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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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ABSTRACT

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.

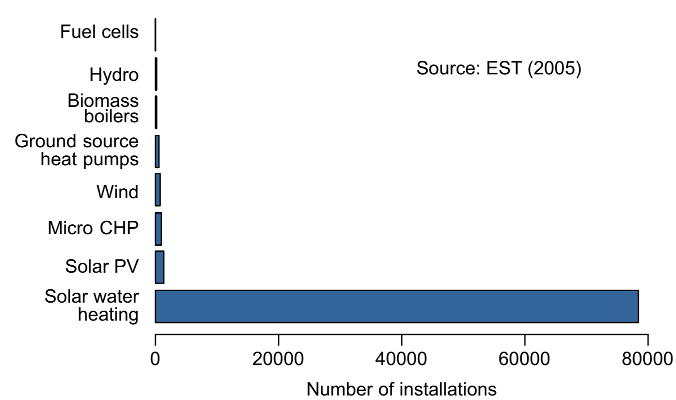

Fig. 1. UK microgeneration installations (EST, 2005).

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