Department for Energy Security & Net Zero

Cabinet Office

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CATAPULT Energy Systems

Feasibility and design: Site energy demand estimator user guide

Public Sector Decarbonisation Guidance

Contents

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1. What is this document for?

This document provides a guide on how to use the Site energy demand estimator tool. It can be read in parallel with the tool to help a user input data. Further guidance information has also been included within the tool..

This guide is broken into two sections.

- The first section is on how to use the tool.
- The second is on the methodology behind the use of the tool.

For more information, please email Energy Systems Catapult – PSDecarbGuidance@es.catapult.org.uk

2. What is the purpose of a site energy demand estimator

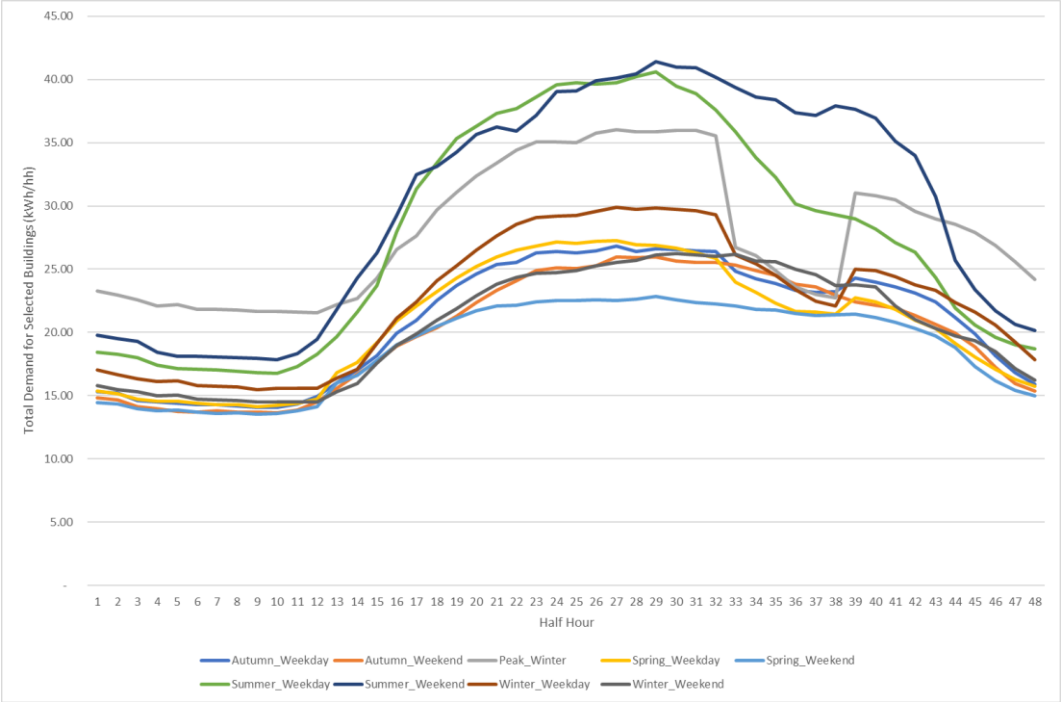
The Site energy demand estimator creates a range of disaggregated building by building energy profiles, based on aggregate information from your site using a set of representative benchmark profiles. This is useful in situations where your site has a single meter for data purposes and you don't have an accurate way of disaggregating consumption across your site.

Once you have a disaggregated building by building view of your energy consumption across the site, it is possible to apply decarbonisation interventions to your site and establish a reference baseline for projected savings.

This tool produces a set of half-hourly demand curves for a whole year for the site. This is achieved by scaling the known benchmarks to match your input aggregate data. Where detailed building data is available, this can be removed from aggregate totals, allowing for the remaining building profiles to be estimated using this tool.

Each export file / output contains modelled estimates of the current energy demands for a particular group of buildings, which might comprise all the buildings on a site, or might only relate to a sub-set of buildings contained within the site, to which the decarbonisation plan will apply.

The figure below illustrates an example output curve for electricity demand broken down by season for a multi-building site. This is the aggregated view, however the estimator will provide a curve per building on your site as required, as well as the total and peak annual demand in kWh. This will be broken down into electricity and heating fuel.



3. How to use the site energy demand estimator

The tool is used in three simple steps as shown below:

1. Add in the data ointo the “Building Energy” tab;
2. Click to run “Update Model” macro, this will start the scaling and calibration of the data;
3. Click on the “Export Demand Data” macro to generate the desired profiles for further use.

Note:

The Site energy demand estimator spreadsheet resource is complex and takes some time to solve given the large amount of data it contains. This can cause complications and can result in Excel slowing or in some cases temporarily crashing.

Please note it also requires macros to be enable in order to work correctly. If you have any issues with this, please get in touch via email.

To ensure work is not lost, it is advised that:

- The calculation method is set to ‘Manual’ (which it has been by default); and
- The workbook is saved after every step is completed.

Step 1: Building energy worksheet

First step is to enter the requested data in the ‘Building Energy’ tab in phases, remembering to save the model at each step. It is often possible to group buildings in the spreadsheet rather than include a line item for every individual building on a site. This is normally a good approach when individual building data is not available. It means that energy demand outputs can benefit from the averaging process and

avoids false confidence in the precision of the outputs. Buildings should be grouped based on their Use Category and Current Heating System type whenever possible and appropriate. For example, all office buildings on a site with individual gas boilers could be represented as a single line item.

The following steps are encouraged:

1. Enter building numbers, plan area, perimeter, storeys and names for each building to be modelled. A maximum of 30 buildings can be modelled (represented by the salmon pink coloured area). The column Floor Area (column O) is set to calculate based on Plan Area and Storeys. When actual floor areas are known this calculation can be overwritten with those values (this will replace the formula).
    a. If there are insufficient rows of calculations, please get in touch via the contact details on the cover of the spreadsheet. Or email Energy Systems Catapult – PSDecarbGuidance@es.catapult.org.uk
    b. Note that as a minimum for this tool to work you must enter a unique numeric value in the Building Number column and the gross internal area in column O.
2. Define the current Use Category using the drop down for each building row. This must be a best fit for the building.
    a. If clearly defined areas within a building have different use category, enter as separate line entry and adjust area accordingly.
3. Define the Current Heating System for each building row using the dropdown for each building.
    a. As with use category, enter separate lines for areas within a building that have separate heating systems.
4. Enter any known annual energy consumption values for each building under the ‘Existing Heating System’ columns as required. If annual energy consumption is known for the site, then enter this in the appropriate cell, above that for individual buildings. Both individual row and site annual demands can be entered and the scaling process will work correctly.
5. If known, overwrite the Floor Area Adjusted value for your buildings (column O). This would be the gross internal area (GIA) and should only be used if the information is available, otherwise it will be estimated based on the already provided plan area and number of storeys.

The following example shows for a range of different buildings the input data required for the tool to function. In these examples there are some where metered energy consumption has been added and others where the site total consumption is the only known data.

SITE ENERGY DEMAND ESTIMATOR

This model uses macros accessed using the buttons below, which may take some time to run. The Export Demand Data macro will also create a new excel file once complete.

Update Model — *Press to update once all known data has been entered*

Export Demand Data — *Press to prepare and export half-hourly load profiles for all buildings*

Input values where known
(in aggregate above headings, or by building below)

Current building heat systems, details and energy usage

							400,000	400,000	320,000	
Building Data Input							**Existing Site Energy Demand**			
Building Number	Plan Area (m^2)	Perimeter (m)	Storeys	Name	Use Category (select from drop down list)	Current Heating System (select from drop down list)	Annual Electricity Demand (kWh)	Annual Gas Demand (kWh)	Annual Biomass Demand (kWh)	Annual Heat Network Demand (kWh)
1	1,000	25	3	Example building 1 - non-metered	Office	GAS_WETBOILER_EXISTING				
2	1,000	40	2	Example Building 2 - non-metered	Restaurants & takeaways	BIOMASSBOILER_EXISTING				
3	1,000	40	1	Example Building 3 - non-metered	Small shops	ASHP_EXISTING				
4	1,000	50	2	Example Building 4 - metered	Retail warehouse	HEAT_NETWORK	75,000			240,000

Heating Fuel (consumed on site)	Floor Area Adjusted (m^2)
Gas	3,000
Biomass	2,000
Electricity	1,000
Heat Network	2,000
	-
	-
	-
	-
	-
	-
	-
	-
	-
	-
	-

The table below provides an explanation of the inputs required and the terminology used. It also indicates whether the cell is for user input or can be overwritten by the user if a value is known.

Sheet / Cell	Description	User Input
B	Building Number - from site map or site reference [this is essential for the model to work and needs to be a unique identifier for each building]	X
C	Plan Area from site map (from OS or other mapping) [if gross internal area is known, this field can be left blank]	X
D	Perimeter from site map (from OS or other mapping) [if gross internal area is known, this field can be left blank]	X
E	Storeys from site survey [if gross internal area is known, this field can be left blank]	X
F	Building name - site information	X
G	Use Category - from site survey, categories based on BEES – drop-down of options	X
H	Current Heating System – drop-down of options	X
I10	Annual Electricity Demand: Site Annual electricity demand by building in kWh (User input) All electricity should be captured, including any used for heating Provision for site wide electricity consumption should	X

	be captured if required Energy centre should be separately identified if applicable (i.e. GSHP, ASHP)	
J10	Annual Gas Demand: Site gas demand for all buildings in kWh (User input) Energy centre should be separately identified if applicable (gas fuelled)	X
K10	Annual Biomass Demand: Site Annual biomass demand for all buildings in kWh (User input) Energy centre should be separately identified if applicable (biomass fuelled)	X
L10	Annual Heat Network Demand: Site heat network demand for all buildings in kWh (User input) For sites with an energy centre supplying the heat network, the energy centre should be captured separately, with provision for any network losses For sites being supplied by an external heat network, this indicates the total imported energy into buildings	X
I	Site Annual electricity demand by building in kWh (User input) – if known	X
J	Site Annual gas demand by building in kWh (User input) – if known	X
K	Site Annual biomass demand by building in kWh (User input) – if known	X
L	Site Annual heat network demand by building in kWh	X

	(User input) – if known	
N	Heating Fuel (on site) - look up based on current heating system selected	
O	Floor Area Adjusted - calculated from plan area and number of storeys or manually input if the building gross internal area is known	Overwrite possible
P10:S10	Sum of values in columns below	
P	Scaled annual electricity Demand - look up from Electricity Demand Curves tab based on current heating system	
Q	Scaled annual gas demand - look up from Gas Demand Curves tab based on current heating system.	
R	Scaled annual Biomass Demand - look up from Biomass Demand Curves tab based on current heating system	
S	Scaled annual heat network demand - look up from Heat Network Demand Curves tab based on current heating system	
U	Estimated direct CO_2 emissions - heat and electricity combined	

Step 2: Update Model

Once the correct building data has been entered, the next step is to:

- Run the macro 'Update Model' by clicking on the button at the top left of the Building Energy tab.
    - This will calculate the spreadsheet, which can be verified by reviewing the calculated values in columns P:S
    - It is advised that you save the spreadsheet after this step

This macro will carry out a series of steps to set and calibrate the scalars that are used to adjust the input data to the benchmarks for the given use cases selected. In the first instance the macro re-sets the scalars to unity to overwrite any previously entered information/scaling. Once this reset has been done, the macro will calibrate the benchmarks against the input consumption data in order to correctly scale the output. This is done for every use case and heating type selected, hence it takes some time to run.

Step 3: Export Demand Data

The 'Export Demand Data' button on the 'Building Energy' tab will export data from the model and produce a set of half-hourly demand curves for a whole year for the site. Note that this will open a new Excel workbook which should then be saved by the user as required.

The structure of the export sheet is standardised and will be presented as per the below table:

Sheet Name	Sheet Description
Building Details	Information on the buildings as modelled – names, floor areas, perimeters, and current heating systems
Electricity Demand Curves	Electricity demand profiles with breakdown by building and use category
Gas Demand Curves	Gas demand profiles with breakdown by building and use category (if applicable)
Biomass Demand Curves	Biomass demand profiles with breakdown by building use category (if applicable)
Heat Network Demand Curves	Heat network demand profiles with breakdown by building and use category (if applicable)

Note:

- For Gas and Biomass, the estimated energy demand curves created for each building detail the heating load met from gas or biomass consumed on site.
- For Electricity, the estimated energy demand curves created for each

building include all electrical load, inclusive of the specified heating system.

- For Heat Networks, the estimated energy demand curves created for each building indicate the heat provided to each building through the heat network, excluding any losses that be incurred through the heat network distribution system.

By default, Heat Networks are assumed to be supplied from connection to an external offsite heat network. For sites with a plant room supplying an internal heat network, a heating plant room should be included, with relevant fuel source identified .

Demand curve worksheets

The top of all the demand curve worksheets contains the same information, namely the aggregate demand estimates for all the buildings listed and selected on the sheet.

The buildings included in these demand estimates can be set using column B. To include a building in the aggregate demand put the value “1” in the appropriate row of column B.

The following table provides a description of the cells in the top row of the tabs.

Spreadsheet Area	Description
D1	Annual demand (kWh) for all buildings listed on sheet
E1	Peak demand (kW) for all buildings listed on sheet
F1:BA1	Modelled half hourly demand for all buildings selected for an autumn week day
BB1:CW1	Modelled half hourly demand for all buildings selected for an autumn weekend day
CX1:ES1	Modelled half hourly demand for all buildings selected for a peak winter day
ET1:GO1	Modelled half hourly demand for all buildings selected for a spring week day

GP1:IK1	Modelled half hourly demand for all buildings selected for a spring weekend day
IL1:KG1	Modelled half hourly demand for all buildings selected for a summer week day
KH1:MC1	Modelled half hourly demand for all buildings selected for a summer weekend day
MD1:NY1	Modelled half hourly demand for all buildings selected for a winter week day
NZ1:PU1	Modelled half hourly demand for all buildings selected for a winter weekend day

Rows 5 to 34 contain demand estimates for individual buildings.

Spreadsheet Area	Description
Column A	Building reference number – from site plan
Column B	Calculate in total flag (set to 1 by default to include in totals on row 1)
Column C	Building Use Category
Column D	Annual demand (kWh) for this building
Column E	Peak demand (kW) for this building
Columns F:BA	Modelled half hourly demand for this building for an autumn week day
Columns BB:CW	Modelled half hourly demand for this building for an autumn weekend day
Columns CX:ES	Modelled half hourly demand for this building for a peak winter day
Columns ET:GO	Modelled half hourly demand for this building for a spring week day

Columns GP:IK	Modelled half hourly demand for this building for a spring weekend day
Columns IL:KG	Modelled half hourly demand for this building for a summer week day
Columns KH:MC	Modelled half hourly demand for this building for a summer weekend day
Columns MD:NY	Modelled half hourly demand for this building for a winter week day
Columns NZ:PU	Modelled half hourly demand for this building for a winter weekend day

4. Methodology

Understanding energy consumption data

A vital step in developing pathways to decarbonise complex sites is having a good understanding of the energy consumption. The understanding ought to be not just at site level but across the campus and be understood for different plant, building types and activities that are undertaken.

Gaining an understanding of the current energy consumption of those sites based on energy data is not always possible. Often energy data is only available for fiscal meters at entry point to the site.

They will be able to give energy data for the whole site often in half hourly intervals but if a site is large and complex this may not indicate what is going on at a plant, building or activity level.

In those instances where the information is not available on a more granular level than site data (or potentially only available through manually read meters), developing appropriate energy demand profiles, based on assumptions or benchmarks, is helpful. It helps as it provides a designer or engineer who is doing the assessment of a site with an understanding of what the energy use profile looks like over a 24-hour period, as well as what the max peak loads might be for particular plant.

This needs to be at a sufficient level of detail so that alternative low carbon technologies can be properly assessed in relation to each other and incumbent systems. Ideally this will include individual natural gas (or other heating fuel) breakdowns and electricity consumption for each building on the site at half-hourly time intervals for an entire year which can be obtained from site wide sub-metering.

Achieving this level of detail enables:

1. Correct assessment of the influence of different technology options on future site energy demands.
2. Aggregation of different groups of buildings on a site to allow

assessment of different solutions for different parts of the site.

3. Correct sizing of heat solution options through detailed understanding of the maximum power output required.
4. Correct understanding of the cost and efficiency of options as a result of correct understanding of the capacity required.
5. Assessment of incremental changes to a site's energy system that relate to
    a. Achievable build or deployment rates
    b. Alignment of introduction of low carbon technologies with asset replacement schedules.

However, in reality this level of detailed data is often not the case and assumptions or benchmarks need to be used to create representative demand profiles. The data required to produce detailed half-hourly energy demand profiles from sub-metering for each building on a site will often not be available due to cost or installation restrictions or may take time to be collected.

Energy consumption data considerations

As the quantity of data available increases, confidence that site energy consumption has been correctly understood also increases, as the does the quality of the outputs (decarbonisation plans, feasibility studies, detailed designs) based on them.

Data is most useful if at least one full year of information is available. Ideally there will be three consecutive years of data to allow typical variations in consumption to account for changes in things like external temperature. This is particularly true for annual demands. If monthly or half-hourly data is available, then it is possible to get an indication of how consumption changes with the seasons provided at least one month of data is available for each season.

In many cases different data might be available for different parts of a site. Examples include:

- Half-hourly electricity demand data available from a single meter for the whole site.
- Half-hourly gas demand data available for some buildings on a site with annual or monthly demand data available for the remaining buildings.
- Annual or monthly gas demand data available at site level.
- Annual or monthly demand data for other fuels (e.g., coal, LPG, heating oil)

available at site level or for a particular area on a site which is not served by the gas network.

The exact mix of energy consumption data will be unique to each site and an appropriate approach will need to be developed to make the best use of it.

In general terms the following approaches are recommended:

- When data applies to several buildings the demand for each building should be estimated based on the internal floor areas of the different buildings. This can be adjusted using appropriate energy benchmarks relating to the different use categories of the different buildings connected to the meter if possible.
- When half-hourly data is not available then standard half-hourly demand benchmarks should be used to produce appropriate demand profiles as detailed in this document.
- Site demand profiles for non-gas fossil fuels should be based on standard half-hourly demand benchmarks unless sub-meter data is available which provides this granularity.

Methodology and structure

The data in the Site energy demand estimator and contained in the export spreadsheet is primarily derived from data from previous ESC projects as well as the Building Energy Efficiency Survey (BEES) conducted by the Department for Business, Energy and Industrial Strategy (BEIS) (now the Department for Energy Security and Net Zero).

This data was used to define the set of building use categories and annual energy demands. In some cases this was supplemented by data from the Energy Performance of Buildings Directive Assessment (EPBD) published by BEIS (now DESNZ) in 2019.

The following sections give further details of the approach adopted.

Energy Benchmarks

For each building use category, the median annual energy demand (in kWh/ m2 of floor area) was obtained from ESC site data, supplement by BEES and EPBD where appropriate. This was for both fossil fuels and electricity.

Existing energy demand profiles

For each building use category half-hourly demand profiles for both gas and electricity were obtained from previous ESC work or from Carbon Culture for a whole years' worth of energy consumption.

Half-hourly data is available across a wide variety of building types and uses allowing typical demand profiles for different building uses to be established. The half-hourly demand profiles were divided by date into different characteristic days and the average demand profile for each characteristic day was calculated. These were then scaled such that the annual demand matched the appropriate energy benchmark. These demands are the total for the building (i.e., gas demand is for heating and hot water, electricity demand is for all uses of electricity combined).

Different characteristic days represent the following proportions of annual demand as shown in the following table.

Characteristic Day	Proportion of annual demand
Autumn Weekday	0.1786
Autumn Weekend	0.0714
Peak Winter	0.00096
Spring Weekday	0.1786
Spring Weekend	0.0714
Summer Weekday	0.1786
Summer Weekend	0.0714
Winter Weekday	0.1776

[3] https://www.gov.uk/government/publications/energy-performance-of-buildings-directive-second-cost-optimal-assessment

[4] https://platform.carbonculture.net/landing/

To get the total annual demand the total for each day must be multiplied by (365 x the appropriate proportion value) and then all-day totals must be summed.

Spreadsheet structure

The spreadsheet contains a single calculation sheet which provides estimates of the energy demand for a particular group of buildings based on their input configuration. For clarity and consistency, the tabs and cells within this spreadsheet are coloured as follows:

Sheet Colour in Model	Sheet Type
	Cover / User notes
	Input Sheet
	Benchmark data

Cell Colour in Model	Cell Type
	Input Cell
	Calculations Cell

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