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Potential for Microgeneration Study and Analysis

Final Report

14th November 2005

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Caveats

While the authors consider that the data and opinions contained in this report are sound, all parties must rely upon their own skill and judgment when using it.

The authors do not make any representation of warranty, express or implied as to the accuracy or completeness of the report. A central element of this report, namely a technology uptake model spanning the period of time out to 2050, is by its nature open to significant uncertainty. The authors assume no liability for any loss or damage arising from decisions made on the basis of this report.

The views and judgments expressed here are the opinions of the authors and do not necessarily reflect those of the DTI.

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Executive Summary

Background

- The Energy Saving Trust, in conjunction with Element Energy Limited, E-Connect and Cambridge University Faculty of Economics, has been commissioned by the DTI to study the UK potential for microgeneration technologies. The technologies included in this study are:
  - solar photovoltaics (PV);
  - wind turbines;
  - small hydro;
  - active solar water heating *;
  - ground source heat pumps (GSHP);
  - bio-energy;
  - small CHP (renewable and non-renewable); and
  - hydrogen energy and fuel cells.
- Microgeneration is defined as any technology, connected to the distribution network (if electric) and with a capacity below 50-100kW. Most domestic installations will be below 3kWe, though thermal systems could be larger.
- Microgeneration could deliver significant efficiency and CO_2 benefits, through increased use of renewables, utilisation of "waste" heat from electricity generation or renewable heating fuels, and avoidance of losses in the electricity transmission and distribution system.
- For microgeneration to have an impact on the UK electricity system, units must be installed by consumers in their millions. This will require a new highly decentralised approach to energy planning and policy. In addition a new understanding of the likely interaction between microgeneration technology and its multitude of potential end users (the general public) must be developed.

(*) Active solar water heating is sometimes referred to as 'active solar heating' or 'ASH' in this report.

The UK Microgeneration industry overview, reveals a young but growing industry.

Current status of microgeneration in the UK

- An industry consultation was used to feed into an assessment of the current status of microgeneration, and more detailed comments taken from a series of roundtables organised independently of this project. .
- There are currently less than 100,000 microgeneration installations in the UK (of which most are solar water heaters installed pre-2000). Level of grant funding is closely correlated with the annual number of installations.
- The sectors seeing the most yearly installations are PV and solar water heating, in response to generous grant schemes. The yearly installations in ground source heat pumps and small wind turbines is also increasing rapidly stimulated by the Clear Skies SCHRI program and rapid cost reductions.
- MicroCHP is only just beginning to enter the market, but there is a very large technical effort on both Stirling engine and fuel cell technologies.

Perceived barriers to the introduction of Microgeneration

- The most commonly perceived barriers to the introduction of microgeneration are: legislation, high cost and the level of consumer awareness.
- The “legislation” barrier refers to problems with planning permission and “expensive metering” (also interpreted as low value of exported electricity), and the lack of targets and incentives for renewable heat.
- High cost of technology is an important barrier: most suggestions for overcoming this relate to the provision of appropriate grant schemes although it is generally recognised that grant support cannot be a long term mechanism.
- Most suggestions on awareness focus on establishing a centrally co-ordinated program to improve information and advice to installers and end users of microgeneration technologies.

Overview of approach to UK market simulation.

The cost of energy from each technology is modelled for the period 2005 – 2050:

- The cost of each technology installed is predicted for the period 2005 – 2050. This is achieved using learning curve analysis.
- The capital installed costs are used to calculate the cost of energy from each system. This is based on factors such as system lifetime and efficiency, and the inclusion of running costs such as maintenance and fuel where applicable.
- The cost of energy values allow prediction of the date at which a technology becomes cost effective.

Application to the UK market:

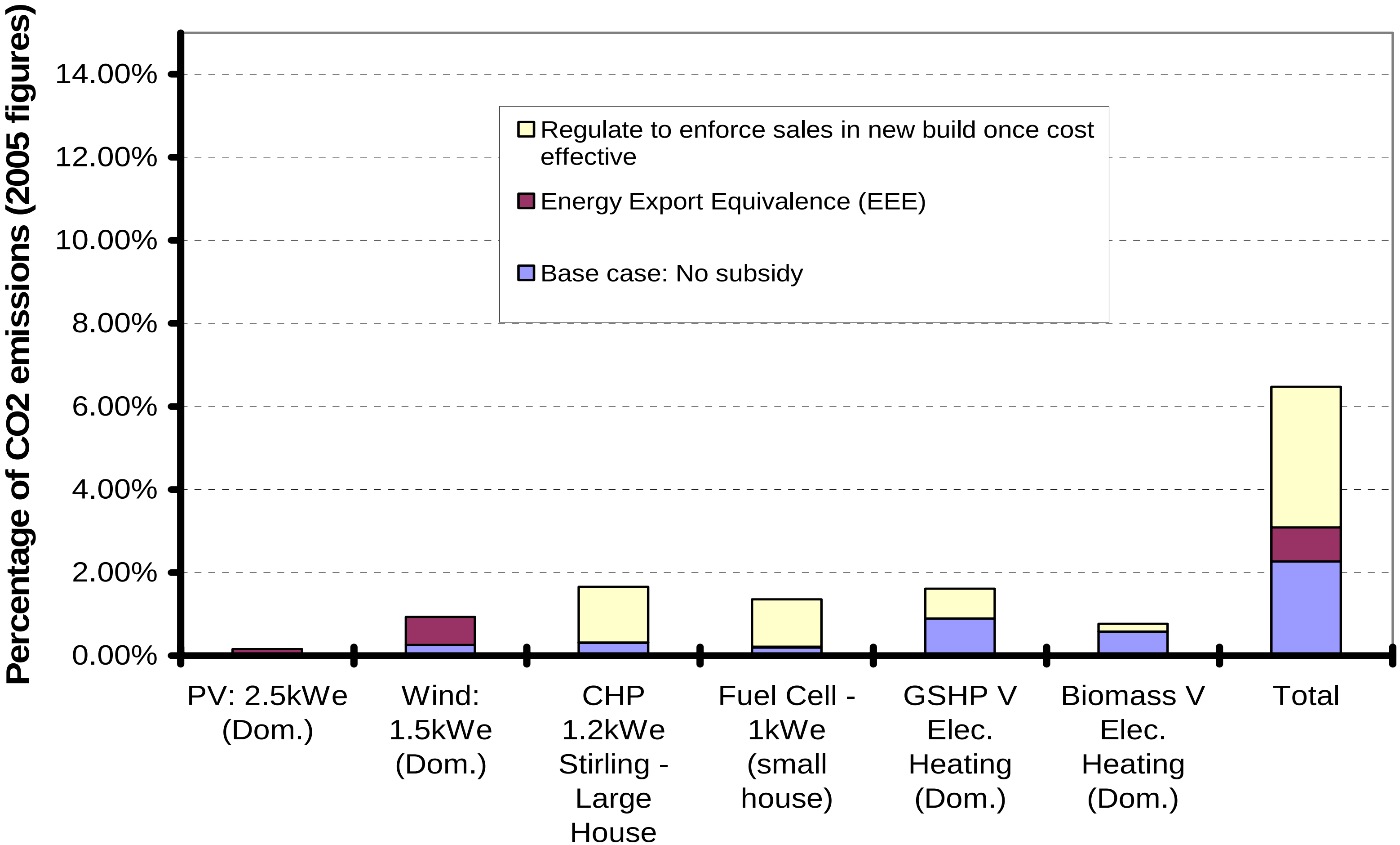
- The cost of energy from above is used to predict the market growth in the UK.
- This is achieved by comparing the generated energy cost with the relevant baseline costs (e.g. grid electricity for PV).
- Technology-dependent market growth conditions are applied including factors such as maximum growth capability and total market size.
- This allows the installed capacity (in terms of capacity, CO_2 savings or investment) to be evaluated for the period 2005 -2050.

Market support

- The above costs are based on un-supported technologies in a commercial environment.
- The model allows for additional market support to be modelled. This includes mechanisms such as capital support, soft loans, Renewable Obligation Certificates (ROCs), regulation and metering options.

Timely regulation of cost-effective technology will be important to achieving significant CO_2 reductions by 2030.

Percentage of CO2 emissions saved due to microgeneration in 2030: (based on 2005 CO2 emissions in the domestic sector).



(*) Based on 198 MT CO_2 p.a. arising from the domestic sector (UK Energy Sector indicators 2005, DTI).

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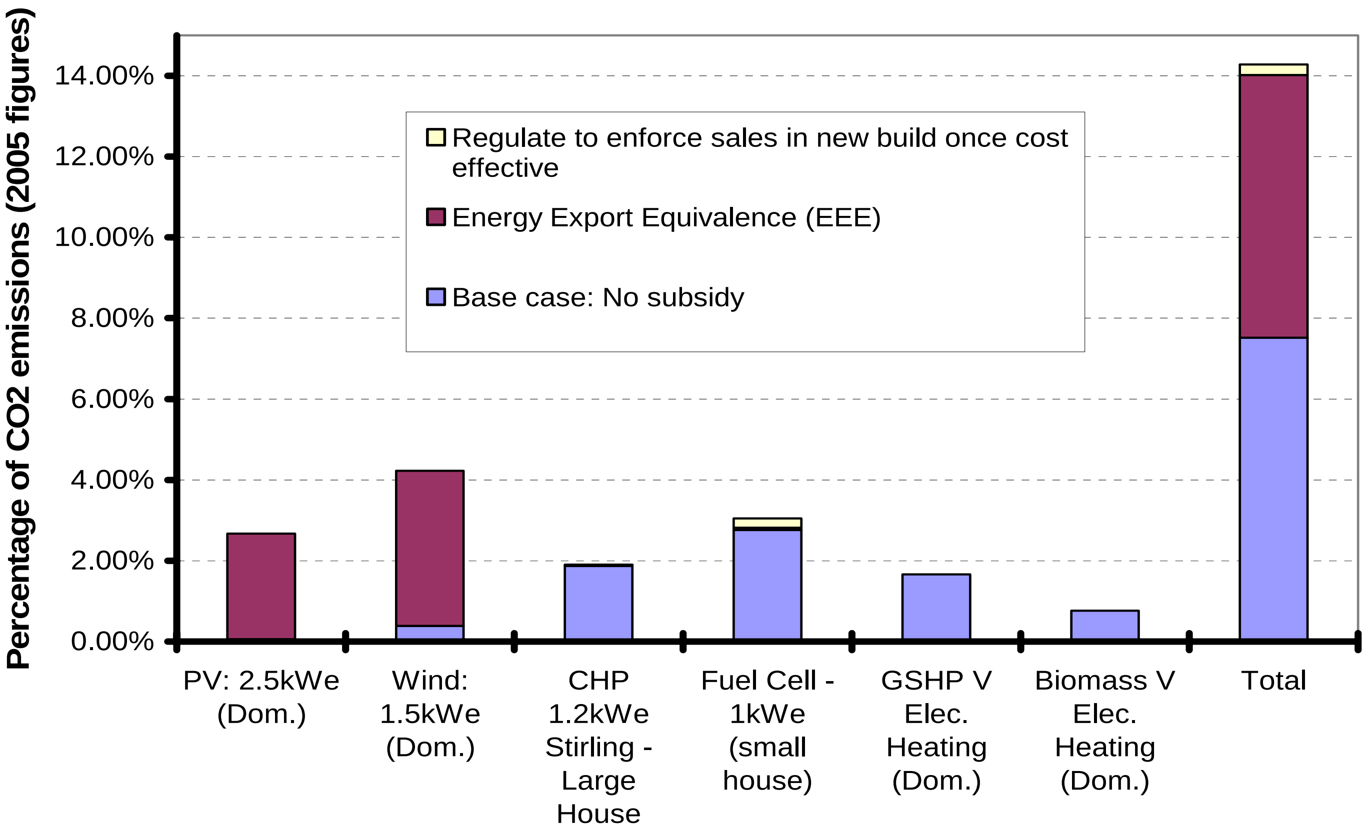
A fair value on exported electricity is vital to achieving significant CO_2 savings by 2050.

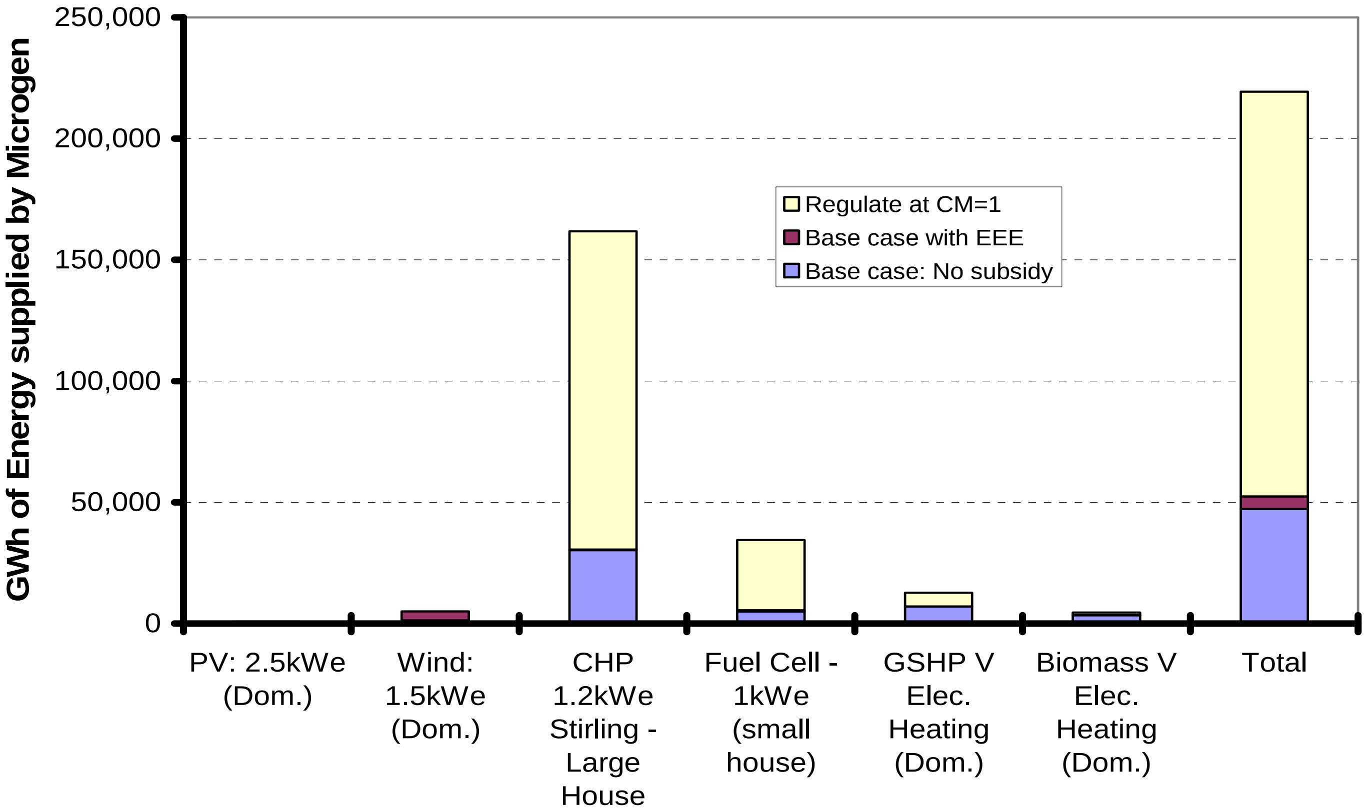
Percentage of CO2 emissions saved due to microgeneration in 2050: (based on 2005 CO2 emissions in the domestic sector).



- Larger fuel cells could make an even more significant contribution, but this could have more implications for the operation of energy markets and the grid.
- Data here is based on 198 MT CO_2 p.a. arising from the domestic sector (UK Energy Sector indicators 2005, DTI).
- Domestic sector CO_2 emissions are approx. 30% of UK emissions (including transport).
- Note: If using 150MT CO_2 p.a., the total 2050 domestic sector CO_2 saving rises to 18%. (This figure used in "Options for a Low carbon Future" AEA 2002.

Timely regulation of cost-effective technologies will be important to achieve significant microgeneration capacities by 2030.

GWh of energy generated due to microgeneration in 2030

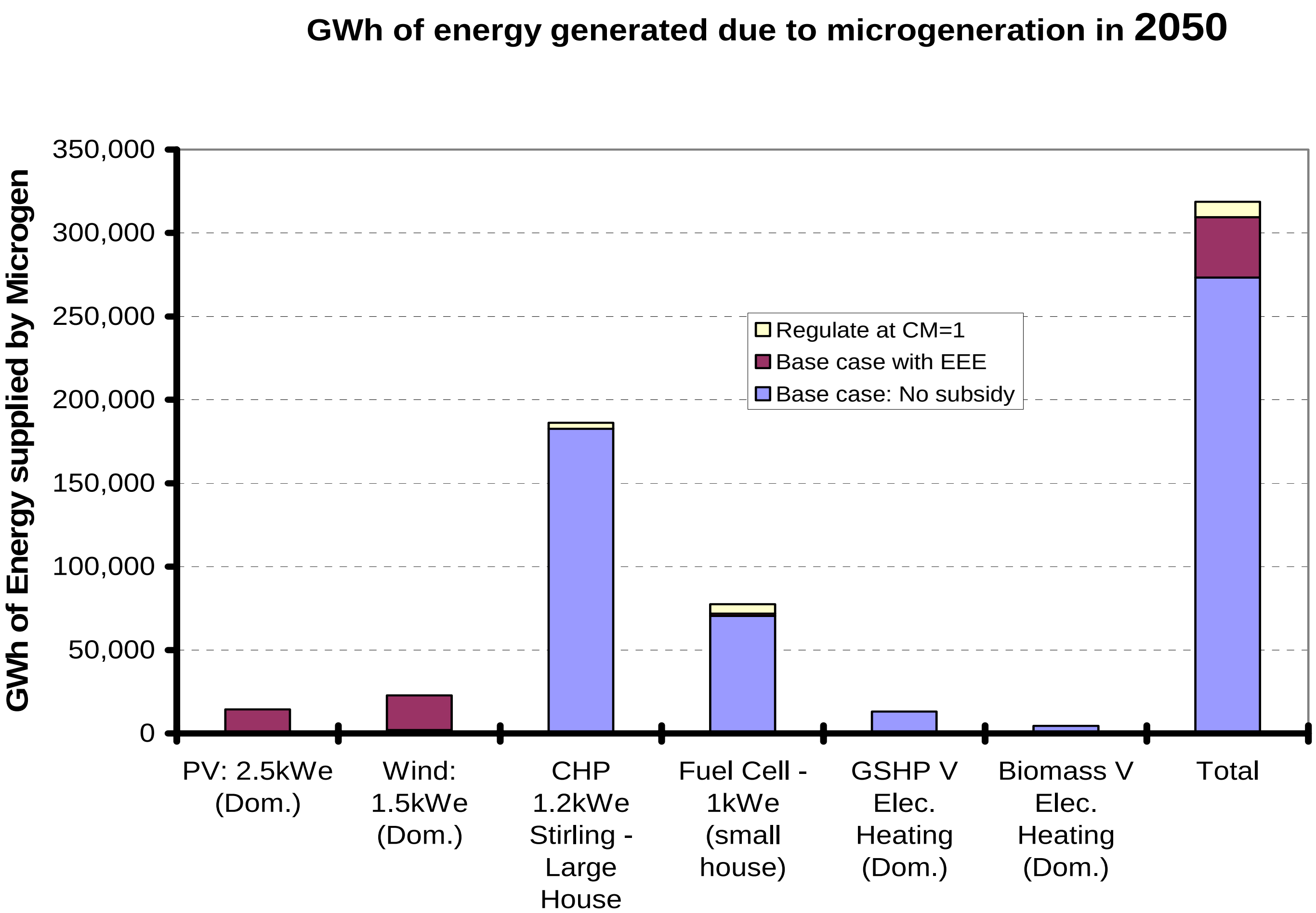


- Data in the graph is for total output, including heat and electricity.
- Electricity demand in UK is circa 380 TWh/annum, or 380,000 GWh/annum (2000 figure). (Electricity only).

PV = Photovoltaics; CHP = Domestic Combined Heat and Power; GSHP = Ground Source Heat Pump.

EEE = Energy Export Equivalence (energy exported to the grid is given a value equivalent to the cost of imported energy).

By 2050, fairer valuation for exported electricity is vital for assisting renewable microgenerators.



- Data in the graph is for total output, including heat and electricity.
- Electricity demand in UK is circa 380 TWh/annum, or 380,000 GWh/annum (2000 figure). (electricity only).
- Summing all microgen. electricity outputs in 2050 gives circa 100TWh/annum (approx 25% of UK 2005 Electricity demand).
- This capacity could be reached sooner subject to improved regulation and support.

Stirling engine CHP: this could be a major contributor to UK domestic energy requirements.

Current status and potential

- Currently, the technology is not far from being cost effective. This is strongly dependent on achieving lifetime and maintenance costs close to those of the incumbent (gas boilers).
- Following likely commercial introduction circa 2010, this sector grows quickly as costs reduce further.
- After cost effectiveness is achieved, as installations grow from very low (current) levels, it could take another 10-15 years before a significant proportion of domestic energy is generated by this technology.
- This technology is likely to be successful in larger dwellings with higher than average heat loads. Over 8 Million homes could be reached by 2050, supplying 40% of domestic heating requirements and 6% of UK electricity supplies.

Support required

- Mass market uptake could be accelerated through energy supplier programmes and then by a requirement for use within the Building Regulations.
- Such regulation need only occur when the technology is cost effective for the consumer, and therefore would be consistent with the current approach in Building Regulations, for example to the requirement for use of 86% efficient boilers at current costs.

Fuel cell CHP: once commercialisation is achieved, this could be the dominant microgen electricity generator.

Current status and potential

- This technology is more suited to smaller dwellings with lower than average heating loads. Any future reductions in domestic heating loads (through higher standards for building fabric) would increase the market for this technology.
- Commercialisation is strongly dependent on achieving lifetime and maintenance costs close to those of the incumbent (gas boilers).
- Cost effective introduction is likely circa 2015. Thereafter costs continue to reduce significantly.
- In 2050, with appropriate support, small fuel cells could supply 9% of UK electricity requirements and reduce domestic sector CO_2 by 3%.

Support required

- As with Stirling engines, mass market uptake could be accelerated through energy supplier programmes and then by a requirement for use within the Building Regulations.
- Such regulation need only occur when the technology is cost effective, and therefore would be consistent with the current approach in Building Regulations, for example to the requirement for use of 86% efficient boilers at current costs.
- An alternative (3kWe) fuel cell has also been modelled. This technology is heat led and oversized relative to domestic electricity demand and so exports a significant fraction of its electrical output. This technology is highly dependent on achieving a more equitable value for exported electricity (EEE). Without this, this technology could produce 1.6% of UK annual electricity demand, but with EEE, this could rise to 18%.

Small Wind: commercialisation could be achieved near term, with a significant contribution to CO_2 reduction.

Current status and potential

- Small wind systems are generally not cost effective at present.
- However, a number of new products have recently come to market with potential for significant volume related cost reductions. As a result, mass-commercialisation could occur circa 2015.
- The potential for small wind is significant – there are a number of UK developers, a suitable UK market of significant size and near term potential for significant cost reductions.
- With appropriate support, small wind could supply 4% of UK electricity requirement and reduce domestic CO_2 emissions by 6%.

Support required

- In the short term, this technology will need to be supported through the period of time until commercialisation is achieved (2015). Projections suggest a capital grant of circa 25-50% could be sufficient to support uptake levels until this time.
- However, commercial viability is highly dependent on acquiring a more equitable price for exported electricity (EEE). This would be the single most important market change for small wind.
- Poorly informed planning decisions could increase costs and reduce the market quite significantly. An objective assessment of the environmental impact of domestic small wind systems is required to provide clarity on this issue, followed by guidance to planners on the key issues including permitted development status.

Photovoltaics: a technology with significant potential, but cost of energy is likely to remain high for some time.

Current status and potential

- Photovoltaics are not generally cost effective at present. In many countries (including the UK) significant incentives are required to maintain the market for small grid connected systems.
- There are small markets where PV is already cost effective, including for remote power and in prestige facades.
- Cost effectiveness is not predicted to occur until 2030. However, a technology breakthrough could reduce capital costs and bring this forward towards 2020.
- Lack of planning issues means the market potential for PV is amongst the largest of those studied.
- If cost issues were overcome, this technology could supply almost 4% of UK electricity demands, and reduce domestic sector CO_2 emissions by up to 3%.

Support required

- Significant incentives will be required to maintain the market until commercialisation is reached in circa 2030.
- Thereafter a more equitable value on exported energy (correcting a current price distortion) will be required to ensure commercial viability.

Biomass heating and heat pumps: renewable heating has significant potential for CO_2 reduction.

Current status and potential

- Both biomass heating and GSHP technologies can be commercial when compared against electric or LPG heating. In general the technologies are not competitive with natural gas or oil fired heating.
- Although only a small proportion of the housing market uses electric heating, and only a fraction of these will be suited to biomass or GSHP, the CO_2 savings are disproportionately large (due to the high CO_2 emissions of electric/LPG heating).
- With appropriate support, these technologies could reduce domestic sector CO_2 emissions by 3%.
- These applications would also be likely to contribute disproportionately to alleviation of fuel poverty in low income households living in the hard-to-treat homes off the gas grid.

Support required

- These microgeneration technologies both rely on wet-heating systems to be installed instead of electric and LPG. This could be a significant barrier due to the perceived simplicity of electric heating systems in particular.
- Regulation could therefore be used to improve uptake in preference to electric or LPG in appropriate regions (especially off the natural gas grid). For example incentivisation in the Building Regulations or in local/national planning guidelines.
- For low income households it may be appropriate to use direct grant support through Warm Front and its devolved counterparts.

Solar water heating: limited cost reduction potential results in low growth.

Current status and potential

- Currently the largest microgeneration industry, installing 2000 units annually.
- Generally, solar water heating is not cost effective at present.
- The technology is most effective if replacing electric heating systems.
- However, while capital costs are projected to reduce, the learning rate appears low and it is not likely that solar water heating will provide cost effective water heating over the timescales of the study without substantial grant support.

Support required

- Significant grant funding (on the order of 50% of capital costs) would need to be maintained long term to support the market.
- Lower levels of grant funding, or access to EEC would assist but installation levels would be significantly lower than potential.

Projections of cost suggest that numerous microgeneration technologies will produce cost competitive energy by 2020.

Current status

- Few microgeneration technologies are cost effective at present.
- Notable exceptions are biomass heating and ground source heat pumps which could be cost effective when compared with electric heating systems. Small commercial scale (sub 50kW) CHP units are borderline cost effective at present without a technology breakthrough.
- The rate at which cost competitive technologies enter the market will depend on some key factors:
  - -the speed at which industry can scale up production and installation capacity and skills;
  - -awareness in, and the size of, the early adopter market;
  - -the extent, type, and effectiveness of policy interventions to develop early niche markets.

  There are significant uncertainties in these factors. The contribution that microgeneration can play in the medium term (e.g. in 2020) in the energy supply and carbon emissions reduction therefore needs more detailed examination.

Potential

- A number of microgeneration technologies have the potential to become part of a commercial, mass market decentralised energy system for the UK, supplying a large fraction of UK electricity and heating requirements at a cost competitive with today's supply. In the process substantial quantities of CO_2 emissions would be avoided.
- There is a wide spread in projected dates when cost competitive energy is produced by microgeneration technologies: Stirling engines are earliest (2010-2015), with small wind and fuel cell CHP following circa 2015-2020. Domestic photovoltaics are unlikely to produce equivalent cost energy before 2030.

A model of the likely uptake of each technology has been established, >15% domestic CO_2 reductions possible.

The table below summarises results for CO_2 emissions avoided (expressed as a percentage of UK domestic CO_2 emissions*) for different microgeneration technologies in the uptake model under different government intervention schemes (these results are not necessarily additive).

	PV: 2.5kWe (Dom.)	Wind: 1.5kWe (Dom.)	Biomass V Elec. Heating (Dom.)	GSHP V Elec. Heating (Dom.)	Active Solar V. Elec Heating (Dom.)	CHP 1.2kWe Stirling - Large House	Fuel Cell - 1kWe (small house)	FC: 3kW (large house)
2030								
No subsidy	0.0%	0.3%	0.6%	0.9%	0.0%	0.3%	0.2%	0.1%
Energy Export Equivalence (i.e. exported electricity sold for the same value as imported)	0.2%	0.9%	0.6%	0.9%	0.0%	0.3%	0.2%	0.2%
Capital subsidy of 25%, whilst costs reduce	0.1%	0.9%	0.6%	0.9%	0.1%	0.3%	0.2%	0.1%
Regulation to introduce tech. in all new build once cost effective	0.0%	0.3%	0.8%	1.6%	0.0%	1.7%	1.3%	0.1%
2050								
No subsidy	0.1%	0.4%	0.8%	1.7%	0.0%	1.9%	2.8%	0.4%
Energy Export Equivalence (i.e. exported electricity sold for the same value as imported)	2.7%	4.2%	0.8%	1.7%	0.0%	1.9%	2.8%	5.5%
Capital subsidy of 25%, whilst costs reduce	0.2%	4.2%	0.8%	1.7%	0.1%	1.9%	2.8%	1.3%
Regulation to introduce tech. in all new build once cost effective	0.1%	0.4%	0.8%	1.7%	0.0%	1.9%	3.0%	0.4%

(*) Based on 198 MT CO2 p.a. arising from the domestic sector (UK Energy Sector indicators 2005, DTI).

A substantial percentage of UK electricity demands could be supplied by microgenerators.

The table below summarises results for microgeneration electricity production (expressed as a percentage of UK electricity demands*) for different microgeneration technologies in the uptake model under different government intervention schemes (these results are not necessarily additive).

Percentage of total UK electrical energy demand.	PV: 2.5kWe (Dom.)	Wind: 1.5kWe (Dom.)	CHP 1.2kWe Stirling - Large House	Fuel Cell - 1kWe (small house)	FC: 3kW (large house)
2030					
No subsidy	0.1%	0.4%	1.0%	0.7%	0.3%
Energy Export Equivalence (i.e. exported electricity sold for the same value as imported)	0.2%	1.3%	1.0%	0.7%	0.6%
Capital subsidy of 25%, whilst costs reduce	0.1%	1.2%	1.0%	0.7%	0.5%
Regulation to introduce tech. in all new build once cost effective	0.1%	0.4%	5.5%	4.5%	0.3%
2050					
No subsidy	0.1%	0.6%	6.3%	9.3%	1.3%
Energy Export Equivalence (i.e. exported electricity sold for the same value as imported)	3.8%	6.0%	6.3%	9.4%	18.4%
Capital subsidy of 25%, whilst costs reduce	0.3%	5.9%	6.3%	9.3%	4.4%
Regulation to introduce tech. in all new build once cost effective	0.1%	0.6%	6.4%	10.0%	1.3%

(*) Based on 380 TWh of electricity p.a. required in the UK (2005).

Summary of network issues.

Network issues

- Voltage rise is the first network issue encountered in the model as micro-generation penetration levels increase.
- Followed by reverse power flow.
- Voltage unbalance is unlikely to cause a problem.
- Fault level constraints were not encountered in the model.
- Following reverse power flow, thermal constraints may be encountered.
- ALL NETWORK ISSUES ARE LOCATION SPECIFIC i.e. the microgeneration level which triggers the need for mitigation measures will be location specific, as will the cost and nature of the mitigation method.

Mitigation

- Any network issue can be resolved.
- This is a matter of economic rather than technical limitations.
- Extrapolation to the GB system is very difficult, ranging from £150m-£240m to mitigate voltage rise, £60m-£650m to mitigate reverse power flow, and £2.5bn (DNO estimate) to mitigate all network issues.
- Alternative mitigation methods, other than the traditional reinforcement, are possible.