Evidence to the EAC
From the Environmental Change Institute University of Oxford

Our evidence is based on recent and current research on the future of UK energy consumption and carbon dioxide emissions, including the following:

- The *40% House* report (Boardman et al 2005), funded by the Tyndall Centre for Climate Change Research, describes a detailed low-carbon future for the residential sector, achieving a 60% cut in carbon emissions by 2050. This is achieved despite a 33% increase in the number of households and delivers a higher level of energy services per person. Two-thirds of the cut comes from demand reduction and one-third from the provision of heat and electricity by low and zero carbon (LZC) technologies.
- A series of computer models of different renewable energy technologies shows that a well-designed future energy system can have multiple benefits in terms of security of supply, reduced peak load and reduced need for expensive, carbon-intensive backup generators (Environmental Change Institute 2004).
- An investigation of conventional cost analysis methods reveals that traditional analysis favours re-investing in existing infrastructure largely because it ignores the dramatic fall in future costs of new technology once that technology has been deployed beyond an early 'demonstration' scale (Hinnells 2005).

Further research is ongoing under the UK Energy Research Centre where ECI is leading the demand reduction theme; under Carbon Vision Buildings, a joint programme sponsored by EPSRC and Carbon Trust; and under Supergen, funded by EPSRC where ECI is one of the research groups analysing the detailed impact on electricity distribution systems of widespread micro-generation.

We focus these comments on the use and supply of electricity (mainly in the residential sector) and we are including both combined heat and power and building-integrated renewables (eg photovoltaics and micro-wind) in the phrase 'micro-generation'. Larger scale sources of renewable energy (wind and marine) are generically identified as 'renewables'.

1. The extent of the 'generation gap'

The extent of any shortfall depends on the level of demand and whether the supply can meet this. Demand is not a given, it is a result of policies, prices, public concern and awareness of climate change, amongst other factors. To date, there has not been a comprehensive strategy to focus on reducing demand. There are substantial opportunities, but whether they are achieved depends largely on new government policy.

In order to achieve a reduction in electricity demand, products and policies can be designed with a focus on either annual consumption or instantaneous power demand or both. The *40% house* project reviewed the opportunities for both and the potential synergies with micro-generation.

DEMAND REDUCTION

A major factor in determining whether the lights stay on could well be the type of lights that we are using: the most secure energy future is one where there is no need for energy supply, because the level of energy service has been provided whilst reducing demand. Most electricity use in the home goes into lights and appliances: about 3,000 kWh pa out of 4,000 kWh pa for the average UK house. In the *40% house* project this 3,000 kWh is reduced to 1680 kWh by 2050, by a strong, European-wide focus on product policy. For instance, the 715 kWh of electricity used for lighting is reduced to 122 kWh pa by installing light emitting diodes (leds) in every fitting in every house: the incandescent bulb is phased out as soon as possible. Policy is working towards this, as the draft revision of the Building Regulations 2006 part L uses a measure of power consumption per unit of illumination to force the use of more efficient lighting technologies. This applies to new buildings only. Despite the growth in the number of households, the switch to leds reduces national electricity use in residential lighting from 17.9 TWh in 2004 to 3.9 TWh by 2050, a 78% drop. As lighting is a major contributor to peak electricity demand (early evening in winter) this is also reduced by 2.75 GW. Policies on other electrical products would ensure the halving of demand by 2050.

Product policy at an EU level, including minimum standards, has been instrumental in transforming the market for household appliances at no cost to industry or governments (Boardman 2004). EU policy needs to be supported and strengthened to ensure that only the most energy efficient products are available to consumers. Policy needs to be based on total energy consumption, not just increased energy efficiency, in order to prevent manufacturers producing ever larger equipment and to encourage consumers to downsize with their new purchases.

Other policies on the use of electricity in the residential sector would focus on the potential for fuel switching with space and water heating. For instance, all-electric tower blocks (where individual gas boilers are not safe) could be transferred over to a combined heat and power system. There would be some growth in electricity demand with the conversion of rural properties, beyond the gas network, from oil central heating to heat pumps.

The UK Energy Research Centre (UKERC) is creating detailed computer models of demand in the various sectors, allowing for the development and comparison of future scenarios describing how carbon emissions reduction targets might be met. The ‘bottom up’ modelling of both supply and demand is only now being started for the UK in a systematic way, looking at the entire economy. The first sector studied – the domestic sector – shows enormous potential for demand reduction through energy efficiency. In other sectors, the gap between published good practice and typical actions is also significant, leading us to believe that modelling of these other sectors will show that similarly large carbon reductions are possible across the UK economy without lower levels of energy service. Creating the necessary computer models is part of the research agenda of the UKERC.

MICRO-GENERATION

In the 40% House scenario, the early contribution from micro-generation comes mainly from combined heat and power (as supported by the Energy Saving Trust’s Community Energy programme). In later years, especially from 2020 onwards, solar photovoltaics (PV) and micro Combined Heat and Power (micro CHP) integrated into individual buildings are projected to make a significant contribution to electricity generation. Micro-CHP is assumed to rely on Stirling engine technology in earlier years, with more efficient fuel cell technology later on as markets develop. More than half of the fuel cell and PV generation is in the last decade of this scenario. The purpose of developing the 40% House scenario was not to pick technology 'winners' in terms of the precise mix of different generation technologies. Rather, the scenario shows one indicative mix of technologies that meets the four key aims of the 2003 Energy White Paper: eliminating fuel poverty, ensuring security of supply, helping UK competitiveness and meeting the 60% carbon emissions reduction target. Other mixes of technology deployment can also be envisaged, but the 40% House scenario shows how a dual policy of demand reduction and deployment of micro-generation can make deep cuts in carbon emissions.

The mix of micro-generation technologies in the 40% House scenario includes sources of heat as well as electricity, all with low or zero carbon emissions (table 1). By 2050, there would be a total of over 53 million installations of these technologies – an average of 1.7 per dwelling.

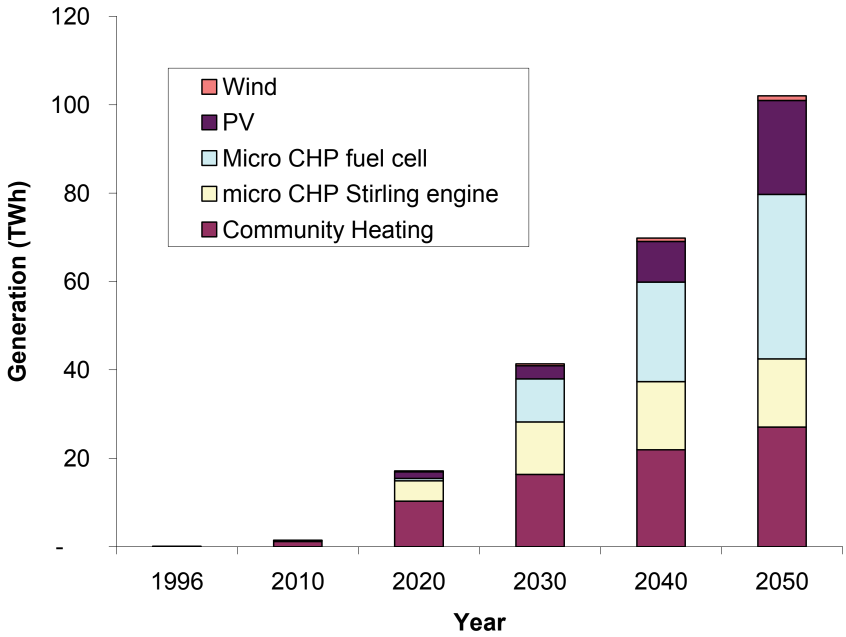
	Heat only	**Heat and electricity**	**Electricity only**
Low carbon	Heat pumps	Gas fired CHP in community heating Gas fired Micro CHP (Stirling engine) Gas fired Micro CHP (Fuel Cells)	-
Zero net carbon	Solar hot water Biomass Geothermal	Energy from Waste or biomass CHP in community heating Biomass in Micro CHP (eg Stirling engines)	Photovoltaics Wind

Table 1. Low- and zero-carbon technologies in the *40% House* scenario

Micro-generation of electricity can ensure that by 2050 the household sector could be a net exporter of electricity, obviating the need for new investment in central generation (chapters 7 and 8 of 40% House report). There are significant challenges in that this level of investment may require a different utility structure, with the development of Energy Services Companies (ESCos) that can design, build, finance, operate and maintain a portfolio of microgeneration in people's homes. Feed-in tariffs that reward small-scale generators for their electricity production have been shown to stimulate step-changes in take-up of these technologies, by paying the cost of generating each unit of electricity (instead of a nominal 2-3p as at present). There are significant benefits in a portfolio approach with a diverse set of generators – spread across technologies and across regions. These benefits include increased security of supply and the better matching of supply and demand at peak times, reducing the need for back-up capacity and improving the overall system efficiency (chapter 8 of 40% House report).

The winter evening peak in electricity demand in the UK is largely attributable to the residential sector: millions of homes use power at the same time in the early evening. This demand for electricity coincides with demand for heating. In the 40% House scenario, demand reduction combined with a portfolio of micro-generation technologies has the potential to reduce winter peak electricity demand by 25 GW (40% of winter evening peak for the whole electricity system).

Figure 1 Electricity generated from different micro-generation technologies in the 40% House scenario, residential sector, UK 2050



Note: wind is micro-wind, integrated into the house, as with the other technologies modelled

In the residential sector alone, it would be possible for the level of demand reduction and the production of electricity from micro-generation to cover the gap left by the retirement of old nuclear power stations and the coal-fired plant that will not comply with the Large Combustion Plants Directive.

B. Financial costs and investment considerations
2. Costs and timescales of different generating technologies?

The scale of investment in new technology required to achieve the *40% House* scenario is not as challenging as might at first be thought. At present it is certainly the case that many micro-generation devices would struggle to pay back within their lifetime. However, the cost of technologies is much more likely to come down than to stay the same. There is an international academic literature, across several disciplines and many technologies on experience curves (also known as technology learning, or learning by doing). Experience curves suggest that for every doubling of the global installation of a technology, costs fall. The fall averages 18% but could be between 5% and 35% for each doubling of installation (Hinnells 2005). On this basis, the costs of most micro-generation would fall and give an attractive payback.

Whilst this theory holds true for most technologies – the situation with nuclear is ambiguous - the potential for successive doublings of the number of installations is clearly high for building-integrated wind, micro CHP, or PV. The *40% House* scenario includes over 30 million installations of micro-generation technology throughout the residential sector – an enormous increase in the number of units already installed.

Nuclear power will not benefit from the future unit cost reductions that are possible for micro-generation technologies.

Life cycle costing

If the real costs of waste storage and decommissioning had been included in the initial cost assessment of existing nuclear power stations, the economics of this technology would not have looked as attractive as they did. The long-term costs were ignored or under-estimated then, but the costs and problems of waste and decommissioning are now unavoidable. This is a salutary lesson in the need for life cycle costing. Even now, the long-term cost of waste storage and management for nuclear energy remains unclear but the estimates continue to rise.

Fossil fuel prices also affect the cost-benefit analysis of alternative sources of electricity supply: sharp increases in the price of oil in the last year or so have exceeded most observers' expectations. Residential gas and electricity prices have risen 32% in the last two years. In the face of such price volatility it is difficult to predict future costs, but the assumptions for future fossil generation need to reflect the possibility of much higher prices.

Analysis of costs needs also to include an assessment of benefits from different scenarios of technology deployment. For example, where peak demand and back-up capacity can be reduced through a portfolio of renewable energy technologies and demand reduction, there are clear financial benefits to the system as a whole. For instance, CHP contributes disproportionately to peak electricity supply. Such whole-system impacts tend to be ignored in cost-benefit analyses where the focus is on reducing cost for one asset-owner or group of asset-owners.

3. What impact would a major programme of investment in nuclear have on investment in renewables and energy efficiency?

Nuclear power is a domineering technology: it contributes large quantities of baseload electricity, but is not flexible (it is either on at full output or off) and cannot track demand. It has to be partnered by large-scale fossil-fuelled plant that can replace or supplement its generation when necessary. Nuclear is not easily partnered by renewables or micro-generation, because they provide variable generation that does not match well with the step-changes of nuclear. The flexibility of large fossil-fuelled plants means that they can be combined successfully with renewables and micro-generation.

Conversely, micro-generation does not fit well with nuclear power. Micro-generation provides power to the user, at the point of consumption. It will always be taken first (the nearest electrons) and cannot be turned off by the national grid. The substantial development of micro-generation could therefore create a situation where the demand for centralised, nuclear generation is dropping, without the ability to partially turn it down. Some development of micro-generation will take place as a result of individual decisions by householders and businesses. Some will be required, for instance under the imminent Code for Sustainable Buildings, future revisions to the Building Regulations and the existing Energy Performance in Buildings Directive. The London Borough of Merton has instigated an obligation to provide 10% of energy on site in large new developments. The growth in micro-generation is not entirely dependent upon new policies (though some are definitely needed), so the electricity system should be preparing to cope with these new sources. They are coming onto the system.

The changes in electricity demand identified in *40% house* would occur gradually, over the years. This also requires a flexible electricity system that can cope with reducing demand, not one that can only provide baseload.

All of these three situations mean that the development of new nuclear power would reconfirm the existing system, at exactly the point where renewables and micro-generation are beginning to be established and become cost-effective. ‘While nuclear power may have low carbon benefits, its overall impact on other low carbon technologies would be greater than the positive benefits. Supporting nuclear power now would not only undermine the short-term development and implementation of other low-carbon technologies, but it would also undermine the longer term transition to a low-carbon sustainable energy system’ (Mitchell pers comm).

A future with both high output from nuclear plant and high output from micro-generation would lead to excess capacity requiring high levels of energy storage, particularly during when demand is low, for instance in the summer months. As energy storage has cost and efficiency penalties, it makes sense to first optimise the match between supply and demand.

The variablility of renewables and micro-generation is often wrongly equated with unreliability: there is a common assumption that so-called ‘intermittent’ renewables are all either ‘on’ or ‘off’ at any given time and that they can therefore never guarantee supply sufficiently. In fact, these technologies generate electricity across a range of output levels and the weather data for the UK as a whole shows that the wind is almost always blowing somewhere; that energy can be converted from diffuse daylight as it can from bright sunshine; that tides and day-lengths are predictable across the seasons. Large-scale deployment of diverse renewables and micro-generation technologies can make the variability of the whole system manageable and, in the right mix, the total output will also follow load.

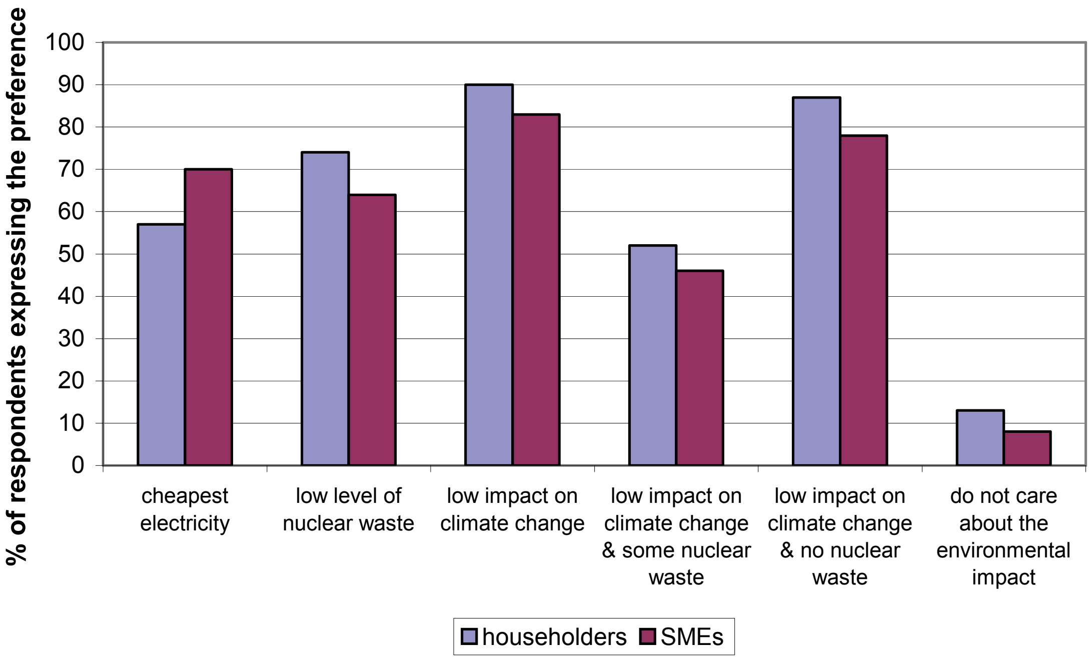
There is therefore an inherent choice to be made between a high-nuclear or a future based on high levels of micro-generation and renewables. This decision should sensibly be made now, at the point where grid infrastructure reinvestment is necessary and can be provided so as to support the chosen electricity generation policy. The ECI is currently conducting detailed research on the impacts of this on electricity network operation, carbon dioxide emissions and energy security as part of the SUPERGEN consortium on highly distributed power systems. This study is analysing the technical and regulatory issues of a transition from a highly centralised distribution system – with significant disincentives to small generators - to one which supports micro-generation.

In this context, it was disappointing that the recent DTI consultation paper on micro-generation lacked vision and ambition for the future of the UK power supply industry. By setting the limits of the debate to the existing market and regulatory regime, the opportunity for deep penetration of micro-generators is effectively hampered by the barriers inherent in the current system. This would be particularly detrimental if policies on the demand side and that affect the provision of micro-generation in buildings result in parallel, but unco-ordinated developments.

Consumer preference

From October 2005, all electricity consumers (domestic and non-domestic) will be receiving information with their electricity bills on the fuel mix of the electricity that they are buying. This is required under the European Electricity Liberalisation Directive and is known as 'disclosure'. There is strong consumer support for electricity generation that has a low impact on climate change and produces no nuclear waste. These two issues emerged as the most important ones in a telephone survey of 200 householders and 100 small businesses (SMEs) in the UK in 2003. Concern about the environmental impact of electricity exceeded the concern to buy the cheapest electricity. Very few respondents stated that the environmental impact of electricity generation was of no concern (Figure 2).

Figure 2: Consumers stated preference for electricity associated with certain environmental impacts, UK 2003



If consumers use disclosure to switch to a supplier where the supply matches their preferences more accurately, the market for nuclear power could diminish substantially. Over half of all households have switched, so far, on the basis of price.

Key conclusions

- There are substantial opportunities for demand reduction using existing technologies, certainly in the residential sector. These reductions need a clear strategy and strong government commitment, but they are achievable with political will. The reductions are both in consumption and peak power demand.
- The *40% house* identified a scenario for the residential sector alone, where the level of demand reduction and the production of electricity from micro-generation would be sufficient to cover the gap left by the retirement of old nuclear power stations and the coal-fired plant that will not comply with the Large Combustion Plants Directive. This achieves the 60% carbon reduction target by 2050 required in the Energy White Paper.

- Several existing and upcoming policies are working towards the support of micro-generation and enabling consumers to choose electricity that reflects their stated preference: there is strong public support for the purchase of electricity generated from renewables and strong public concern about electricity from nuclear power. These new initiatives should be enhanced by future policy, not stranded by it.
- The costs of reducing demand and of installing micro-generation and renewables will drop, probably significantly, as a result of economies of scale from technology learning. These experience curves and therefore cost savings are achieved more quickly with micro-generation and renewables than with nuclear power stations, because of the number of installations: about 30 million with micro-generation in the home by 2050 under the *40% house* scenario.
- The design of the infrastructure and markets needed to support a distributed system of electricity generation is quite different from the one required for centralised generation (including nuclear) so that a decision is needed imminently about which path the UK should be going down;
- Similarly, nuclear and micro-generation do not mix well: both should be the first call on the system and micro-generation will always be used first in the home;
- Variable micro-generation (and larger renewables) can be designed to mirror variable demand (and vice versa) to minimise the need for either back-up or storage. For instance, combined heat and power contributes significantly to electricity generation at times of winter peak demand.
- Efficient lighting would significantly reduce the winter peak demand (by 2.75 GW in the residential sector in the *40%* house scenario) and would be a major contributor to keeping the lights on.

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