPs should use the same COP-temperature curves as for fully electric HPs, until better data is made available. The data was collected in 2016.

For COP versus temperature figures, values are given for various heat pump output temperatures. If models differentiate between these heat pump modes, any may be used. Otherwise, the W55 (water temperature) values could be used, representing the more likely operating mode when an ASHP is installed in an existing building. If there is a factor about the building stock (such as suitability for underfloor heating) that makes the lower temperature W35 value appropriate, then that could be used instead.

For heat pumps installed in the future, future efficiency improvements due to technology advancement by the time of installation may be accounted for, if suitable sources are used; however future improvements should be scaled from the efficiencies presented here (i.e., from 2014 for the DECC SPF data, or 2016 for the BEIS COP data). This means efficiencies from this source may be scaled to represent efficiency values in the model's base year, as well as their improvements to 2050.

Likewise, efficiency uplifts may be used to scale these figures to represent low temperature heat pumps, and non-domestic heat pumps, if suitable sources are used. As with future efficiency improvements, these must however be scaled from the 'baseline' data presented here.

7.4 Example Data Extract

High Temperature Air Source Heat Pump data

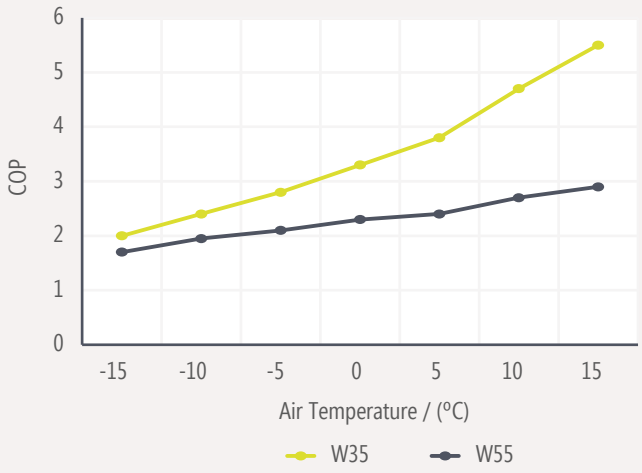

Figure 3: Rated COP versus air temperature for a typical air to water heat pump at different water output temperatures (source Figure 12)

High Temperature Ground Source Heat Pump data

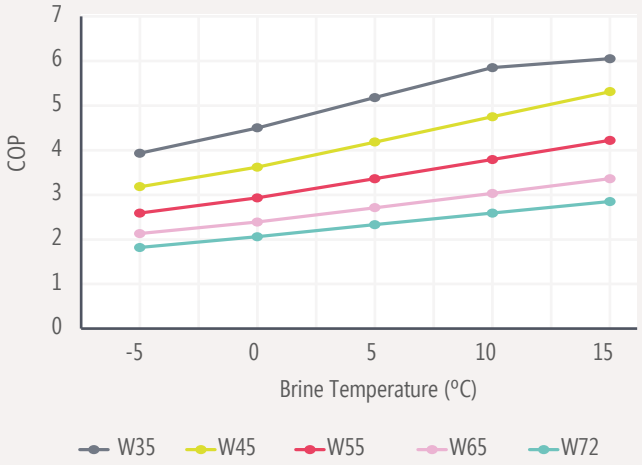

Figure 4: Rated COP versus brine temperature for a typical ground to water heat pump at varying water output temperatures (source Figure 13)



Item 8
Insulation measure costs – Domestic

8.1 Data Source Summary

Data Source Name	BEIS, Domestic cost assumptions - what does it cost to retrofit homes
Data Source Link	https://www.gov.uk/government/publications/domestic-cost-assumptions-what-does-it-cost-to-retrofit-homes
Data Retrieved	10/05/2022
Data Last Updated	09/11/2017
Expected Update Frequency	No updates expected
Data Source Maturity	High

8.2 Rationale for data standardisation

Building energy efficiency improvements arising from insulation retrofits are likely to feature heavily in LAEP decarbonisation pathways. Although individual costs of retrofits will vary widely due to each retrofit's individual complexities, over many dwellings in a given area costs will converge to an average. Average costs are not expected to vary significantly regionally, although labour costs may be higher in certain parts of the country.

8.3 How to use the data

The data source presented here contains installed costs for a range of insulation measures, gathered from surveys and interviews with installers. The table below sets out the measures included in the dataset.

Table 18: Insulation measures included in the source, and notes on their usage in LAEP modelling

Insulation Measure	Notes on data usage in LAEP analysis
Wall Insulation	
Internal Wall Insulation	-
External Wall Insulation	-
Cavity Wall Insulation	-
Party Cavity Wall Insulation	Only two interviewees provided cost data; one in £/m^2, and another gave a flat cost figure for all applicable type and size of dwellings. There is seemingly wide disagreement between both cost values - therefore this is considered unreliable data. Many LAEP analyses may not consider this measure, it is believed to be relatively unusual.
Roof Insulation	
Loft Insulation (Joists)	It is noted that the LAEP analysis is unlikely to know whether joist or rafter insulation is the applicable choice for a particular dwelling. Therefore, cost data for joist or rafter insulation may be used, as long as the loft insulation efficiency improvement calculation is based on the same measure.
Loft Insulation (Rafters)	
Flat Roof Insulation	-
Floor Insulation	
Underfloor Insulation	-
Glazing	
Replacement Double Glazing (panes and frames)	Although the data presented in this source is for replacement double glazing, it is expected that the costs are similar for newly installed double glazing. This data may therefore be used for newly installed double glazing.
Secondary Glazing	-

Cost data is presented in both £/m^2 of insulation, and in fixed (£) for total cost per household. For the fixed (£) figures, costs are given for several different dwelling types and sizes (e.g., small flat <54m^2, large flat >54m^2, small mid-terrace house <76m^2, and so on).

It is important to note that the presented £/m^2 and the fixed (£) for each archetype do not necessarily align; this is due to respondents to the interview providing data in differing formats. The authors of the dataset have not attempted to consolidate the fixed (£) costs into the £/m^2 figures or vice versa, therefore it should not be assumed that they are analogous to one another.

The dataset has sections for each measure that provides extra information, for example, the cost breakdowns provided by each interview respondent are given, alongside the respondent's main target sectors (e.g., private, social, new build, retrofit), and a rough number of projects that contributed to the cost estimates. The number of companies providing costs in £/m^2 form, versus in fixed (£) for different archetypes, is also shown - providing a valuable indication of which of the headline figures may be more reliable. For example, for cavity wall insulation, only one respondent provided data in £/m^2 form, while all others provided fixed (£) values for each archetype. Therefore, the summarised fixed (£) values are likely to be more reliable than the summarised £/m^2 values. Additionally, the authors of the data have included their own reliability rating form 1-5 for each set of respondent data.

As the data is provided in both £/m^2 and fixed (£) form, and since considerable additional background information regarding each respondent's cost estimates is provided, the exact cost data inputs are not standardised; rather those undertaking the analysis are encouraged to consider how the data is best integrated into their methodology, and to process the data accordingly. For example, if costs are modelled on a variable £/m^2 basis, but for a particular measure the fixed (£) values are considered more reliable, then assumptions regarding the fixed (£) may be made to convert these into £/m^2 values. There is likely to be a minimum cost associated with any installation. If £/m^2 values are used care should be taken to ensure that small properties are not assigned unrealistically low costs.

In the headline figures for each measure, Low, Medium, and High values are provided. These are based on the range of costs seen in the interview responses. In general, the medium estimate is likely to be most appropriate when post-processing data, unless as stated above there is reason to discount some respondent data when applying to a model or project.

Future price reductions may be accounted for if a relevant source of data can be referenced. Note that the current prices should still be based on data from the source presented here, and future prices should be scaled from this 'baseline' current price.

Although not explicitly stated for each cost, it is assumed that VAT is excluded from the figures provided. Additionally, while not explicitly stated, it is assumed that the costs represent 2016 prices, since the data was collected over 2015/16 and aimed to provide "current" (to that time) cost estimates.



8.4 Example Data Extract

The tables below show an extract of the data for cavity wall insulation; a cost summary table, and a more detailed breakdown of the costs given by each organisation.

Table 19: Extract of cost summary table for Cavity Wall Insulation

Cost Summary Table		Low	Medium	High	No. of Interviewees (excl. outliers)
No. of homes contributing to cost estimates		Hundreds of thousands in total			9
Cost per m^2 wall area (materials + labour)		£5	£6	£6	1
Cost per house type	Small flat (<54m^2)	£300	£300	£0	6
	Large flat (>54m^2)	£350	£390	£0	6
	Small mid-terrace house (<76m^2)	£0	£410	£0	4
	Large mid-terrace house (>76m^2)	£450	£450	£0	4
	Small semi-detached or end-of-terrace (<80m^2)	£0	£500	£0	5
	Large semi-detached or end terrace (>80m^2)	£0	£640	£0	6
	Small, detached house (<117m^2)	£550	£680	£800	3
	Large, detached house (>117m^2)	£750	£960	£1,200	6
	Bungalow (around 117m^2)	£0	£590	£550-£600	7

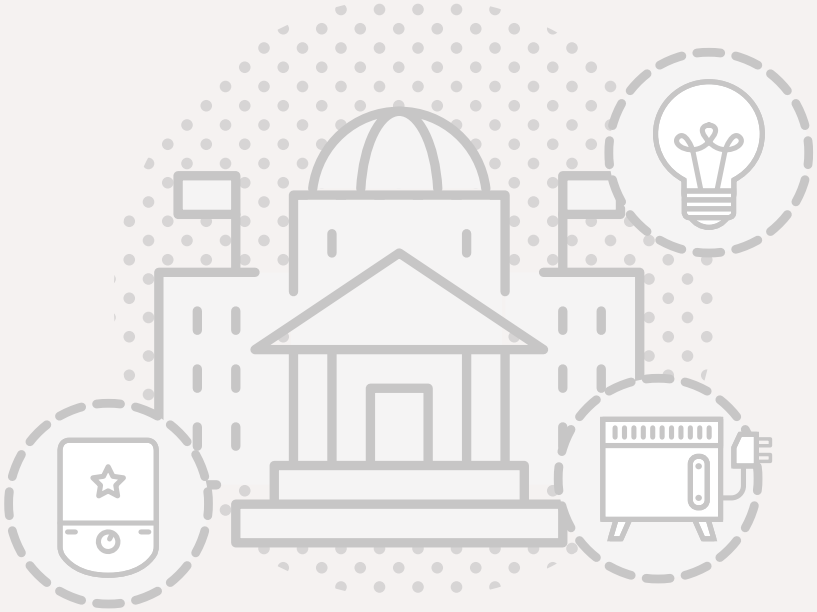

Table 20: Extract of costs by organisation for Cavity Wall Insulation. Note additional information and data from more organisations is included in the data source – this is provided as an example of data given.

Costs by Organisation				
Organisation		1	2	5
Company Size		Large	Smaller	Smaller
Company Specialisms[12]		IWI, EWI, CWI, PWI, R ...	CWI, R Worked in area for over 20 years.	CWI, R, F Boilers
Company main sectors (e.g., social housing, private owned, private rented)		Various	Mainly social, some private. Also commercial.	Private Also new build.
Reliability rating (1-5, with 5 being most reliable)		5	5	4
Total cost (materials + labour) for a specific project		-	-	£500
No. and type of homes in project		100,000s per year in total	-	1 house, 80m^2
Project location		Various	Works in Bristol and nearby area	Based in Suffolk
Cost per m^2 wall area (materials + labour)		£5-£6	-	-
Cost per house type	Small flat (<54m^2)	-	£300	£300
	Large flat (>54m^2)	-	£350-£400	£400-£450
	Small mid-terrace house (<76m^2)	-	£350-£400	£400-£500
	Large mid-terrace house (>76m^2)	-	£450	£400-£500
	Small semi-detached or end-of-terrace (<80m^2)	-	£500	£500
	Large semi-detached or end terrace (>80m^2)	-	£600-£650	£650
	Small, detached house (<117m^2)	-	£750-£800	£550-£600
	Large, detached house (>117m^2)	-	£1,000-£1,200	£750-£800
	Bungalow (around 117m^2)	-	£600	£550-£600

12 The abbreviations "IWI", "EWI" etc. refer to the types of work conducted by the company, e.g., "IWI" refers to Internal Wall Insulation. Refer to the source data's Summary Tables for further information.

Item 9

Insulation measure efficiency improvements

There are numerous ways in which models could account for the impact of insulation retrofits on heating demands (e.g., by applying % reductions on pre-retrofit heating demands, or by separately calculating heating demands with and without insulation measures applied).

Therefore 'Efficiency Improvements' here refers generically to the impact of retrofits on heating demands, rather than to percentage or absolute demand reductions.

9.1 Data Source Summary

Data Source Name	BRE Group – Standard Assessment Procedure
Data Source Link	https://www.bregroup.com/sap/standard-assessment-procedure-sap-2012
Data Retrieved	04/04/2022
Data Last Updated – Latest Version	12/2014 – SAP 2012
Expected Update Frequency	Irregular (Next version, SAP 10.2, expected to be adopted for official purposes June 2022)
Data Source Maturity	High

9.2 Rationale for data standardisation

Building energy efficiency improvements arising from insulation retrofits are likely to feature heavily in LAEP decarbonisation pathways. Efficiency improvements for non-domestic buildings are highly variable due to their wide range of use-cases and construction types, therefore only domestic buildings are discussed here.

Dwelling types and ages vary considerably by region, and the efficiency improvements for a particular retrofit measure also varies by dwelling type and age. For example, the energy savings resulting from a cavity wall retrofit will be much greater for a detached versus a mid-terrace dwelling.

Therefore, in order for models to sufficiently represent local areas, efficiency improvements for each retrofit option must be expressed by archetype, with an archetype being characterised by the dwelling type and age.

9.3 How to use the data

This dataset allows for the calculation of efficiency improvements from a wide range of retrofit measures.

It is noted however that there are alternative approaches that can be used in these calculations. One approach is to use data based on real changes in monitored energy use once retrofit has occurred. These kinds of data source are better for reflecting any performance gap between theoretical and actual performance of measures, but due to small sample sizes they may not give as much granularity on building types.

The recommendation is that any data source used for the calculations of efficiency improvements should **account for the effects of different dwelling types and ages**, so that variations across the area covered by a LAEP can be identified.

9.4 Example Data Extract

The table below shows an extract of the U-value data for different wall types and dwelling age bands from the SAP document.

Table 21: BRE Group, Standard Assessment Procedure (SAP 2012). 2014. Table S6, p.131. Data accessed 04/04/22

	Wall U-values – England and Wales			
	Age band			
Wall Type	**A**	**B**	**C**	**D**
Cavity as built	2.1	1.6	1.6	1.6
Unfilled cavity with 100 mm external or internal insulation	0.35	0.32	0.32	0.32
Filled cavity with 100 mm external or internal insulation	0.22	0.22	0.22	0.22



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Energy Systems Catapult
7th Floor, Cannon House
18 Priory Queensway
Birmingham B4 6BS

Telephone +44 (0)121 203 3700
Email info@es.catapult.org.uk
es.catapult.org.uk

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