Programme Area: Distributed Energy

Project: Macro DE

Title: Executive Summary - DE2002 / WP2.3: Energy Demand Analysis in GB

Abstract:

The objective of the Distributed Energy (DE) Programme is to increase the uptake of DE through the development of integrated systems in order to reduce through-life costs, improve ease of installation and increase efficiency in the combined generation of heat and electricity. Within this programme framework the objective of the Macro DE FRP will develop and validate a software methodology to enable the design of optimised DE solutions where clusters of demand sites are linked with appropriate DE supply equipment. The project will quantify the opportunity for Macro level DE (up to 50MW) in GB and the potential to accelerate the development of appropriate technology by 2020 for the purposes of significant implementation by 2030

Context:

This project quantified the opportunity for Macro level Distributed Energy (DE) across the UK and accelerate the development of appropriate technology by 2020 for the purposes of significant implementation by 2030. The project studied energy demand such as residential accommodation, local services, hospitals, business parks and equipment, and is developing a software methodology to analyse local combinations of sites and technologies. This enabled the design of optimised distributed energy delivery solutions for these areas. The project identified a number of larger scale technology development and demonstration projects for the ETI to consider developing. The findings from this project is now being distilled into our Smart Systems and Heat programme. The ETI acknowledges that the project was undertaken and reports produced by Caterpillar, EDF, and the University of Manchester.

ETI Executive Summary

Programme: Distributed Energy

Project Name: Macro DE

Deliverable: DE2002 / WP2.3: Energy Demand Analysis in GB

Introduction

The objective of the Distributed Energy (DE) Programme is to increase the up-take of DE through the development of integrated systems in order to reduce through-life costs, improve ease of installation and increase efficiency in the combined generation of heat and electricity. Within this programme framework the objective of the Macro DE FRP will develop and validate a software methodology to enable the design of optimised DE solutions where clusters of demand sites are linked with appropriate DE supply equipment. The project will quantify the opportunity for Macro level DE (up to 50MW) in GB and the potential to accelerate the development of appropriate technology by 2020 for the purposes of significant implementation by 2030

As such the key outcomes from the project are:

- Evaluation of the potential benefits of system aggregation and optimisation techniques
- Characterisation of energy demand and supply profiles for typical UK site types (typically 100 kWe – 10 MWe)
- Development of software methodology which analyses and integrates combinations of sites to enable optimised DE solutions
- Benefits case for the development of such an approach
- Identification of the deployment and CO2 reduction opportunity for macro DE systems

The project is split into 5 work packages

Work Package 1: DE Design Characterisation

Define clearly the current industry practices and tools used in the identification, development, design, implementation and operation of DE schemes. This will form the baseline to compare the proposed aggregation and optimisation tool to determine the benefits in later work packages.

Work Package 2: Site and Zone Energy Demand Characterisation

The objective of Work Package 2 is to generate DE Zones of similar thermal demand across the UK. The first task (2.0) will assess the various data sets available, define the methodology to generate energy demand profiles for characteristic DE zones, and provide an estimate on the level of confidence on the results produced in WP2. The second task (2.1) will assess and map the current energy demand, and develop of 10 to 20 representative DE Zone types with typical aggregated temporal energy demand. The third task (2.2) will assess and characterise the current thermal waste recoverable from manufacturing industries within the UK.

Work Package 3: DE Supply Equipment

This Work Package will characterise DE equipment, based on specifically defined criteria, within the DE technology value chain, for inclusion into WP4's new pre-prototype tool library. Additionally, potential technology development options will be identified that could significantly improve the performance of DE solutions.

Work Package 4: Tool Development Methodology

Work Package 4 (WP4) will outline a methodology for the development of a software tool to identify optimal DE solutions to satisfy the aggregated electrical, heating and cooling demands for each characteristic zone. The cost of implementing and operating the DE solution and the resulting CO2 emissions will be estimated for each characteristic zone.

Work Package 5: Benefits Case

Work Package 5 will summarise the benefits of the DE Zone approach to aggregate energy demand and supply for optimising DE solutions. The results of the DE zone aggregation and optimisation approach will be compared using business as usual baseline performance.

This report is the final report in work package 2 and provides a summary of the work undertaken in the following areas:

- Calculation of the temporal thermal and electrical energy demand for the residential and tertiary sectors in Great Britain
- A study of the potential use of excess heat generates by GB industry.

Output (1) builds heavily on prior work in deliverable D2.0 which developed a methodology for the calculation of energy demand. This methodology provides a means for estimating residential and tertiary energy demand at an MLSOA level. An MLSOA is a Middle Layer Super Output Area, they are defined by the UK government and are part of a geographical hierarchy that covers England and Wales. Each MLSOA has a minimum population of 5,000, or around 2,000 households. MLSOAs do not align to postcodes or to electoral wards. There are 8429 MLSOAs in England and Wales.

The approach undertaken to the calculation of temporal and electrical energy demand for Great Britain relies on the aggregation of demand across a number of MLSOAs (typically 5) to create a zone of demand. Taking this approach across the entire country around 1,000 different zones of demand. These zones can then be clustered into classes of demand, from these classes a single zone can be selected to characterise that class and subsequently be used in distributed energy system design and calculation of potential benefits for the UK.

The conclusion of the work the following outcomes:

1) The total demand for heat and electricity across residential and tertiary sectors in GB was calculated at
    a. Heat 458,392GWh per year
    b. Electricity 198,747GWh per year
2) Of this demand nearly 50% has been assessed as being viable for district heating, accounting for 4660 MLSOAs out of 8429.
3) 948 zones of demand were created from the above 4660, these account for around 4% of the GB land area.
4) This implies that macro-scale district heating is viable only in areas of high residential and tertiary energy demand.
5) Through the classification process 20 characteristic zones of demand were identified, with considerable focus applied to ensure that these zones were distinct to one another, and possessed homogeneity within each class
6) The 20 characteristic zones of demand were used for the basis of further analysis within the pre-prototype tool developed in work package 4 and also in the benefits case analysis carried out in work package 5.

Basis of Designs

This report summarises the process for creating the 946 zones of demand across GB which were subsequently turned into 20 characteristic zones of demand. There are 5 tasks associated with this process

1) Calculation of the energy demand of all 8429 MLSOAs
2) Creation of DE zones (clustering)
3) Calculation of load curves and time bands for all DE zones (Temporal Demand Calculation)
4) Grouping of the DE zones into 20 classes (Classification)
5) Verification of results
    a. Distinctiveness between classes
    b. Homogeneity of zones within each class

In addition a study into the quantity of waste heat in GB was conducted.

The following sections provide a brief summary of the processes involved in each of the above steps. Extensive detail is presented in the actual report, references to the report are provided to extensive plagiarism, the subject is complex and the process should be described in full to avoid and detail being missed.

Energy Demand Calculation

Summary: pp3 of deliverable D2.3

Detail: pp44 of the deliverable

This section builds on the D2.0 processes for estimating demand at and MLSOA level. In this report the quality of underpinning data associated with residential energy demand is improved through use of GB wide housing stock data proprietary to EDF and weather adjusted benchmarks (using a formula specified in CIBSIE's TM46 guideline). Residential electricity demand is extracted from DECC energy consumption data for standard and economy tariffs.

The outcome of this piece of work is that the total residential and tertiary thermal energy demand in GB was estimated at 458,392 GWh / year. The total electricity demand in the GB was estimated at 198,747 GWh / year, where residential electricity demand is about 115,908 GWh.

Clustering

Summary: pp8 of deliverable D2.3

Detail: pp66 of the deliverable

The clustering approach aims to identify regions in GB where a district heating network (DHN) supplied by a distributed energy system could be economically and environmentally viable. The economic viability in this context is defined by two factors:

- The heat density
- The total heat demand.

The environmental effects will be addressed in the GB benefits case in work package 5.1 together with the economic effects .The clustering algorithm is based on middle layer super output area (MLSOA) level.

The outcome of this piece of work is that 946 zones of demand were identified across GB, of which 11 were above the maximum heat demand specified for an individual zones of 500GWh. These 11 zones were single MLSOAs classed as outliers (see appendix J of the report).

The zones identified cover more than half of the MLSOAs in GB and account for around 4% of the total land area. The conclusion which can be drawn from this is that district heating on a macro scale is only viable in cities and larger locations. To analyse opportunities and give recommendations for smaller settlements and towns then data points need to be smaller than MLSOAs.

Temporal Demand Calculation

Summary: pp10 of deliverable D2.3

Detail: pp79 of the deliverable

To estimate the size of the heat supply centre and to optimise its runtime schedule the temporal energy demands (heat and electric) aggregated for DE zones have been calculated. These load curves represent the total annual demand split up into 8760 hourly values. The load curves get simplified into 40 characteristic values which comprise the peak and 39 values to describe a typical week in three seasons (i.e. 13 values for each week in each season).

The process of determining these time bands contains five steps:

1) Calculation of the annual energy demand per house type and per CIBSIE TM46 Tertiary building type for each DE zone. This is similar to the energy demand calculation described above, however the tertiary demand is constrained to the 29 separate values in CIBSE &M46.
2) Creation of annual demand profiles (heat and electricity)
3) Mapping of demand types to profile types
4) Calculation of zonal temporal energy demand curves (heat and electricity)
5) Calculation of time bands and characteristic hourly energy demand values

Classification

Summary: pp13 of deliverable D2.3

Detail: pp87 of the deliverable

The objective of the classification process is to cluster the zones of demand into a number of classes from which a characteristic zone of demand can be extracted. The ensuing characteristic zones are used for analysis by the tool created in work package 4 and also in the creation of the benefits case work in WP5.

Two methods of statistical analysis are used for the clustering process:

1) K-means algorithm
2) Ward's method

Extensive details of each approach and their respective application to the clustering process are provided in the deliverable.

A key step in the classification process was the selection of 5 key parameters used to determine the distinctiveness between classes and homogeneity within classes, these are:

- heat demand in the tertiary sector (kWh)
- Total heat demand (the sum of domestic and tertiary heat demand) (kWh)
- The density of total heat demand (total heat demand per hectare) (kWh per hectare)
- The ratio of annual base and peak heat demand – B/P (dimensionless or kWh/kWh)
- The Load Factor, calculated as the total heat demand divided by the product of 8760 and the annual peak heat demand (dimensionless or kWh/kWh)

The outcome of this process is to create 20 classes of demand from the 946 zones created as part of the clustering process. From each class the zone closest to the class centroid was identified as the characteristic zone for that class. In addition to the characteristic zone, a further 4 zones from each class was selected to verify the homogeneity within the class. In simple terms the smaller the difference between these zones means the more homogeneous and compact the class. This in turn means that the characteristic zone represents its class in a good way.

Verification of Results

Summary: pp22 of deliverable D2.3

Detail: pp137 of the deliverable

The verification of results involves checking the homogeneity of zones within a class and the distinctiveness of classes from one another. This was achieved by using the Macro DE design tool developed in work package 4 of the project. The design tool generates the design for ran optimised energy centre and estimates the costs and performance of such DE solutions. For each class the characteristic zone and the 4 other zones selected were applied to the tool. The performance results indicate that the characteristics of the classes (across annualised capital cost, total annualised cost of the DE centre, the district heating network and the overall DE solution and CO_2 emissions from fuel consumed by the DE centre) vary across a wide range, supporting the proposal that the classes are distinct.

Assessment of Industrial Waste Heat and its Potential for District Heating

Summary: pp23 of deliverable D2.3

Detail: pp159 of the deliverable

The calculation of waste heat from industry was carried out in 4 steps:

Step 1: Determination of energy consumption per industrial site

Since, there are no public data of energy consumption per industrial site, a procedure based on the use of site specific data contained in the EU ETS National Allocation Plan, which provide annual CO2 emissions per committed industrial site, was adopted.

- Step 2: Determination of waste heat ratios

The work determines for each industrial sector the ratio of waste heat to input fuel energy, in other words, the fraction of the primary energy consumed by a site that is lost from the site as waste heat. It is based on previous analysis made by University of Bath, complemented by EDF R&D feedback from audits. When several different industrial processes exist within a given sector (i.e. blast furnace or basic oxygen furnace for the iron and steel sector) several ratios can be provided. The ratios are expressed with “lower” and “upper” bands, to take into account the large discrepancy between industrial sites.

- Step 3: Determination of waste heat potential per industrial site

Application of waste heat ratio (determined in step 2) to energy consumption (determined in step 1) provides the waste heat potential per industrial sector (UK□SIC codes).

- Step 4: Visualisation

The locations of each industrial site with a potential for usable waste heat (and their sector reference) have been marked on a UK map.

Results summary and Key findings

Work Package 2 of the ETI Macro DE project investigates the energy demand of all MLSOAs in GB, creates macro scale DE zones of up to 500 GWh where district heating is viable and clusters them into 20 classes. These classes have been tested for their homogeneity within a class and the heterogeneity between classes. Additionally, the temporal demand for the residential and tertiary sectors is calculated and a study about the potential of waste heat in GB conducted.

The total GB demand has been calculated for the residential and the tertiary sector, both electrical and heat demand. Indicators data, benchmarks and profiles have been collected on different levels, down to postcodes, to ensure the requested granularity. It can be concluded that the knowledge about the tertiary sector is lower than the residential sector. The reasons for this could be the diversity of the tertiary sectors, the lower heat demand, but most likely the fact that historically the tertiary sector has been of less interest. In conclusion, the total calculated GB heat demand of these two sectors is 458,392 GWh per year and the total electrical demand 198,747 GWh per year.

Of this demand nearly 50 % has been assessed as viable for district heating. These 4660 MLSOAs out of 8429 have been clustered into 948 DE zones. Although more than 50 % of the MLSOAs are included within the DE zones, they cover only about 4 % of the area of GB, which leads to the conclusion that macro scale district heating can only be established in areas of high residential and tertiary energy demand, thus cities or other densely populated areas. A limitation of this study has been the size of MLSOAs, especially in rural areas where a lot green space such as forests or fields are included in the MLSOA area. For these MLSOAs a further study, e.g. on the base of LLSOA or even smaller is recommended.

During the classification process the 948 created DE zones have been grouped into 20 classes. Out of each class, one DE zones has been chosen as representative for all DE zones of this class. These 20 Characteristic Zones will be used for further analysis within the ETI Macro DE project. The Characteristic Zones have to be analysed independently of their actual locations, because they are typical for their class in terms of energy demand, but not in terms of area or region.

The 20 classes have been tested on their distinction between each other and the homogeneity within each class. The first task – the distinction – can be shown by the difference of annual heat demands, energy densities or further parameters.

The second part of work package 2 was a study about the availability of waste heat in GB. It was shown that industrial sites can be an additional heat source for DE zones as the heat is already produced and is currently being lost. There is the need for further analysis to assess the temporal availability of the waste heat source and how surplus heat can be damped, but this should be done on a site by site basis.

Further work

The outputs from work package 2 form a key building block for the remainder of the project, in particular the creation of a benefits case for macro scale DE in GB and identification of potential technology development opportunities which would facilitate the up-take of macro scale DE in the UK. This work will be addressed across the 2 of the 3 deliverables in work package 5, namely:

D5.1 GB Benefits Case report

D5.3 Assessment of Technology Development Opportunities

These deliverables are complemented by a third, D5.4 Project Summary Report.

References

Extensive references are included within the deliverable.