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What changes, if any, would increased levels of low-carbon decentralised energy have on the built environment?☆

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A B S T R A C T

Low-carbon decentralised energy technologies (DETs) have become increasingly popular in recent UK energy policy debates. Many of the technologies involved are well established, but it is only with their increased technical maturity and the imperatives of climate change, energy security and fuel poverty that DETs have been realistically suggested as an integral part of our future built environment. This review will consider the possible physical and behavioural impacts of increased levels of low-carbon decentralised energy, presenting both recent research in this field and an analysis of policy trends and future scenarios.

1. Introduction

Low-carbon decentralised energy technologies (DETs) have become increasingly popular in recent UK energy policy debates. Many of the technologies involved are well established, but it is only with their increased technical maturity and the imperatives of climate change, energy security and fuel poverty that DETs have been realistically suggested as an integral part of our future built environment. This review will consider the possible physical and behavioural impacts of increased levels of low-carbon decentralised energy, presenting both recent research in this field and an analysis of policy trends and future scenarios.

2. State of current science

Recent research on the impact of DETs can be structured around three themes: the physical impacts of individual DET installations, the behavioural impacts of these installations, and the anticipated growth of the market for them.

2.1. The physical impacts of DETs

The term 'decentralised energy technologies' encompasses a diverse group of approaches. Most commonly, it refers to microgeneration, which is defined by the Energy Act 2004 as any installation that produces less than 50 kW of electricity and 45 kW of heat. This could involve fuel cells, solar photovoltaics (PVs), solar hot water, small-scale wind and hydro, heat pumps, combined heat and power (CHP) and other technologies. The diverse nature of these means that the energy output of an installation is no guide to its physical impact on the built environment. This is recognised in a current consultation document from the Department of Communities and Local Government, which proposes that microgeneration installations should be generally permitted subject to technology-specific impact constraints. For example:

- *Solar microgeneration (PV and hot water)*: must not protrude above the highest part of the roof, and not be visible from public highways in Conservation Areas.
- *Heat pumps*: subject to noise restrictions and Conservation Area visibility restrictions.
- *Wind turbines*: when mounted on a building, not more than 3 m above the highest part of the roof, 2 m maximum blade diameter, subject to noise and vibration restrictions, not permitted in Conservation Areas unless stand-alone and not visible from the highway.

The existence of rules such as these shows that DETs are relatively well accepted by planners. The physical impacts of microgeneration technologies will probably not change significantly in the near future, although there may be some improvements, for example in noise reduction.

It is important to recognise that DETs are not limited to supply-side technologies. The 2007 Energy White Paper notes that

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demand-side measures such as smart metering, consumption feedback through better billing and electronic displays, and energy-efficiency measures such as more efficient lights and appliances, and better insulation, are the most cost-effective carbon abatement measures. In fact, supply-side microgeneration is one of the most expensive abatement measures. The majority of demand-side technologies have no notable external physical impact. Instead, their primary contribution is in influencing consumer behaviour.

2.2. The behavioural impacts of DETs

Consumer behaviour and energy consumption has been an area of interest since the oil shocks of the 1970s. In recent years, however, this body of work has shifted from how and why people use energy in their lives to a more interventionist focus on how consumers can be encouraged to use energy more responsibly and contribute to policy goals (Abrahamse et al., 2005).

Such research on DETs has focused on two questions. The first explores the role of microgeneration and how generating one's own energy can change behaviour. Table 1 summarises recent research in this field, with particular reference to solar PV systems. Although PVs are only one type of DET, these studies demonstrate the types of behavioural impacts that DETs can encourage. For example, evidence was seen of load-shifting to use electricity when it is being produced, an increased awareness of domestic energy consumption, and further investments in energy-efficiency measures. These responses were seen with a variety of consumers from deep-green early adopters to social housing tenants who simply moved into a DET-fitted home.

These results also hint at the second major behavioural research theme, the effect of improving consumers' energy information. A recent review of energy displays, smart metering and informative billing notes that this type of direct feedback can lead to energy savings of 5–15% (Darby, 2006). Ofgem is currently coordinating a 2-year trial of smart meters and energy displays in approximately 40,000 UK households to further understand the benefits of these technologies. These advances demonstrate that, while traditional demand-side measures such as improved appliance efficiency and better insulation will continue to play a vital role in reducing domestic energy consumption, there is significant potential to engage with consumers through changes to their information environment.

However, behavioural responses to DETs may not always be positive or easily predictable. A recent assessment from the UK Energy Research Centre details how increased efficiency can lead to a rebound effect, negating some or all of the savings predicted (Sorrell, 2007). The report argues that a supportive policy environment, such as adequate carbon and energy pricing, is needed to mitigate any rebound effect losses. Likewise, the behavioural impact of DETs must be assessed within a wider context.

2.3. DETs and a low-carbon future

To determine the overall impact of DETs on the built environment, one needs to consider not only the impact of individual technologies but also the potential scale of the market. One of the most significant pieces of research in this area has been the *40 Per Cent House* report from Oxford's Environmental Change Institute (Boardman et al., 2005). In order to reach a 60% reduction in CO_2 emissions by 2050, the report estimates that every home in the UK will need to have approximately two microgeneration technologies as well as a full complement of demand-side efficiency and information measures. With approximately 26 million households in the UK, this implies a radical transformation of the built environment.

Other research broadly supports such a scenario. The Energy Saving Trust examined the potential of microgeneration and suggested that such technologies could produce as much as 40% of the UK's electricity needs alongside a 15% carbon reduction. Fig. 1 shows the status of specific microgeneration technologies in the UK. Recent estimates suggest that there are now approximately 100,000 installations in total, and as this diagram shows, solar water heating accounts for most of them.

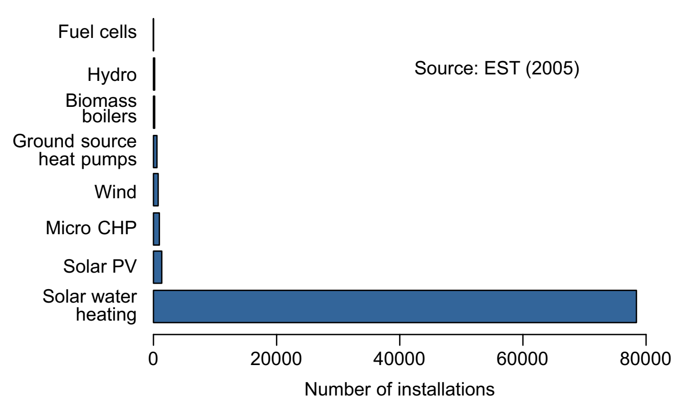

Fig. 1. UK microgeneration installations (EST, 2005).

Table 1
Existing research on PV and household behavioural responses

Study	Location (sample size)	Key findings
EC (1997)	France (21)	'Increased awareness of the value of electricity generated has led system owners to take other energy savings measures in their homes.' (p. 5)
Haas et al. (1999)	Austria (21)	High consumers (>3500 kWh per year) reduced overall demand after installation of PV, low consumers increased demand; PV is 'the last part in a chain of energy conservation investments' (p. 189)
Schweizer-Reis et al. (2000)	Germany and Spain (>300)	Evidence that respondents with off-grid PV 'happy with this limitation [of electricity production]; it makes us feel responsible for our energy consumption' (p. 8). Load shifting and conservation behaviours seen in response to monitoring devices
Erge et al. (2001)	Germany (68)	Consumption of PV households was 'not different' from that of non-PV households (p. 483)
Dobbyn and Thomas (2005)	UK (29)	Found changes in behaviour (e.g. turning off lights, shifting loads, investigating additional generation capacity) especially in 'passive' adopting households (e.g. social housing)
Jenny et al. (2006)	Cuba (49)	Residents with off-grid PV 'developed rules and agreements for coordination of their energy use that have led to good adaptation to the dynamics of energy production.' (p. 353)
Bahaj and James (2006)	UK (9)	Detailed monitoring of consumption found that 'increased energy awareness can lead to changes in the way energy is used, reducing overall consumption' (p. 2121)
Keirstead (2007a)	UK (118)	Found three distinct types of households: large savers (35% saving on pre-PV electricity consumption, 8% of sample), small savers (9% electricity saving, 34% of sample), no change (55%). Considered primarily early-adopters

A related piece of research was conducted by the University of Sussex's Science and Technology Policy Research Unit. *Unlocking the Power House* (Watson et al., 2006) considered the institutional arrangements that could be used to achieve a decentralised energy future. It suggests that the business model by which microgeneration is promoted will be an important determinant of the impacts of DETs on the built environment. For example, the economic and institutional barriers to installing a given microgeneration technology may be off-putting to individual households, whereas energy service companies or community projects may be able to leverage further resources and capacity. Other research in this vein, considering how the interaction of technologies, consumers and institutions might deliver a low-carbon future, is being supported by the £14 million Carbon Vision partnership between the Engineering and Physical Sciences Research Council and the Carbon Trust.

3. Future outlook

Recent years have seen the introduction of a number of initiatives aimed at promoting DETs. In this section, these policies are examined to explore the likelihood of the advances noted above being achieved.

3.1. The 2007 Energy White Paper

The Energy White Paper and the recent microgeneration strategy highlighted the Government's commitment to four energy policy goals: security of supply, competitive markets, reducing carbon emissions and alleviating fuel poverty, and noted the potential contribution of DETs.

DETs contribute to energy security in two ways. Supply-side technologies such as microgeneration make more efficient use of existing fuels, or use locally-available renewable resources, in either case reducing the need for imported fuels. They can also add to efficiency. The former DTI estimated that £7.8 billion will need to be invested in the near future in the electricity transmission and distribution systems (DTI, 2006). Evidence from the USA has suggested that distributed generation can offer over 200 separate benefits over a centralised system, largely related to the performance of network infrastructure (Lovins and Rocky Mountain Institute, 2002). However, a UK expert in this field recently noted that more work needs to be done to quantify the benefits of distributed generation in this country (Strbac, 2007).

The Climate Change and Sustainable Energy Act 2006 confirmed the value of DETs as a tool for reducing carbon emissions. But it remains uncertain whether the market will deliver large-scale microgeneration. Recent critiques of EU and UK policies have noted that investors face significant uncertainty when trying to assess the scale of government targets and their likely impact on carbon prices in cap-and-trade markets (e.g. Gross et al., 2007; Newbery, 2007). This can be seen in the drafting of the Climate Change Bill, where there has been debate about whether the UK should be pursuing a 60% cut in carbon emissions by 2050 or a more aggressive target, perhaps 80%.

DETs also offer fuel-poor households the opportunity to reduce their reliance on potentially expensive grid fuels. Recent progress on fuel poverty has been achieved largely through falling energy prices and increasing household incomes via credits. Without improvements to energy efficiency, households can quickly return to fuel poverty when prices rise. Demand-side DETs, such as insulation or smart meters, will be key to reducing fuel poverty. The Sustainable Development Commission has recently called on the regulator Ofgem to promote demand-side DETs as part of its efforts to help the fuel poor.

When considering the prospects for DETs, it is important to note that the Energy White Paper also signalled renewed interest in centralised generation, via options such as the possible replacement of the UK's nuclear power stations, constructing the Severn Barrage, or developing carbon capture and storage technologies. A key question is whether the UK's energy systems, particularly electricity, will shift to a decentralised model or be renewed in the centralised mould. Early evidence suggests that there has been insufficient integration of departmental roles to facilitate a cohesive push towards decentralised energy systems (Keirstead, 2007b). But more research is needed and the picture should become clearer in the next few years as the present debate over nuclear power and the Severn Barrage moves towards a conclusion.

3.2. The role of local government

Just as central government has emphasised the role of centralised energy technologies, local government can encourage DETs. While national policy is undoubtedly important for setting standards, providing funding and setting market conditions, a recent report by the Local Government Association highlights the many measures that can be adopted at a local level. Communities around the UK have already acted to improve energy performance by adopting green procurement policies, forming partnerships with local businesses and community groups, considering energy during regeneration efforts and other initiatives (LGA, 2005).

Planning is a particularly important area of local influence. One of the most successful DET initiatives of recent years has been the Merton Rule, whereby local councils require new developments of a certain size to provide a portion of their energy needs from on-site renewables. This policy has been adopted by approximately 150 councils across England but recently there has been speculation that central government will withdraw support from such local planning initiatives in its upcoming Climate Change Planning Policy Statement. In a recent *Guardian* article, a representative of the British Homebuilders federation said that this was to ensure consistency and cost-effectiveness along the path to the 2016 zero-carbon house (Seager, 2007). Without this type of local support, the prospects for DETs are likely to be greatly diminished.

3.3. Code for sustainable homes

In addition to the present grant schemes and pilot projects, central government can promote DETs through its policies in the building sector, such as the Code for Sustainable Homes, Building Regulations, Energy Performance Certificates and Home Information Packs. These measures are intended—among other objectives—to encourage developers to incorporate DETs into new housing and provide consumers with the information needed to identify and purchase an energy-efficient home. Although the UK's housing stock is only replaced at a rate of about 1% per year, these programmes are important for creating product demand and installation experience that can be applied across the building sector.

Although it covers many aspects of a new home's sustainability, the Code for Sustainable Homes (CSH) is particularly relevant to DETs as it includes detailed provisions on energy performance (DCLG, 2007). It has been proposed that these standards will be gradually made mandatory by inclusion in the Building Regulations. This means that by 2016 all new homes built in the UK should be net zero-carbon, the energy requirement of the top Level 6 certification of the current CSH, thus providing a significant boost to microgeneration. However, the CSH is currently a voluntary scheme. Recently proposed changes are likely to make only a CSH rating—not a detailed assessment—mandatory. Making CSH assessments mandatory would support DETs both now and within a long-term framework, building the industry's familiarity and experience with these technologies in anticipation of large-scale expansion.

A full CSH assessment also covers a building's 'management', both during construction and operation. Innovative demand-side DETs such as smart meters and monitors could fall under this section but at present are only implicitly referred to as part of the new homeowner's 'user manual'. This means that the CSH and its eventual translation into the Building Regulations emphasise supply-side DETs. Without explicit support for demand-side DETs, the behavioural change benefits of smart meters and monitors may not be seen in the 2016 zero-carbon house.

3.4. Other sectors and DETs

Recent research and policy (and hence this report) have been largely focused on the domestic sector but the scope for DETs is potentially much broader. For example, the service and industrial sectors together account for approximately 43% of the UK's final energy consumption, versus 31% for domestic consumption. In large industrial applications, DETs such as combined heat and power are already common. Yet between the small-scale domestic and the large-scale industrial systems, there is significant potential for DETs in small and medium enterprises and the public sector. Research under Carbon Vision's Building Market Transformation project (ECI, 2007) and the UK Green Building Council (UKGBC, 2007) is exploring this field although insufficient energy consumption data and a lack of appropriate design tools present major obstacles. The other significant energy consumption sector, transport, may also link with DETs. Technologies such as fuel cells can be used for transport and as a source of decentralised energy. This cross-fertilisation between sectors means that a technological advance in one field could have significant impact on DETs in other areas. Fuel cells and solar photovoltaics are strong candidates for such breakthroughs.

3.5. 2050 outlook

These policy debates and research themes suggest two possible scenarios for DETs by 2050. In the first, existing centralised generation systems such as nuclear power and fossil fuel electricity generation are rejuvenated in low-carbon form, for example by adding carbon capture and storage to fossil fuel generation. In this world, the built environment remains largely similar to the present day, with DETs occupying a larger but still niche role. The second scenario, precipitated perhaps by acute climate concerns or the onset of peak oil, could see a dramatic shift to decentralised technologies. This would mean not only changes to the physical built environment, perhaps with a different grid structure and new technologies in the home, but also associated shifts in culture, governance and social structure, such as less commuting and a greater focus on local facilities. Therefore, to understand which of these or other possibilities might occur, one must consider the present policies discussed above as well as wider trends in economics, design, skills and culture.

4. Conclusion

Recent research has identified two significant realisations about the impact of DETs. First, while individual installations may have known and relatively small impacts on the built environment, analyses of the potential for market expansion suggest that the largest impact is likely to come from the sheer number of DET installations. The second advance has been an increased recognition of the potential benefits from the behavioural impacts associated with DETs, particularly with demand-side technologies such as display devices and smart meters.

There are currently several policy initiatives relevant to the future prospects for DETs. But these debates are still unresolved and it is difficult to determine whether visions of a decentralised low-carbon energy infrastructure will be realised and, if so, in what form. Some of these questions should be resolved in the coming months and years. Key issues to watch include the rejuvenation of centralised generation, the structure of support mechanisms such as the Code for Sustainable Homes, and the increased importance of consumer behaviour issues, such as the results of the smart meter and energy display pilot projects.

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