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The economics of distributed energy generation: A literature review ☆

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ABSTRACT

The UK electricity system is likely to face dramatic technical and institutional changes in the near future. Current UK energy policy focuses on the need for a clean, affordable and secure energy supply. Decentralisation of the electricity system is recognised as one means of achieving efficient and renewable energy provision, as well as addressing concerns over ageing electricity infrastructure and capacity constraints. In this paper we provide a critical literature review of the economics of increased penetration of distributed energy generation. We find that there exists a large volume of research considering the financial viability of individual distributed generation technologies (and we are necessarily selective in our review of these studies, given the wide variety of technologies that the definition of distributed generation encompasses). However, there are few studies that focus on the pure economics of individual or groups of distributed energy generators, and even fewer still based on the economy-wide aspects of distributed generation. In view of this gap in the literature, we provide suggestions for future research which are likely to be necessary in order adequately to inform public policy on distributed generation and its role in the future of UK energy supply.

Contents

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1. Introduction and Overview

Driven by various technological advances, regulatory issues and emissions reduction policies, the UK electricity supply framework, and its associated transmission and distribution networks, has been undergoing significant change in recent years. The development of renewable electricity generation technologies, the growth of competition in the electricity industry, concerns over ageing infrastructure and capacity constraints have stimulated increasing interest in the potential for distributed electricity generation to address such issues. Distributed generation[1] (DG) encompasses a broad range of typically (though not always) 'low carbon' or 'efficient' technologies which are small-scale in comparison to conventional generation, and located closer to the end user. Such technologies may give rise to benefits in terms of transmission and distribution savings, as well as their potential to remove the need for costly infrastructure and capacity upgrades.

Moreover, the UK Government sets out three key priorities in its Energy Review: to reduce greenhouse gas (GHG) emissions; to secure its future energy supply; and to reduce fuel poverty [36]. Whilst some changes to the current UK energy system may lead to trade-offs among these goals (such as the potential for high-cost renewable energy installations to reduce emissions but increase fuel poverty), increased penetration of distributed energy technologies may contribute towards the achievement of all three goals simultaneously. There are potential emissions savings associated with the low carbon output (on average) of DG technologies; whilst increased diversification in the range of the type of energy supply technologies and resources associated with DG could mean reduced reliance on energy imports and increased security of supply of UK energy;[2] and the 'efficient' nature of DG technologies such as CHP, combined with possible savings relating to reduced system transmission and distribution costs, could contribute towards lower-cost energy supply than that associated with conventional centralised generation. Whilst in its report the Government acknowledges that the existing centralised system of energy production and delivery provide 'economies of scale, safety and reliability', it also states that a 'combination of new and existing technologies is making it possible to generate energy efficiently near to where we use it, potentially delivering lower emissions, increased diversity of supply and in some cases lower cost'. Thus DG has the potential to achieve a 'triple dividend' in terms of meeting energy policy objectives.[3]

In this review we acknowledge the potential for distributed energy resources fundamentally to alter the way in which UK energy requirements are met. Conventionally, the UK electricity framework is characterised by large-scale, centralised electricity generation plants. Electricity is delivered to a huge number of consumers located across a large area via a complex transmission and distribution network. In the past, this system is widely understood to have worked well, providing the advantage of economies of scale, reliable, secure and relatively low-cost electricity to consumers. In contrast, DG technologies are located close to the demand source. A greater number of smaller, modular energy generation devices are required, each producing much smaller amounts of energy. DG systems can either be stand-alone or grid-connected. In the former case the DG technology produces power independently of the grid, and the operational capacity is matched to the demand. In the latter, the main purpose is for the device to service the electricity needs in the local area. Any surplus generation is fed into the grid, whilst any shortage of electricity is drawn from the grid (see Fig. 1a and b). In such a system, both demand and generation are directly connected to the distribution network, close to the point of end use. Consequently, the electricity losses and inefficiencies, which occur as centrally-generated electricity is transported across the network, are potentially reduced, and the electricity supply system as a whole is more flexible. Such developments may avoid (or certainly delay) the need for the widely anticipated and costly investments in the existing centralised electricity network, which would otherwise be required to address capacity constraints and ageing infrastructure. Furthermore, the government's Energy Review [36] suggests that a 'community-based energy system could lead to a greater awareness of energy issues, driving a change in social attitudes and, in turn, [could lead to] more efficient use of our energy resources'.

Despite these potential theoretical benefits of distributed energy generation, there are also a number of complexities and constraints involved in its further penetration into the energy mix. The integration of distributed generation technologies within the existing network is likely to create significant issues relating to the costs of energy provision and price of electricity, power quality, infrastructure requirements, and technical performance. DG necessitates a more active distribution network than that which currently exists in the UK. In particular, there is a need for electricity to flow in two directions, both from the network to the consumer for use at home or in industry, and also from the distributed generation source to the network when exporting excess generation (Figs. 1a and b). Furthermore, there are considerable uncertainties regarding the financial viability of individual and wide-spread DG applications, as well as the social costs and benefits attached to the increased penetration of distributed generation in the UK, not to mention the macroeconomic effects of such a fundamental change in energy provision.

In this paper we provide a critical review of the literature on the economics of distributed generation. This is with a view to informing the wider energy policy community and identifying important informational and research gaps, as policy makers seek to make decisions towards developing an efficient, secure and financially and environmentally viable electricity network for future energy needs.

Evaluating the economics of the increased penetration of distributed energy generation is not straightforward. Distributed energy technologies vary widely in terms of their technological design and generation capacity, as do their capital, maintenance and fuel costs. For example, there are the potential costs of electricity infrastructure adjustments that may be required in order to make widespread use of distributed energy. These potential costs should sensibly be compared to the alternatives, such as the network upgrades that would be necessary to increase the capacity of conventional, centralised generation. Furthermore, there are uncertainties regarding the characteristics and extent of future policy support mechanisms, as well as the likely regulatory and institutional arrangements for distributed electricity generation (for example generators' obligations and costs for connecting to the grid). Data on the financial costs and benefits of distributed energy generation tend to be highly project-specific and estimates of the social costs or benefits of such generation (for example potential reduction in carbon emissions) are necessarily assumption-driven and subject to uncertainties. As such, there are no standard models or tools for analysing the economics of distributed generation. In this paper we consider the findings from a range of research that we believe to be informative about the key

[1] The term 'distributed generation' is commonly referred to in the literature, but the terms 'dispersed', 'embedded', 'decentralised' and 'on-site' are also used with reference to the same concept.

[2] Though the link between reduced energy imports and increased security of supply of domestic energy is far from clear. Stirling [82] provides a useful discussion of the factors affecting energy security of supply.

[3] The Scottish Government regards economic growth stimulated by the energy sector (with a particular emphasis on renewable technologies) as a further ambition for Scottish energy policy. If DG stimulates economic activity, there exists the potential for an additional dividend (see e.g. [4]).