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Northern Ireland Assembly

Research Paper 94/08 **April 2008**

THE RELIABILITY AND COSTS OF RENEWABLE TECHNOLOGY

Research and Library Services

This paper provides an overview of research that has been conducted into the reliability and costs of the integration of renewable technologies with reference to the domestic sector.

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SUMMARY OF KEY POINTS

- Microgeneration is defined as follows, "The small-scale production of heat and/or electricity from a low carbon source".
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- The Energy Saving Trust states that many microgeneration technologies will produce cost competitive energy by 2020.
- The high cost of the technology is perhaps the most significant barrier, with most suggestions for overcoming this relating to the provision of grant schemes.
- The Stern Review concluded that the potential costs of unchecked climate change are far higher than the costs of taking action.
- The Code for Sustainable Homes has been developed using the Building Research Establishment's (BRE) EcoHomes System. The Code for Sustainable Homes can be used as a tool for home builders to highlight the sustainable performance of their homes.
- There are six levels to the Code; level 1 refers to the minimum energy efficiency/carbon emissions and water efficiency standards with level 6 indicating the maximum.
- Dennis Anderson from Imperial College London states that "This technology (renewable) is technologically and economically feasible".
- As most renewable technologies are in their infancy, potential for further reductions through innovation exist.
- Anderson states that the market costs of the low carbon options are higher than those of fossil fuels.
- Renewable technologies differ greatly in terms of their technical characteristics, costs and technological maturity.
- Biomass for heat and electricity production contributes approximately 4% of primary energy in the US, 11% in Austria, 17% in Sweden and 20% in Finland.
- With the exception of biomass, renewable generation is both intermittent and unpredictable, presenting challenges for electricity system operators, particularly in relation to peak supply

CONTENTS

INTRODUCTION

This paper provides an overview of research that has been conducted into the reliability and costs associated with renewable technology. The paper details the various types of renewable technologies that could be employed in Northern Ireland in order to reduce the level of Carbon Dioxide emissions in relation to the domestic sector. The paper refers to academic research that has been conducted into the reliability of supply and the cost associated with the integration of renewable technologies.

A MICROGENERATION STRATEGY FOR NORTHERN IRELAND

Microgeneration is defined as follows,

"The small-scale production of heat and/or electricity from a low carbon source[1]"

The Energy Saving Trust states that at a UK level, many microgeneration technologies will produce cost competitive energy by 2020. The rate at which cost competitive technologies enter the market will depend on a number of factors including[2]:

(1) the speed at which industry can increase production and installation capacity
(2) awareness in, and the size of, the early adopter market
(3) policy interventions in terms of their type, effectiveness and extent

There are a variety of dates cited in relation to when microgeneration will become a source of cost competitive energy with the earliest estimate between 2015 and 2020. It is stated that domestic photovoltaics (PV) are unlikely to produce competitive cost energy before 2030 [3]. There are currently less than 100,000 microgeneration installations in the UK (of which most are solar water heaters installed pre-2000). The annual number of installations is closely correlated with the level of available grant funding. Most installations in relation to PV and solar water heating[4].

BARRIERS TO INTRODUCTION OF MICROGENERATION

The barriers to microgenration include:
(1) high cost
(2) legislation/planning permission
(3) the level of consumer awareness

The Energy Saving Trust state that the high cost of the technology is perhaps the most significant barrier, with most suggestions for overcoming this relating to the provision of grant schemes. There will be a continuing need to provide significant capital support for these technologies[5].

[1] Our Energy challenge: Power from the people Microgenration Strategy, http://www.berr.gov.uk/files/file27576.pdf
[2] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[3] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[4] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[5] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk

Stirling Engine and Fuel Cell Combined Heat and Power (CHP)

Combined Heat and Power is a technology that generates electricity and heat simultaneously, and can be fuelled by a variety of sources such as gas, coal, oil, biomass and hydrogen[6]. This technology is not far from being cost effective, however this is strongly dependent on achieving lifetime and maintenance costs close to those of oil/gas boilers. It could take another 10-15 years, once it is cost effective before a significant proportion of domestic energy is generated by this technology. Two types of CHP can be installed; firstly, Stirling engine is likely to be successful in larger dwellings and older dwellings with higher than average heat loads. Over 8 million UK homes could be reached by 2050, supplying 40% of domestic heating requirements and 6% of UK electricity supplies[7]. Secondly, Fuel Cell CHP is more suited to smaller dwellings with lower than average heating loads, particularly new buildings. Cost effective use is likely around 2015. Indeed, it is estimated that in 2050, small fuel cells could supply 9% of the UK electricity requirements and reduce domestic sector carbon dioxide emissions by 3%[8].

Wind

The Energy Saving Trust notes that the current market for wind turbines is not based on cost-effective purchasing and is likely to slow down. Small wind systems are generally not cost effective currently. However, a number of new products have recently been produced with the potential for significant cost reductions. The potential for small wind systems is significant or with appropriate support, could supply 4% of the UK electricity requirement and reduce domestic carbon dioxide emissions by 6%[9]. This technology will need to be supported until commercialisation is achieved, suggestions of a capital grant of 25-50% could be sufficient to support uptake levels. However, commercial viability is dependent on acquiring an equitable price for exported electricity[10].

Photovoltaics

Photovoltaics (PV) are not generally cost effective at present and are not predicted to be so until 2030. Incentives are required to maintain the market for small grid connected systems. A lack of planning issues means that the market potential for PV is amongst the largest. If cost issues were overcome, this technology could supply almost 4% of UK electricity demand, and reduce domestic sector carbon dioxide emissions by up to 3%[11].

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[6] Envocare, http://www.envocare.co.uk/combined_heat_and_power.htm
[7] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[8] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[9] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[10] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[11] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk

BIOMASS HEATING AND HEAT PUMPS

Both biomass heating and Ground Storage Heat Pump (GSHP) technologies can be viable when compared to electric or Liquid Petroleum Gas (LPG) heating, but in general these technologies are not competitive with natural gas or oil fired heating (comparison made using 2006 statistics). The carbon dioxide emissions savings are disproportionately large (due to the high CO2 emissions of electric/LPG heating). These technologies could reduce domestic sector CO2 emissions by 3% by 2050[12].

SOLAR WATER HEATING

Currently, solar water heating is the largest microgeneration industry, installing 2000 units annually. However solar water heating is not cost effective at present. Significant grant funding (in the order of 50% of capital costs) would be needed[13].

BUILDING A GREENER FUTURE: TOWARDS ZERO CARBON DEVELOPMENT

The UK document entitled 'Building a greener future: Towards zero carbon development' highlights The Stern Review conclusion that the potential costs of unchecked climate change (up to 20% of global GDP) are far higher than the costs of taking action (around 1% of global GDP)[14].

In 2004 the UK's total carbon dioxide emissions were 152.5 Million metric tons of Carbon (MtC). Emissions from the domestic housing sector represent around 27% of this figure. Moreover, climate change itself may lead to further developments, for example a growth in the take-up of home air conditioning units[15].

The Existing Buildings Review in the UK, led by Communities and Local Government, has examined the potential for reducing energy usage and carbon emissions in the existing housing stock, the Review concluded that a large cost-effective potential exists. In relation to the existing homes, a maximum saving of 7MtC could be made per annum. The building of new homes will need to accommodate the predicted population and demographic changes; early estimates suggest that we would need to reduce emissions by about 30MtC in the domestic sector by 2050[16].

Estimates based on experience of low and zero carbon technologies indicate that costs could be reduced significantly with the doubling of installation capacity. Predictions state that if there were 12 million installed Micro-Combined Heat and Power (CHP) units the additional cost might fall from around £2,000 to £400 for example[17].

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[12] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[13] Energy Saving Trust, *A Microgeneration Strategy for Northern Ireland*, http://www.energysavingtrust.co.uk
[14] Building a Greener Future: Towards Zero Carbon Development, http://www.berr.gov.uk/files/file39387.pdf
[15] Building a Greener Future: Towards Zero Carbon Development, http://www.berr.gov.uk/files/file39387.pdf
[16] Building a Greener Future: Towards Zero Carbon Development, http://www.berr.gov.uk/files/file39387.pdf
[17] Building a Greener Future: Towards Zero Carbon Development, http://www.berr.gov.uk/files/file39387.pdf

CODE FOR SUSTAINABLE HOMES: A STEP-CHANGE IN SUSTAINABLE HOME BUILDING PRACTICE

The Code for Sustainable Homes has been developed using the Building Research Establishment's (BRE) EcoHomes System[18].

The Code states that due to a more environmentally conscious public there is a growing demand for homes that offer reduced environmental impact and lower running costs. There is an increased need for home builders to demonstrate their capacity in sustainable home building, and to market the sustainability of their homes to homebuyers. The Code for Sustainable Homes can be used as a tool for home builders to highlight the sustainable performance of their homes, and to differentiate themselves from their competitors[19]. The Code is based on performance against each element but does not state how to achieve each level[20].

COSTS AND BENEFITS APPROACH

There are six levels to the Code; level 1 refers to the minimum energy efficiency/carbon emissions and water efficiency standards with level 6 indicating the maximum. It is stated that on average achieving Code level 3 would save households around £50 per year, and achieving Code Level 4 around £100 per year, compared to current consumption levels in new houses. Work has been commissioned by the Housing Corporation and English Partnerships on the costs of delivering Code level 3, or a 25% improvement in energy/carbon levels, which estimates the costs to be around 2-3%, or around £2,000 per dwelling, on the basis of current technologies[21].

COSTS OF ABATING CARBON EMISSIONS IN THE ENERGY SECTOR

Dennis Anderson from Imperial College London states that as a society the potential exists to move towards low carbon emissions, and achieve a virtually zero carbon energy system in the long term, if energy is used more efficiently and low carbon technologies are employed. Indeed, he states that[22];

"This technology (renewable) is technologically and economically feasible"[23].

The document 'Costs and finance of abating carbon emissions in the energy sector' states that renewable energy resources are significant, for example solar energy alone could meet world energy demand using less than 1% of land now under crops

[18] Code for Sustainable Homes: A step-change in sustainable home building practice, http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf
[19] Code for Sustainable Homes: A step-change in sustainable home building practice, http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf
[20] Code for Sustainable Homes: A step-change in sustainable home building practice, http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf
[21] Code for Sustainable Homes: A step-change in sustainable home building practice, http://www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf
[22] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[23] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

and pasture. Resources also with potential are wind, tidal, stream, wave, geothermal energy[24].

Cost trends for such technologies are said to be encouraging with the cost of wind has fallen fourfold since the mid1980s. Most technologies are in their infancy and potential for further reductions through innovation exist. The issue of intermittency will need to be addressed if solar and wind technologies are to provide energy on the scale required. Examples provided to demonstrate how this could be achieved include the development of storage technologies, such as hydrogen and changes to the way power grids are operated[25].

ENERGY INFRASTRUCTURES

Fuel cells for combined heat and power and solar PV offer possibilities for decentralised generation on a small scale. There could then be millions of small scale generating sets on electricity grids resulting in millions of consumers becoming independent of grids. The technological options that are currently the most promising include the full range of renewable energy technologies (wind, biomass, solar, geothermal, wave and tidal stream technologies[26].

COSTS AND POLICIES

Anderson states that the market costs of the low carbon options are higher than those of fossil fuels and that a substantial task of transforming energy infrastructure to accommodate the new technologies exists[27]. The impacts on economic growth and development are likely to be very small – approximately a loss of 6 months growth over 50 years[28].

The experience of the Global Environment Facility with investments under the UN Framework Convention on climate Change shows that funding mechanisms can achieve financial leverage. Funds could be taken from the private financial sector and industry. The past decade has seen progress in the technologies discussed and in our understanding of how energy systems might evolve[29].

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[24] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[25] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[26] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[27] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[28] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[29] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

Technologies

Renewable technologies differ greatly in terms of their technical characteristics, costs and technological maturity. Some technologies are better suited to specific geographical regions and many technologies have non-carbon environmental impacts and implications for other policy priorities, for example security of supply[30].

Renewables

Wind, geothermal, wave and tidal technologies have the potential to supply significant amounts of energy. There is potential for technical improvements and cost reduction – though technical advancement differs considerably between renewable technologies. However, all are currently under used compared to both their potential and size of the global energy market; currently accounting for just 1% of world primary energy consumption[31].

Solar

In terms of solar energy, approximately 30% of the spectrum is theoretically available for electricity generation and the rest can provide heat. The coincidence between solar outputs and energy needs is better in sunny latitudes where there is a strong demand for electricity for daytime air conditioning; however, the overall resource potential is still large even in cloudy climates; studies for the UK government (DTI 1998) suggest that photovoltaics (PV) on buildings in principle could supply around two-thirds of UK annual electricity demand[32].

There are two technologies for turning solar energy to commercial energy:

(1) Photovoltaics (PV) – which directly convert light into electrical current
(2) Solar-thermal systems

PV Technologies

PV is typically available in the form of panels and can be used for four main types of application[33]:

(1) small scale provision of electricity in remote regions
(2) very small scale applications such as calculators
(3) building integrated systems (BIPV) that may also be connected to the grid
(4) central station supplies, providing electricity to the grid

PV systems currently cost around £2500 per kW, plus installation costs. They are still several times the cost of other renewable energy technologies such as wind. In a

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30 Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
31 Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
32 Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
33 Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

limited number of cases PV materials are able to offset the costs of alternative building materials and this can improve the economics considerably[34].

In 1960s and 1970s costs were as high as approximately £150,000 per kW, but costs declined rapidly. However, world markets still remain small with shipments amounting to 250 MW in 2001 (as compared to over 70,000 MW of new electricity generating plant); but they are expanding at over 25% per year. Many independent studies suggest that the costs of the PV will continue to fall[35].

HIGH TEMPERATURE SOLAR THERMAL TECHNOLOGIES

Most operational experience to date has been obtained from schemes in California, whose aggregate capacity is 400 MW; they were installed in the 1980s, and have a good operational rating over a 15 year period. Aside from the projects in California there has been operational experience in research centres in Spain and Israel[36].

WIND

Estimates of wind resources depend on the availability of sites, turbine size and wind speeds. Wind resources are large on a global scale and, in principle, exceed global electricity demand. Wind technologies have two types: large turbines, designed to supply electricity to the grid, which are typically in the range 1-2 MW rated capacity and have a blade diameter of around 100 meters. Small turbines rate from around 3kW up to around 100kW, which are widely used in the leisure and off-grid markets[37].

Since the first wind farms of the late 1980s:

(1) the annual energy output per turbine has increased 100-fold
(2) turbine rated capacity (for typical commercial machines) has increased from 55kW to 1MW
(3) From 1995-2000 the weight of turbines per kW installed has halved
(4) From 1997-2000 noise levels were halved

These factors have reduced the capital costs and improved the efficiency and reliability of the turbines. Costs for onshore wind are likely to fall to around 3.0 cents/kWh at good sites. At present little offshore wind capacity is installed anywhere in the world [38].

Wind regimes are generally higher and more stable offshore and the absence of noise constraints mean that turbines can spin faster, increasing the output for a given

[34] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[35] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[36] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[37] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf
[38] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

size of machine. Costs are widely predicated to fall; the UK Energy Review suggested that costs could fall to around 1-2 pence/kWh as development proceeds. Despite limited experience of offshore generation, costs have already fallen. Offshore wind currently delivers electricity at a cost of 3 to 4 pence/kWh[39].

BIOMASS ENERGY

Biomass for heat and electricity production contributes approximately 4% of primary energy in the US, 11% in Austria, 17% in Sweden and 20% in Finland. Biomass for district heating and CHP is also well established in Denmark and Germany. Biomass already has significantly more market experience than any other renewable option[40].

Biomass can be used in multiple ways[41]:

(1) direct combustion in small and large boilers for electricity, district heating and combined heat and power (CHP)
(2) gasification to produce a fuel for heat and electricity generation
(3) production of liquid and gaseous fuels for transport.

The potential for increased use of biomass resources is substantial. Biomass technologies are undergoing development both for small and large scale applications. Short-term market growth in biomass energy is likely to be based on the production of heat and electricity using combustion and gasification technology. Future biomass electricity costs from dedicated plants fuelled with energy crops could be around 0.025 pence/kWh[42].

ELECTRICAL INTEGRATION ISSUES

With the exception of biomass, renewable generation is both intermittent and unpredictable. Thus, presenting challenges for electricity system operators, particularly in relation to peak supply[43]. Renewable sources of energy give rise to a number of differences in the way in which power is fed into electricity networks and in which networks These include: intermittency (variable outputs); decentralisation of generation (smaller scale generating units); and remoteness of some generation options (distance from existing infrastructures and demands)[44].

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[39] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

[40] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

[41] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

[42] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

[43] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

[44] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf

Fluctuation of energy supply from renewable sources arise from the fact that intermittent supplies are not able to provide much of the firm capacity to ensure reliable supplies in the event of high demands and failure of other forms of generation. It appears that the potential for renewables will come to depend increasingly upon the costs and viability of a range of options for coping with intermittency, such as increased interconnection, demand management techniques and storage technologies[45].

[45] Imperial College Centre for Energy Policy and Technology, *Assessment of Technology Options to Address Climate Change*, http://www3.imperial.ac.uk.pls/portallive/docs/1/7294718.pdf