Programme Area: Distributed Energy

Project: Macro DE

Title: Executive Summary - DE2002 / WP5.1: GB Benefits Case for Macro DE

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 / WP5.1: GB Benefits Case for Macro DE

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.

Work package 5 is split into 3 deliverables:

- D5.1: GB Benefits Case
- D5.3: Technology Development Opportunities
- D5.4: Project Summary Report

Basis of Designs

The assessment of the potential for DE across GB follows a staged process. It makes use of the 20 Characteristic Zones (CZs) which have been identified in work package 2 of this project as representative of areas potentially suitable for macro DE.

A macro DE scheme is optimised for each CZ made up of a District Heating Network (DHN) and energy centre. The optimisation produces the lowest ‘levelised heat cost’ solution for the CZ. These results are then aggregated to a GB level by multiplying up to all zones within each class represented by a CZ. By comparing the macro DE heat costs with counterfactual costs from air source heat pumps (ASHPs) and gas boilers, an assessment can be made on where macro DE offers a more economic solution. Different GB uptakes can then be assessed based on zones where macro DE is economic, a net economic case (with some economic zones cross subsidising some un-economic zones), and a maximum CO2 reduction case (where the macro DE costs are not considered).

The modelling in work package 5.1 is based around twelve assessment scenarios. These scenarios are used to define the input assumptions used in the optimisation model, and allow the assessment of sensitivities which may impact the potential for DE across GB.

The central scenario (scenario 7) is termed the "base case" and contains the central set of assumptions around which the other scenarios are constructed. The base case assumes that schemes are commenced in the 2020s, representing a period of mass deployment of DE. The economic assumptions include an 8% discount rate, central capital cost assumptions, central energy prices, and the inclusion of CO2 pricing. A market penetration of 80% is assumed meaning that 80% of the potential customers in a zone connect to the DE scheme.

Sensitivities examined in the other scenarios include:

- 2010 (scenario 1) and 2030 (scenario 12) deployment of schemes.
- A 3.5% discount rate (scenario 2).
- 100% market penetration (scenario 3)
- Plus and minus 20% changes to capital expenditure of the DHN and energy centre prime mover (scenarios 4, 5, 9, 10).
- No carbon price included (scenario 11).
- Low and high energy prices projections (scenarios 6 and 8).

The scenarios are illustrated schematically in figure1:

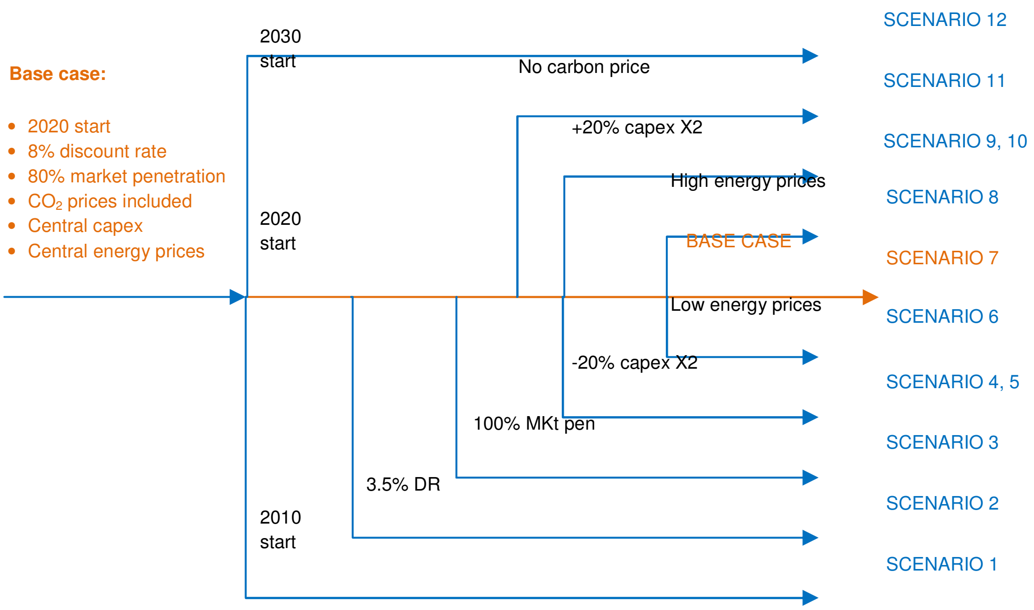

Figure 1: Schematic of the scenarios. Sensitivities are indicated around the base case

Results summary and Key findings

There is a very large potential for macro DE using gas fired CHP in the 2010s and 2020s.

This report demonstrates that up to 43% of the GB heat market, consisting of 12.4 million homes and 2.9 million non-domestic connections could be economic for macro DE schemes using gas engine CHP. This is predicted under the central conditions of an 8% discount rate, 80% market penetration, and central energy price projections. This provides a large economic benefit to customers with a saving of £5.6 billion in heat cost against a gas boiler counterfactual (equivalent to a 29% reduction in cost) and £15.4 billion saving against an ASHP counterfactual (equivalent to a 53% reduction in cost) in the 2010s. Large CO2 reductions are also achievable of 38% of the current emissions associated with heating buildings. The cost and carbon savings available from macro DE schemes are largest in the 2010 scenario suggesting that GB should be investing and installing macro DE schemes as soon as possible. This will provide the largest annual benefits, but also the largest cumulative benefits over the lifetime of the schemes. This is particularly important in the context of climate change where a reduction in cumulative emissions (i.e. early savings) is more important than annual savings (i.e. late savings).

The macro DE schemes are predicted to save circa 50% in primary energy compared with a gas boiler counterfactual, and 31% compared with an ASHP counterfactual. The flexibility offered by the DHNs provides future opportunities for new technologies and alternative energy and fuel sources, allowing energy and CO2 savings to be retained in the future compared with the counterfactual building scale options.

In the 2010s and 2020s, virtually all zones are economic for all scenarios compared with both counterfactuals, resulting in heat cost savings of between 30% and 50%. The savings per a domestic customer are circa £62 per year per £1 billion GB saving, and for non-domestic customers £79 per year per £1 billion GB saving. This means that in scenario 1, the average home connected could save approximately £350 per year annualised cost against gas boilers and £950 per year annualised cost against ASHPs.

Using the central case as an example to understand the order of magnitude of the market size, the following figures are obtained:

- The total investment potential in energy centres is circa £35 billion. This includes the plant (and replacement during a schemes lifetime), energy centre building, and associated services.
- The total investment potential in DHNs is circa £93 billion.
- The total potential for installed CHP capacity is circa 47 GW thermal.

These values show that the potential market for macro DE equipment and services is significant enough to support extensive up-scaling of relevant industries in the GB if local manufacture and supply chain is to be developed. Sectors that could particularly benefit are: steel pipe, gas-engines and generators, civil engineering construction, domestic plumbing components and installers.

Despite the technical and economic potential, many barriers exist which future policy aimed at supporting macro DE can help overcome.

By overcoming the barriers associated with macro DE schemes, in particular facilitating strong levels of uptake to access the heat market, and providing a fair electricity price for CHP generated electricity through changes to the electricity market, macro DE can be economic in all the classes identified in both the 2010s and 2020s. The importance of a favourable electricity price is demonstrated in the modelling, with a reduction in revenue of 20% reducing the GB potential for economic macro DE schemes to around half. This has a larger effect than carbon pricing therefore suggesting that policy which only considers carbon pricing may have limited impact on the viability of macro DE if electricity revenues are not also directly supported.

Achieving a high market penetration will be important, and policy could be used to assist with this. The modelling demonstrates that provided a high proportion (typically around 80% but scheme dependent) of the market can be achieved, it is not necessary to access all customers allowing for some flexibility, but these types of penetration levels, especially in the private sector and domestic sectors will require policy support. Schemes will need to be effectively marketed, and customers potentially incentivised, or the use of regulation to encourage connection.

These conditions combined with large scale deployment and diversified schemes, results in optimised schemes where large proportions of the heat can be provided by the CHP units, improving the overall efficiency and primary energy savings.

Macro DE may be a significant contributor to GB electricity supply with wide spread deployment.

Achieving the economic potential of macro DE will result in high levels of electricity generation of up to 62% of the total GB demand. It will be important to understand how feasible this is, although there will be good synergies between heat generation and electricity demand, especially if non-macro DE areas take up heat pumps. The performance of the grid in the modelling is independent of the amount of macro DE generated electricity and this need to be examined together in future work.

DHN costs dominate the capital expenditure and access to low cost finance can help reduce this impact.

The economic and environmental performance of macro DE in the 2020s will be affected by a number of factors. The lowest levelised costs are achieved with access to lower discount rates of 3.5% in scenario 2, demonstrating the importance of controlling the cost of capital finance. This represents significant public sector investment in schemes. The DHN costs typically represent around two thirds of the overall capital expenditure, except in commercial/institutional building orientated zones (where they can be considerably lower). Therefore changes in DHN costs (scenarios 5 and 10) have a greater impact than energy centre costs (scenarios 4 and 9). WP1 also identified that DHNs may cost more in the UK than in Continental Europe and so this disparity needs investigating. Importantly, macro DE remained economic in virtually all zones across all scenarios, demonstrating the robustness of the solution.

The CO2 savings from gas CHP will reduce in the 2030s, but alternative forms of generation can make use of the flexibility offered by DHNs.

In the 2030s, gas CHP remains the most economic technology for macro DE schemes, but is no longer predicted to save carbon. It is not predicted that large scale heat pumps will be taken up if cost is the prime driver, and additional CO2 constraints and market interventions are required to ensure that macro DE schemes are developed which save CO2 compared to the counterfactuals. The combination of large scale heat pumps and gas engine CHP allows CO2 savings of greater than 50% compared with gas boilers to be achieved in this period, with a commercial GB Benefits Case potential of 6% of the heat market, and an economic GB Benefits Case of 21% of the heat market.

If heat pumps are used as a replacement on existing macro DE schemes, the economics will be improved due to the prior payback of part or all of the DHN, creating a larger economic market and greater CO2 reduction.

In order to maintain a larger share of the heat market, the 5.1 modelling demonstrates that further technology development and potentially newer technologies will be required to ensure that schemes can remain economic and provide acceptable CO2 reductions. This is examined in the 5.3 report and analysis.

Further work

The findings from the Macro DE project will feed into the ETI Smart Systems and Heat programme.

The report makes the following recommendations for future work:

1. The modelling suggests that gas engine CHP could provide up to 62% of the GB electricity demand. It is recommended that further work examines the potential of the electricity network to accept this level of distributed electricity generation, and assessed how this scale of generation can be accommodated alongside other sources of generation and the demand profile. Further modelling by the ETI using the ESME model will help to substantiate the need for this analysis. It is likely (and currently in the DECC roadmaps) that some form of fossil fuelled thermal electricity generation will be in operation until 2050. Whilst this is the case, it makes sense for this to be distributed allowing capture of the waste heat for macro DE. Therefore if macro DE schemes are deployed at a large scale, CHP is likely to have a long term future.
2. The high levels of electricity generation could have a strong synergy with heat pumps being used in non-macro DE areas and other future electricity demands (such as electric vehicles). It is recommended that this is examined further to understand the relative scales of deployment of macro DE (urban areas) and micro DE (rural areas), and the

corresponding changes in electricity demand and generation. With macro DE predicted to be a major electricity producer if fully deployed to potential, finding economic uses for this electricity (potentially in micro DE, but also electric vehicles) will be important.

3. During the 2030s, there is a role for both gas engine CHP and heat pumps on macro DE schemes. This modelling assumes a simple average marginal electricity grid factor, but the schemes could be operated in a smart manner to use the most appropriate technology depending on grid conditions. For example at times of high demand and low wind output gas CHP would be used and at times of low demand and high wind output heat pumps would be preferred. It is recommended that a "smart mode" of operation is examined including the use of tighter CO2 constraints in the 2030s, to refine and optimise the concept of a combined gas CHP and heat pump system. This could include the examination of control parameters, technology and communications options, and systems and mechanisms currently used elsewhere, such as the national grid. This analysis will also need to include an understanding of how future energy demand patterns may change (see point ii).
4. The modelling in this work is based around a central market penetration level of 80% with a sensitivity of 100%. The central case represents a high uptake whilst allowing for some flexibility, but may require policy to incentivise or regulate connection to achieve. At lower levels of penetration, it is unlikely that schemes will attract investment unless future guarantees of connection increases are provided. It is recommended that further work assesses the sensitivities around market penetration levels in more detail, including benchmarking penetration levels against existing schemes, and taking some example schemes to understand how scheme specific factors such as DHN layout and customer types could influence this.

References

D2.0 Development of a methodology to calculate energy demand

D2.3 Energy Demand Analysis in GB

D5.3 An assessment of the GB benefits associated with potential DE technology development