Integrating Microgeneration into Energy Networks and Buildings ('Unlocking the Power House')

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End of Award Research Report

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Background

Microgeneration in individual homes has been the subject of increasing policy and industry attention in recent years. Although there are only around 100,000 microgeneration installations in the UK, the Energy Saving Trust believes that microgeneration could supply 30-40% of UK electricity demand by 2050 (Energy Saving Trust, 2005b). If adopted by large numbers of households in this way, microgeneration could bring about fundamental change to our energy system. Many consumers would become energy producers, leading to a breakdown of the traditional distinction between energy supply and demand. Established regulatory frameworks and energy infrastructures could need to change radically to deal with a fundamental decentralisation of power and control.

Our existing energy infrastructures including power plants as well as transmission and distribution networks are mainly built on century old concepts about energy provision. The generation of power at the point of consumption in our homes would significantly help to increase the overall efficiency in the system by reducing losses and increasing the integration with the provision of heat. This may also have other positive benefits in connecting citizens to the source of the energy they use, thereby encouraging them to think about and possibly reduce their energy demand.

Objectives

This project investigated how microgeneration might be deployed in the UK and its possible implications for domestic consumers, energy companies and the energy system as a whole. Working closely with industry and government it identified technical, regulatory and institutional changes that might stimulate the market uptake of microgeneration technologies. The aims of the project were set out in the original proposal. The main objective of the research is: **to work with industry and government to help tackle the main challenges associated with microgeneration.** Its more specific aims were:

- To make an original academic contribution that focuses on the effect of microgeneration on consumer-supplier relationships, on the wider energy system, and on developments in housing;
- To develop a set of business models for microgeneration investments that reflect a variety of approaches to ownership and operation;
- To validate these business models with data from real microgeneration installations and possible future developments in collaboration with industry and government;
- To identify possible modifications in technical standards, regulatory frameworks and institutional arrangements to the uptake of microgeneration in the UK; and
- To work with energy and housing policy makers who are responsible for implementing these modifications.

These aims and objectives have largely been fulfilled by the project. A number of challenges affected the fulfilment of the objectives. Section 7 of the End of Award Report Form provides further details of these and their impact on the project.

Methods

Three models for microgeneration deployment

The organising framework for the project was provided by three microgeneration deployment models (Watson, 2004). The models were inspired by the different visions for microgeneration. Some visions highlight the potential of microgeneration to fundamentally change the energy system by shifting its centre of gravity away from large-scale 'top-down' infrastructure towards more local 'bottom-up' micro-grids (The Economist, 2000). Others emphasise the potential contribution of microgeneration to the UK's environmental goals. The Green Alliance's Micro-generation Manifesto argues that microgeneration technologies can enable individuals to play a part in attaining these goals (Collins, 2004).

The models developed for this project do not capture all possible visions. They were designed to reflect different roles for consumers and energy companies, and a range of technical and institutional implications. The different role consumers could take was of particular interest. Consumer involvement ranges from a passive role to a more active role in microgeneration investment and operation. The former role does not imply substantial change. The latter sees consumers as becoming more active as financial investors and as contributors to policy goals through behavioural change (Dobbyn and Thomas, 2005). This more active role is associated with 'co-provision' (van Vliet, 2004) – the provision of energy services by a partnership of individuals, communities, the private sector and the State. The philosophy of co-provision has been widely discussed within government in recent years (Halpern, Bates et al., 2004; Willis, 2006). Advocates cite the need for citizens to share the responsibility for public service in areas such as health and education.

The three alternative deployment models applied in the project are shown in Figure 1 as 'Plug & Play', 'Company Driven' and 'Community Microgrid'.

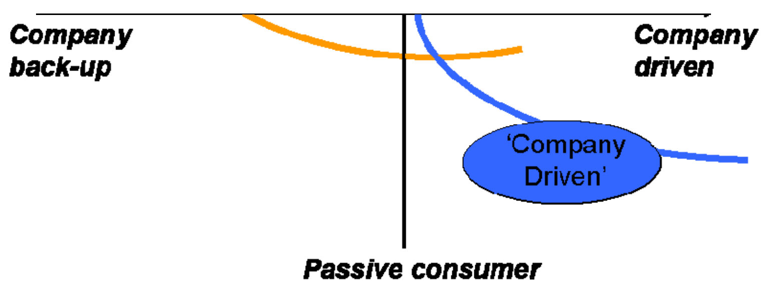

Figure 1: Deployment models for microgeneration technologies

Under a 'Plug & Play' model the homeowner purchases a microgeneration unit and will recoup their investment by a reduced electricity bill and potentially by other sources of income. These include payment for units of electricity exported to the grid and incentives for renewable electricity generated.

'Company Driven' approaches include financing and operation by an energy service company and could ultimately mean that the microgeneration unit will be controlled remotely and operated according to the company's needs. This could help balance supply and demand, and to avoid buying electricity from the wholesale market. In the short term it is however more likely that microgeneration units will be part of domestic energy service packages that do not include remote control[2].

Alternatively, microgrids could be used for the deployment of microgeneration in a local area using a 'Community Microgrid' model. This approach could be based on private networks. This would increase the economic value of the micro-generated output due to avoidance of network charges that constitute up to one third of the average UK electricity bill.

Applying the models

These three models were analysed from several perspectives. The diagram in Appendix 1 shows the main activities, which of the three participating universities carried them out and how these were integrated. The analysis comprised three elements: quantitative calculations of technical and economic performance; qualitative assessments of the impacts on the energy system, housing designs and consumer acceptance; and an examination of policy and regulatory implications.

The quantitative analysis included data collection and modelling to characterise the half-hourly performance of three microgeneration technologies: micro-wind, solar photovoltaics (PV) and micro-combined heat and power (micro-CHP)[3]. The project team obtained real data for electricity demand and solar PV output from 9 houses in a social housing scheme in Havant. The occupancy of these houses included a family with young children, a single retired person and a young professional couple.

Models were developed for micro-CHP and micro-wind since real data was not yet available. Whilst the project intended to use data from the Carbon Trust's micro-CHP field trial (The Carbon Trust, 2005), this data had not been made public. Instead, a building simulation package, TRNSYS, was used to generate electricity output profiles. For micro-wind, a new model was developed using wind data 10-30m above ground level from 6 sites around the UK (Bahaj, Myers et al., 2007). This data was corrected for height and the effect of surrounding structures, trees etc. Both corrections lead to significantly lower wind speeds. The corrected wind speeds were combined with power curves for micro-wind devices of up to 1.5kW output to generate half-hourly electricity output data.

The output data for each technology was processed using an economic spreadsheet model to generate payback times for each technology. The impact of different types of installation such as house type and location were examined. A number of potential policy developments such as changes in fiscal rules were also tested. Within the Company Driven model, three different energy service contracts were assessed (Watson, Sauter et al., 2006):

- A standard supply contract with an upfront payment by the consumer;
- A lease contract with a regular lease payment and an upfront payment; and

[2] For this reason, the name of this model was changed part-way through the project from 'Company Control' to 'Company Driven'.
[3] For more details of the quantitative models and their assumptions, see Watson, J., R. Sauter, et al. (2006). Unlocking the Power House: Policy and system change for domestic microgeneration in the UK. Brighton, University of Sussex.

- A contracting arrangement where the customer pays for the heat consumed instead of the gas delivered, but continues to pay for the electricity consumed.

Whilst it was possible to carry out this economic analysis for the Plug & Play and Company Driven models, it proved to be more difficult for a Community Microgrid model. The project did not have the resources to develop a more complex economic model of a microgrid. Therefore, a decision was taken to analyse this model from a qualitative perspective.

Each model was assessed from a number of qualitative perspectives. One key question was to what extent microgeneration might be a 'disruptive technology' (Christensen, 1997). A large technical systems approach was used to analyse this issue by assessing the impact of microgeneration deployed using each of the three deployment models on different aspects of the energy system. At the same time, some further conceptual work was carried out to understand what these models might mean for the social acceptance of microgeneration by consumers (Sauter and Watson, 2007b).

Once the first economic results were available, semi-structured interviews were conducted with a range of interested actors including microgeneration developers, housing and construction companies, energy companies, policy and regulatory authorities (see full list in Appendix 3). Interviewees were asked about the modelling assumptions and policies to check plausibility and inclusiveness. The interviews also discussed potential policy and regulatory changes and, where relevant, possible business models for companies. The housing and construction industries were treated slightly differently since microgeneration technologies are less well known in these industries. In addition to interviews, a workshop was held at Imperial College in May 2006 for these industries to provide information and gather more collective views.

Throughout the project, the team were advised by an advisory group from government, industry and academia (see Appendix 2). The group met three times and gave valuable advice on activities and emerging results. In addition, team members met in between advisory group meetings at regular intervals. A key issue raised early on by the advisory group was the need to integrate the various activities and outputs that were being conducted from a range of disciplinary and interdisciplinary perspectives. The project schematic that is reproduced in Appendix 1 shows how integration was achieved. All aspects of the project are reflected in the public report *Unlocking the Power House* (Watson, Sauter et al., 2006) that summarises the main results.

Results

The quantitative appraisal of three microgeneration technologies showed that the performance of these technologies varies significantly. Solar PV's output varies with orientation – with south facing arrays performing best. Stirling engine micro-CHP units are more economic in large and/or inefficient houses that have high heat demand. Micro-wind is likely to be most economic in areas with an excellent wind resource such as rural or seaside locations – if installed in many urban areas, its performance will be poor.

Impact on carbon dioxide emissions

The appraisal included a brief analysis of potential carbon emissions savings. CO_2 savings depend on assumptions about emissions from displaced electricity from the UK grid. The analysis compared the CO_2 emissions from a micro-CHP unit with a thermal efficiency of 85% to a new condensing boiler with an efficiency of 92%, assuming CO_2 emissions of 0.19

kg/kWh of gas. If micro-CHP replaces electricity from CCGTs, CO_2 emissions are around 10% lower. For the UK grid supply mix the savings are around 20%, and for coal they up to 30%. As an example this means for a 2 bedroom bungalow with an annual heat demand of around 17,750 kWh, yearly savings are 460 kg of CO_2 (compared to CCGT), 1,051 kg of CO_2 (average UK grid), or 1,722 kg of CO_2 (compared to a coal plant).

Annual CO_2 savings for micro-wind and PV are calculated only on the basis of the carbon dioxide factor for grid-displaced electricity suggested by the Building Regulations – 0.568 kg/kWh (ODPM, 2006). For a good micro-wind site (1.5kW turbine, load factor 0.13) with an annual output of 1680 kWh this leads to annual CO_2 savings of 956 kg of CO_2 and for a south facing 1.5kW PV array, the saving is 726 kg of CO_2.

Overall, these calculations show that the three micro-generation technologies are likely to reduce CO_2 emissions significantly. Whilst this conclusion is robust for solar PV and micro-wind at good sites, the ongoing Carbon Trust trials indicate that our calculations might overestimate the savings from micro-CHP (The Carbon Trust, 2005).

Payback times under current conditions

The economic analysis of these three technologies shows that microgeneration is not particularly attractive for consumers or energy companies under current conditions. Some results for the analysis of a 'Plug & Play' deployment model are summarised in Figure 2.

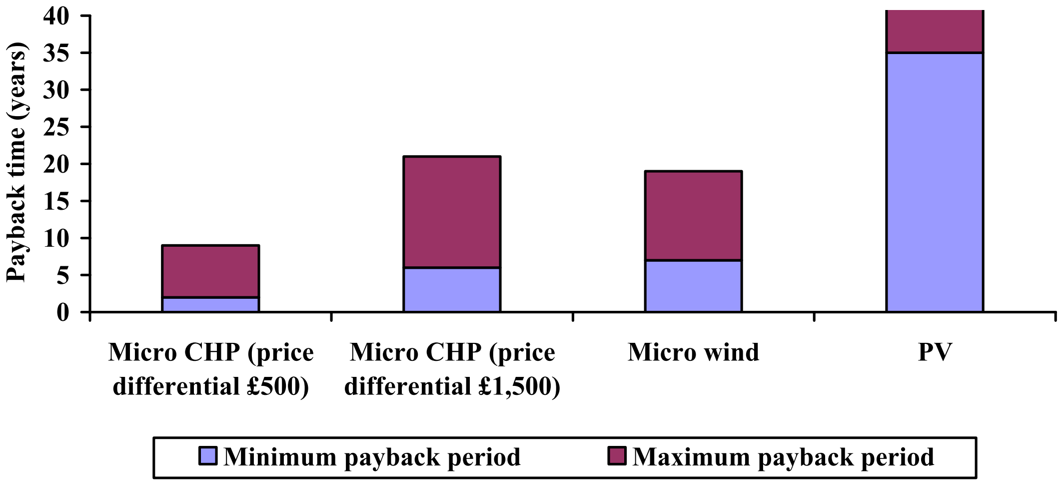

Figure 2: Payback times under current conditions for 'Plug & Play'

For micro-CHP payback times under current conditions depend on the price differential in comparison with the purchase of a new condensing boiler. For a £500 price differential, payback time ranges between 2 years (for a very high heat demand of almost 40,000 kWh per year) and 9 years (for a low heat demand of around 7,200 kWh per year). For a £1,500 price differential, payback time varies from 6 years and around 20 years. For micro-wind payback times are between 7 and 19 years depending on location. For the two south-facing 1.5kW PV arrays, payback times vary from 35 to 48 years depending on how much of the micro-generated output is consumed on site.

The Company Driven models of microgeneration deployment were also analysed under current conditions. For company investment in micro-CHP two cases were compared: first, a 2 bedroom bungalow with an annual heat demand of 17,750 kWh and annual electrical power output of 2,380 kWh and second, a 4-bed detached house with annual heat demand of 31,440 kWh and an annual electricity generation of 3,760 kWh. Under our assumptions, a standard contract is not viable for the 2-bed bungalow. It would achieve a profit (or positive net present value, NPV) in year 10 for the 4-bed detached house. The lease contract would achieve a positive NPV after 11 years for the 2-bed bungalow and after 7 years for the 4 bed detached house. Micro-CHP contracting would take 20 years for the 2-bed bungalow and 8 years for the 4-bed detached house to reach a positive NPV.

For PV and micro-wind, only lease contracts were tested – in the case of micro-wind for 2 different wind sites. This shows that under current conditions a contract for micro-wind would reach a positive NPV after between 7 and 13 years. A 1.5kW south facing PV installation would achieve a positive NPV in year 14 under our assumptions.

Barriers to adoption

Whilst economics are not the only driver for investment in microgeneration, many consumers are put off by high up-front costs and the long payback times involved (Oxera, 2006). Further barriers to uptake were identified from the literature and the project interviews. These are related to technology, regulation and the lack of information and knowledge. New technologies such as micro-CHP will need to overcome scepticism by customers and demonstrate their technical reliability and performance. Regulation is generally built around the traditional centralised power generation. As a result, microgenerators face regulatory disadvantages – for example the complex administrative procedures to access Renewable Obligation Certificates for renewable microgeneration technologies. Finally the lack of sufficient information and knowledge can prevent people from considering the installation of a microgeneration in their home.

Some of these barriers are now being addressed through the government's Microgeneration Strategy (Department of Trade and Industry, 2006b) and the Climate Change and Sustainable Energy Act. These initiatives reflect the consensus that microgeneration has a desirable role to play in our energy future and will improve the attractiveness of these technologies. However, these measures may not go far enough since they fail to take into account some of the implications of microgeneration.

Of particular importance is the failure of policy to give investors in microgeneration a 'level playing field'. In practice, this would mean giving consumer-generators access to the same incentives as large power producers - incentives that include tax breaks, access to the wholesale electricity market and access to Renewable Obligation Certificates (ROCs). For consumers who might be more likely to accept microgeneration if it were provided by energy service companies (Sauter and Watson, 2007b), current policy also fails to deliver. Although there were proposals in the Energy Review to encourage energy companies to provide energy services rather than energy supply, these proposals will not be implemented until at least 2011 (Department of Trade and Industry, 2006a).

Testing a level playing field

Our research analysed to what extent a level playing field could enhance the uptake of microgeneration technologies in the UK. Under a level playing field consumers as 'co-providers' would have access to the same fiscal treatment and benefits as energy companies already have. Furthermore the treatment of micro-generated output in the settlement system would have to change.

The current fiscal system disadvantages householders in two ways. Private individuals purchasing a microgeneration unit or investing in energy saving measures do not have access to capital allowances (Chesshire, 2003). Companies can partially offset their investments against profits and reduce their tax burden. In addition, companies offering energy service contracts to domestic customers do not have access to these allowances either. This is despite the statement in the Energy Review that 'the principle that fiscal measures can play a part in achieving our environmental goals has been established' (DTI, 2006: 131).

Therefore, our analysis investigated what the effect would be if all investors in energy infrastructure were given access to the same tax benefits. A 'level playing field' in tax treatment would include the following changes:

- Individuals investing in microgeneration technologies will have access to the same capital allowances as companies have already;
- Enhanced capital allowances will be available for all microgeneration technologies;
- Capital expenditure within domestic energy service contracts will qualify for capital allowances.

To implement these changes, individuals could use the current system of tax returns. Alternatively, a new 'salary sacrifice' scheme could be set up for microgeneration and energy saving investments. Employees would be able to pay part of an employees salary into a fund (or to repay a loan) before tax is deducted. This would allow limited grant funding to be targeted at those on lower incomes.

The second important change to establish a level playing field would be in providing access to half-hourly pricing for micro-generated output. This would require the wholesale electricity market's settlement system to be extended. Based on smart metering technology this would not only provide real-time pricing to homeowners but also enable a range of possibilities for demand management and consumer engagement. Smarter designs of meter are now available that can measure real-time imports and exports, and can be linked to display systems for consumer feedback. Research has suggested that smart meters and display systems could stimulate behavioural change amongst consumers (Darby, 2006).

Enhanced capital allowances (ECAs) and half-hourly pricing of exports were applied to both the Plug & Play and Company Driven deployment models to assess their impact. Only the results for micro-CHP are given here as examples (see Figures 3-5). Results are given in full in the *Unlocking the Power House* report (Watson, Sauter et al., 2006).

Within the Plug & Play model, householders were assumed to have access to ECAs, to pay income tax on earnings from power sales, to have access to Renewable Obligation Certificates and to get paid the real time system buy price for exports. For comparison an export reward of 5p/kWh[4] was used for micro-CHP in order to test the aim of the Microgeneration Strategy for a 'fairer reflection of the value of the exported energy' (Department of Trade and Industry, 2006b: 25).

The analysis compared a £500 and a £1,500 price differential between the costs of a micro-CHP unit and a replacement boiler. It provided a range of payback times for low heat demand (and low power output) and high heat demand (and high power output). Assuming a price

[4] A 'fair' export reward for each technology was calculated by dividing the annual value of exports based on half hourly wholesale 'system buy prices' for 2005 by the total amount of electricity exported during that year.

differential of £1,500, Figure 3 shows that a 'level playing field' provides the most attractive framework for homeowners. It more than halves payback times for the low heat demand from 21 years to 9 years for a 40% marginal tax rate payer. For an export reward of 5p/kWh, the maximum payback time would be 14 years.

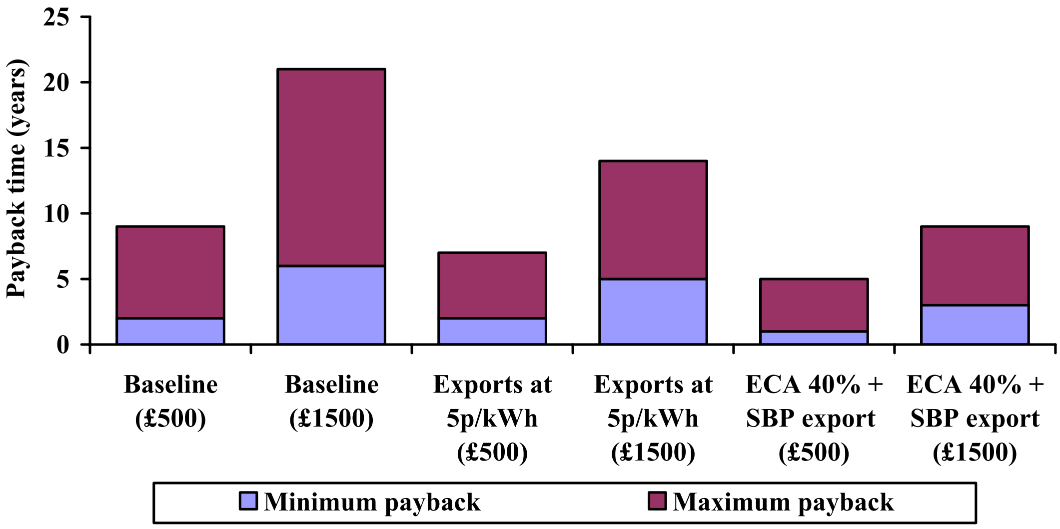

Figure 3: Micro-CHP payback times with a level playing field for 'Plug & Play'

For Company Driven investments the analysis shows how company access to capital allowances for expenditure as part of energy service contracts would increase the economic viability for each technology. It compares access to standard capital allowances (SCA) and enhanced capital allowances (ECA). Furthermore it tests the influence of a 10% electricity price increase per year and reduced installation costs in 2016 using the Energy Saving Trust experience curves (Energy Saving Trust, 2005a).

For a 2 bed bungalow, access to capital allowances can reduce payback times for micro-CHP from above 20 years to 11-14 years under a standard contract. Times are reduced from 11 to 7-8 years under a lease contract, and from 20 to 11-12 years under a contracting arrangement. Similarly for a 4 bed detached home a positive NPV would be reached in year 5 or 6 instead of in year 10 under a standard contract, in year 5 under a lease contract, and year 5 or 6 instead of in year 8 with contracting. Figures 4 and 5 summarise these results.

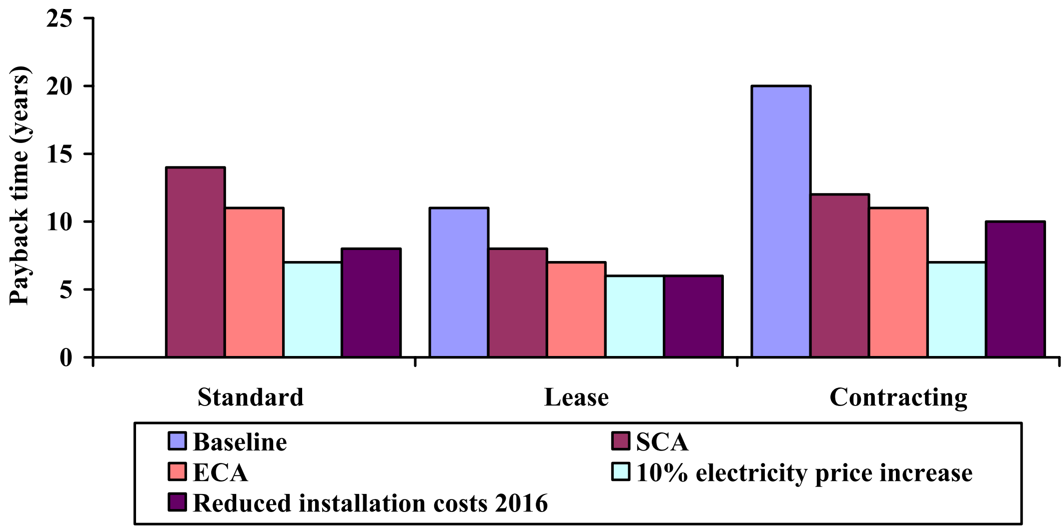

Figure 4: Micro-CHP payback times with a level playing field for 'Company Driven' (2 bedroom bungalow)

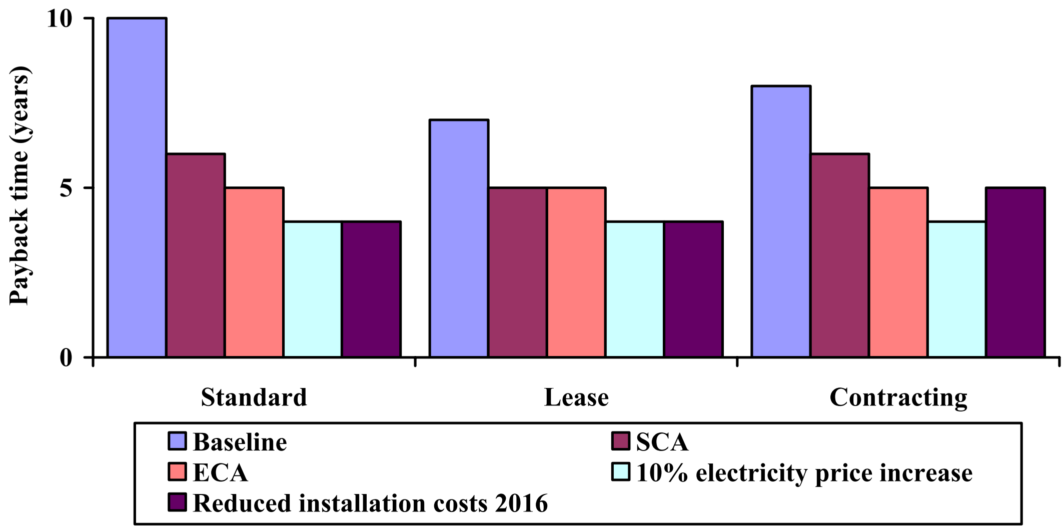

Figure 5: Micro-CHP payback times with a level playing field for 'Company Driven' (4 bedroom house)

Such a level playing field for investments in microgeneration would considerably improve the economic attractiveness for Plug & Play and Company Driven models. For those technologies that are eligible (micro-wind and PV), payback times would fall to levels currently seen by recipients of grants from the Low Carbon Buildings Programme. Furthermore, the use of tax and other incentives might overcome the cyclical nature of government grant funding which adds unnecessary uncertainty for consumers and installers.

A disruptive technology?

These potentially more wide-ranging reforms to level the playing field for microgeneration led the research to consider disruptiveness (Christensen, 1997). The project team analysed the extent to which the three microgeneration deployment models might lead to incremental or radical changes to the energy system (Sauter and Watson, 2007a).

This analysis built on the concept of large technical systems (Hughes, 1983) to broaden out the firm-based analysis of disruptiveness that has often been used (Abernathy and Clark, 1985). It showed that microgeneration's impact on the system depends heavily on the model of deployment, the driving forces behind deployment and the consequent arrangements for ownership financing, operation and technological integration. For each of the models, some impacts are likely to be disruptive whilst others will be more incremental.

Whilst the consumer driven Plug & Play model is more disruptive for the relationship between system participants (eg consumers and suppliers), some variants of the Company Driven model imply more radical changes at the technology level since they require more sophisticated load management solutions. On the other hand, an expansion of microgeneration by incumbent energy companies does not imply major changes to industrial structure. Most of the changes required could be technical in nature. However, Plug & Play and Community Microgrid will involve a considerable number of new actors (e.g. regional market operators, new types of energy company) and/or old actors in a new position in the system (eg consumers acting as co-producers). Community Microgrid could be the most disruptive of the three models, with potentially radical impacts across the electricity system.

Under any of these models, the impacts of microgeneration could go beyond the system for electricity provision. They may have knock-on effects on other technical systems, such as those for housing design/construction and for telecommunications. Policies and regulations will need to take these effects into account.

Implications for infrastructure

The project interviews highlighted significant implications of microgeneration for the UK's energy infrastructure. The case of metering has already been mentioned. Microgeneration could present an opportunity to modernize the UK's meter stock. It would make sense to install a 'future proof' smart meter when microgeneration is installed since the additional costs would be small. This would allow consumers to take advantage of market-reflective prices for their exports. Going further, the government's current cautious approach to smart meters is questionable (Department of Trade and Industry, 2006a). A national roll-out could aid future integration of microgeneration and would also facilitate a broader energy service market – a market that might include more Company Driven deployment.

Our interviews and workshop also showed that there are significant opportunities for microgeneration in new construction developments. The Climate Change and Sustainable Energy Act encourages local authorities to set targets for this. Integrating microgeneration in new housing designs could reduce costs. Innovations in IT and telecommunications will enable the integration of microgeneration technologies while improving the general performance of the buildings. The development of affordable home automation systems based on networked devices might eventually help to maximise the efficiency of energy usage in the home and integrate microgeneration fully. In addition, evidence from Germany shows that it is desirable to include flexible service areas and space (e.g. as cellars) in new buildings so that future developments in microgeneration and home energy automation can be accommodated.

There are also implications for the UK's energy network infrastructure. If sustainable visions for developments such as Thames Gateway are to be realised (Department of Trade and Industry, 2006a), strong intervention is likely to be required by government. Such developments are substantially different from the UK's current energy system. In the absence of strong intervention, an opportunity for the implementation of local energy systems based on Community Microgrid models (including heat networks) could be lost. Energy regulation has a role to play here too. The Registered Power Zone scheme developed by the regulator, Ofgem allows electricity network companies to innovate and recover costs from consumers. So far, the rules governing this scheme have been too restrictive to rebuild their capacity for innovation.

Overall, the research showed that microgeneration can make a powerful contribution to a sustainable energy future. Microgeneration can be both a result of changes in existing energy systems and potentially the cause of radical change. Our research has underlined the interdependence of technical, institutional and social factors that inhibit or enable the diffusion of sustainable technologies. Technically, energy networks will have to be able to cope with two-way flows. Policies, regulations and institutions will need to change and to acknowledge that the distinction between energy supply and demand is not as sharp for micro-generators. Finally, consumers will have a new position in the energy system – whether as hosts of microgeneration installed by company or as 'co-providers' of their own energy services.

Activities

A variety of activities have been carried out by the project team. The project participated in the ESRC Sustainable Technologies Programme network on the governance of sustainable technologies co-ordinated by Dr Joseph Murphy. Team members took part in two meetings – in Milton Keynes in 2004 and in Edinburgh in 2005 – and hosted the third meeting in SPRU in 2006. The main output was a book: *Governing Technology for Sustainability* which was published by Earthscan in January 2007.

The project team collaborated internationally with a German research programme on Transformation and Innovation in Power Systems (TIPS) funded by the Germany Ministry of Research[5]. Jim Watson is a member of the TIPS programme advisory board. A joint book chapter (see Appendix 4) is being written which contrasts microgeneration in the UK and Germany. They also worked with a Swiss project investigating microgeneration business models and consumer attitudes. Activities included presenting at a PhD workshop and an academic workshop on the social acceptance of renewable energy in January 2006[6]. The latter led to a paper by SPRU team members for a special issue of *Energy Policy*.

Several conference papers have been presented (see Appendix 4). These included papers to national UK conferences (the British Institute for Energy Economics) and international conferences (e.g. the World Renewable Energy Congress). Numerous other presentations were made including to the 2005 open meeting of the International Human Dimensions Programme, the Royal Academy of Engineering 'Energy 2100' event, a University of Brighton sustainability conference, Greenwich City Council and SEEDA (South East England Development Agency).

The project has also actively engaged with policy makers, parliamentarians, industry and the media. Regular feedback was obtained from the project advisory group (see Appendix 2). This engagement also included submissions to government consultations, participation in

[5] http://www.tips-project.de/
[6] http://www.iwoe.unisg.ch/org/iwo/web.nsf/wwwPubInhalteGer/weitere+Veranstaltungen?opendocument

workshops, evidence to House of Commons Select Committees and interaction with policy reviews. Further details are given below under 'Impacts'.

Outputs

Throughout its duration, the project team have disseminated their results in a variety of ways. Highlights are discussed in section 2A of the End of Award Report Form. A full list of project outputs is provided in Appendix 4 of this research report. These included academic publications, policy-oriented reports and submissions, and conference presentations.

Impacts

The project's outputs have informed policy and parliamentary discussions in a number of ways. The clearest evidence of this is a Parliamentary written question from Dai Davies MP about the *Unlocking the Power House* report. In his reply on 30th November 2006, the Minister for Science and Innovation, Malcolm Wicks stated that:

> 'My right hon. Friend the Secretary of State considers that the report "Unlocking the Power House" makes an important contribution to the growing body of research on the deployment of microgeneration technologies and will help to inform the development of the microgeneration aspects of the Energy White Paper.'

A high-level launch event for *Unlocking the Power House* was attended by 70 people. Section 2B of the End of Award Report Form gives further details. This included senior participants from several government departments, industry and other organisations. Following its publication, Unlocking the Power House was discussed with the Stern Review team (it is cited in Chapter 17 of the Stern Report) and the energy group secretariat of the Quality of Life Policy Group set up by the Conservative Party. The Conservative Party leader, David Cameron visited the University of Southampton team involved in the project on the 6th July 2006.

The project contributed to the work of three House of Commons Select Committees. The results of the project were submitted in written evidence to the Environmental Audit Committee (in the Sussex Energy Group's evidence to their inquiry entitled 'Keeping the Lights On') and the Trade and Industry Committee (inquiry into 'Local Energy Networks'). In both cases, project team members were called to give oral evidence. In March 2006, Jim Watson was appointed a specialist adviser to the House of Commons Environment, Food and Rural Affairs Committee in March 2006 to assist with its inquiries into climate change. The second of these inquiries 'The Citizen's Agenda' includes microgeneration in its terms of reference.

The project's results and team members' expertise have been covered by local and national media (see Appendix 4 for a full list). Jim Watson has contributed to items on BBC Online, the BBC World Service, Newsnight, BBC South East news, *The Guardian* and *The Independent*. A briefing session on microgeneration is being organised with the Science Media Centre in March 2007.

The project has also fed insights into industry discussions. This has included contributions to the Micropower Council's Policy Development Group that focuses on a range of issues including fiscal incentives. A number of industry representatives participated in the project advisory group (see Appendix 2). Team members have also met with other companies – for example Ceres Power, a developer of fuel cell technology.

Future Research Priorities

Given the level of interest in microgeneration and the wider agenda of energy saving in the home, there are many opportunities for further research. Some priorities for further work by team members include:

- Further work to monitor the performance of micro-wind technology and develop a better assessment of its limitations and potential. The University of Southampton team members have had some preliminary discussions with the Energy Saving Trust about this.
- Further work on the impact of technologies such as microgeneration, smart meters and information displays on consumer behaviour. Some work on this area is being carried out within the Sussex Energy Group.
- Integration of project results with work led by the University of Southampton under the EPSRC Sustainable Urban Environment programme. Further funding is being sought from this programme with the Sussex Energy Group and other partners.
- Further research on integration between policies to support microgeneration and those to reduce energy demand/carbon emissions in households. These include proposals to encourage household energy services. This is being taken forward as part of the Sussex Energy Group's research on future UK energy policy.

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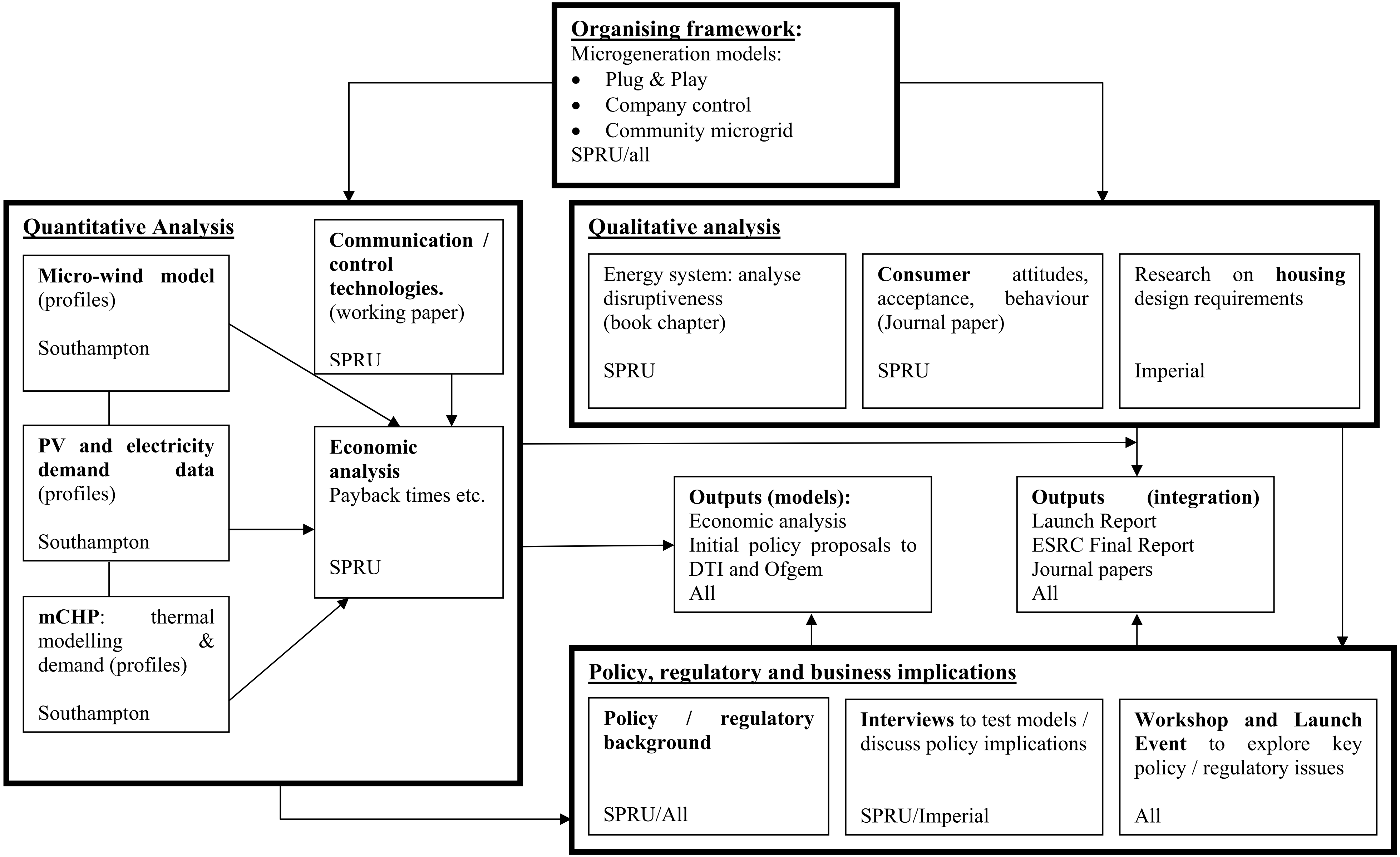
Appendix 1 – Schematic of main project activities and outputs



Appendix 2 – Members of the Project Advisory Group

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The Carbon Trust
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Appendix 3 – List of interviewees

These are given in chronological order.

	Name	Position	Affiliation	Date
1	J. Harrison C. Baldwin	Business Development Manager Regulatory Analyst	E.ON UK	14/11/05
2	R. Logan		Building Research Establishment, Garston	02/01/06
3	S. Noirot	Research Engineer	3E nv, Brussels	10/01/06
4	G. Hartnell S. Berry D. Crowe	Director of Policy Head of Micro Renewables Researcher	Renewable Energy Association	17/01/06
5	R. Courtney	Consultant Engineer		01/02/06
6	T. Parker	Development manager	Sustain Ltd., Bristol	02/02/06
7	I. Stares	Development Manager	Baxi Group UK	21/02/06
8	I. Sidebottom		Jaga Heating Technology UK	27/02/06
9	R. Crisp	Assistant Director, Energy Strategy Unit	DTI	01/03/06
8	J. Lucas	Design Authority Task Leader	ELEXON	06/03/06
10	I. Manders D. Pitcher	 Renewable Energy Project Manager	Energy Conservation and Solar Centre	06/03/06
11	R. Burton	Senior Manager	EDF Energy (retail)	07/03/06
12	A. Jones	Chief Executive Officer	London CC Agency	08/03/06
13	E. Reed	Strategic Development Manager	Energywatch	08/03/06
14	D. Sowden	Chief Executive	Micropower Council	09/03/06
15	W. Patterson	Fellow	Chatham House	10/03/06
16	C. Monaghan	Strategy Manager - Renewables	Energy Saving Trust	10/03/06
17	D. Hirst	Inventor	Responsive Load Ltd	13/03/06
18	O. Knight	Energy Policy Analyst	SDC	14/03/06
19	D. Openshaw	Head of Asset Management	EDF Networks	15/03/06
20	J. Kimber M. Orrill	Head of Energy Efficiency Senior Marketing Manager	Centrica / BG	22/03/06
21	K. MacLean	Head of Sustainable Development	Scottish & Southern	23/03/06
22	J. Costyn A. Wals	Head of Environmental Policy	Ofgem	27/03/06
23	S. Bhatti	Innovation & Quality Manager	Southern Housing Group	29/03/06
24	M. Elliott	Product Development Innovation Group	EDF Energy	28/03/06
25	T. White	Director	Climate Change Capital	11/04/06
26	M. Smith A. Burgess D. Parish		HM Treasury	11/04/06
27	M. Kay	Electricity Regulatory Affairs	United Utilities	09/05/06

		Manager		
28	D. Mitchell		Home Builders Federation	10/05/06
29	B. Richie	Innovation Director	Wilmott Dixon Housing (now inSpace)	15/05/06
30	P. Chelapowski	Director	POKO Architects	06/06/06
31	K. Francis		The Steel Construction Institute	22/06/06
32	R. Morgan		Ceres Power ltd	30/06/06
33	R.K. Venables		Crane Environmental Ltd.	11/07/06
34	R. Shaw		Town & Country Planning Association	04/07/06
35	P.R. Chambers		Pell Frischmann Consulting Engineers Ltd.	11/07/06
36	K. Drage	Operations Director	Geothermal International	11/07/06
37	D. Fisk	BP Prof. in Engineering for Sustainable Development	Imperial College	17/07/06
38	D. Scott	Researcher	Tanaka Business School, Imperial College	10/08/06
39	A. Hawkes	Research Associate	Imperial College	14/08/06

Appendix 4 – Full list of project outputs

Journal Articles

- Bahaj, A.S., L. Myers and P.A.B. James, 2007. Urban energy generation: Influence of micro-wind turbine output on electricity consumption in buildings. *Energy and Buildings* 39 (2), 154-165
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- A.S. Bahaj and James P.A.B., 2004. Direct and indirect benefits of PV in social housing. Invited paper. Proceedings World Renewable Energy Congress (WREC-VIII), Denver, 29 Aug – 3 Sept.

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- Watson, J., 2006. Micropower in the UK: Turning the system upside down? University of St. Gallen PhD Seminar on Sustainable Energy, Idyll Hotel, Gais, Jan 12/13.
- Sauter, R., J. Watson, 2005. Microgeneration: A Disruptive Technology for the Energy System? SPRU-Eindhoven Workshop on Transitions, SPRU, 27th October.
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- 'Green homes 'deserve energy bonus'' *The Independent* 9th October 2006; http://news.independent.co.uk/business/news/article1822233.ece
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- Interview with *The World Today* for the BBC World Service, broadcast 16th Nov 2005
- Interview with *Digital Planet*, BBC World Service, broadcast 14th February 2006
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