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Title

INNOVATIVE MANAGEMENT OF MICROGENERATION TECHNOLOGY IN UK RESIDENCES

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ABSTRACT:

In this research, an investigation of various microgeneration technologies is presented. Microgeneration in newly build homes accounts for almost half of UK CO2 emissions and energy demand savings and has been growing for several years. A survey has been conducted of builders in Manchester city in the UK, and the results are presented together with an analysis of implementation in new build houses. Based on the analysis, including an economic analysis of Payback times, for four different technologies namely Wind Turbine, Solar Photovoltaic, Solar Thermal System and Biomass System, this report helps the house building industry to realize the risks and issues associated with building microgeneration units. In addition a case study of a company specialised in the area of microgeneration has been done. The Case study looked at the views of the company on the practical issues of microgeneration in the UK. These views are also presented in the report. Solar thermal energy is found to be most attractive compared with the three other microgeneration technologies. Finally key conclusions are drawn and some suggestions are given for future work.

Key words: microgeneration, renewable energy, sustainable energy, sustainable buildings

INTRODUCTION:

The UK Government has set a target of 80% reduction in CO2 emissions by 2050 compared to the level of emission of Carbon dioxide in 1990's (HM Government, 2008). The domestic sector accounts for nearly 25% of UK emissions from the generation of heat and electricity for homes (DEFRA, 2008). In order to make the household sector to move to a low-carbon track, it is indeed vital to transform it in a better quality of housing with high environmental performance. The transformation of household sector for better environmental performance will require system-wide innovation and change comprising new technologies, new markets and new institutional supporting systems (Carid, 2008).

The supply of new homes by the construction companies to the UK housing stock will have an accumulative impact on the ability of the domestic sector to contribute to the 2050 carbon reduction target set by UK Government. The UK government has set a target that all new homes will need to be zero carbon by 2016 (DCLG, 2008). Further, one third of the housing stock (around 8 million new homes) will have been built between 2007 and 2050 (DCLG, 2007). The scale of new build is being given particular impulse by the UK government target of delivering 3 million new homes by 2020 (DCLG, 2007). The new housing development industry is therefore a significant change agent that may bring about this low-carbon transformation in the domestic sector.

In this research study, a comparative analysis on the performance of various microgeneration units that use technologies like wind energy, Solar Photovoltaic (PV) cells, Bio-mass system, and Solar thermal power source is carried out. The primary focus will be in the microgeneration technology (MGT) field within this sector. The development and widespread diffusion of MGTs are seen as a key part of the drive to lower CO2 emissions (DTI, 2006; Element Energy, 2008). In its recent Energy Review, the government reaffirmed its commitment to reduce the UK's CO2 emissions by 60 percent by 2050 (BRE, 2005). One of the key elements of the government's approach to achieving this ambitious target is to make significant improvements to the UK's energy efficiency, including energy use by businesses, the public sector, and individual households. The Energy Review estimated that by 2020, the UK could save 25 MtC by implementing **"cost-effective"** energy efficiency measures that would repay investments with greater savings on energy consumption (BRE, 2005).

Aim and Objectives:

a. Aim

The aim of the research is to compare and analyze various microgeneration technologies on the parameters of technology performance, capacity of the unit, amount of Carbon dioxide emitted, Cost of the unit, cost of operation, Payback period and cost of maintenance.

b. Objectives

The key objectives in this report are as follows:

1. To compare the cost of various microgeneration technologies for various design of houses in UK.

2. To determine the level of carbon emissions and carbon emission savings among various microgeneration technologies and to forecast the reduction of carbon emissions for 2030 and 2050.
3. To determine the payback period for various microgeneration technologies.
4. To suggest suitable microgeneration unit for different types of houses in UK.

LITERATURE REVIEW:

Comparisons of Different Microgeneration Technology:

The microgeneration technology has been compared by carbon saving, cost effectiveness, and local impact taken from (BERR, 2008) as follows,

Unique Analysis Microgeneration Technology:

The various microgeneration technologies has been discussed which covers the

- Carbon and cost savings
- Lifetime energy
- Cost-effectiveness expressed as simple payback
- Capital Costs
- Risk associated with the technology & Technology Overview.

These are the some of the things that have been taken from NHBC Foundation, (2008) and ERR, (2008) which are discussed and analysed as follows,

Technology	Carbon Saving	Cost effectiveness	Local impact
Biomass	a. 75% annual average boils efficient. b.0.33Kg of Co2 per Kwh of delivery heat on oil fired c. 0.66 Kg of Co2 per KWh of delivery heat on coal fired.	a. Wood and logs are cheap b. 4 times cheaper than LPG or electricity	a. Building type equipment that slumbers is best build to high heat loss and high thermal mass building
Solar PV	a. Domestic 1.5KWp installations have an annual yield of around 1200 KWh. b. 512Kg per annum of power station Co2 emission.	a. Solar PV manages to pay back the capital expenditure over their operating lives which 20% is reduced.	a. Solar PV installations are generally unobtrusive and the array is silent in operation.
Wind Turbine	a. 2.5 KW wind turbine yielding 4000+ KWh a year offsets over 1700 Kg power states Co2 emission.	a. Larger wind turbine system can prove financially beneficial on side where the resources are good and more economical by reliving the fuel property.	a. The wind turbine should be located optionally for capture of clean wind. It is placed in wind blowing direction.
Solar Thermal	a. Domestic sized installation has an annual yield of 1600-2000KWh, reducing Co2 emissions by 400-1000 Kg per annum.	a. It has payback times in excess of 10 years but depends on the system type orientation.	a. Solar thermal installations are generally unobtrusive and extremely quiet in operation.

***Table** (Comparisons of Different Microgeneration Technology)*

Different Microgeneration Technology:

a. Biomass:

Biomass nearly always refers to wood fuel, as wood chip is rarely suitable at this scale. Biomass is only a renewable resources if the trees are replaced once felled for fuel. Various technologies have been used in the new build houses. The log stoves, which are manual feed, give radiant and convective heating which may be fitted with the back boiler to provide water and space heating. It is clean flame burn and catalyser models produce less smoke than ordinary models (Jowit, 2009). Efficiencies have been made typically around 70% compared with open hearths at 15%. Ranges are the Manuel feed that have hop tops and usually are used for roasting and baking ovens. These have an efficiency produce typically around 60%-70%. Pellet Stoves are the type most commonly used in homes. These systems have automatic control of operation, including air supply and fuel delivery to burner from an integral fuel hopper, allowing efficient operation and extended periods between refills. Some are fitted with back boilers for water and or space heating. The overall efficiency is typically 80%. The main product of Biomass is pellet boilers which have automatic control of operation, including air supply and fuel delivery to burner from integral fuel hopper. It allows efficient operation and extended periods between the refills typically every 24 hour. They are plumbed in to the electric circuit which heats the radiators and hot water cylinder. A main electricity connection for the combustion is control system is required; this has efficiency up to 90% (BERR, 2008).

b. Solar Photovoltaic systems:

The light energy in sunlight is converted directly into electricity by photovoltaic (PV) cells which are semiconductor devices. It does not have any moving parts to be involved in it. This has individual cells which only generate low voltage and currents, so that they are usually grouped in the rectangular modules which compress a transparent cover, a metal mounting frame and a back plate, thus forming a weather proof enclosure. PV cells can also be made into solar slates or solar tiles for integration into roofs, or bounded on glasses on metal sheets placed for incorporation into architectural glazing and fascia systems. The cheaper parts of variants convert almost around 5% of the solar energy of electricity; but some high level products are claimed by some to achieve 18%. All types can capture energy when the sky is overcast, but the total output is reached when the sun is shining perpendicularly or straight on to the cells from a clear sky. However, because of the wind variations in outputs, PV installations are not usually described in terms of their area but which are rated according to their peak power output (kWpeak or KWp), defined using a standard method of measurement. The module areas are currently required per KWp output for the different technology which are monocrystaline which is 8m^2 and amorphous which is 20m^2 (Lane, 2002). PV use depends upon the various location in UK which is between 900 and 1100 kWh of solar energy falls on each m^2 of shaded surface annually. In most places in UK, PV installations have been made which generates around 800 Kwh annually per KWp of installed capacity. In most of the new build houses, the PV installations are controlled by the grid operator. This is known as DNO (Distribution Network Operator) which needs to be noted. Larger systems require prior permission for the connection to be obtained from the DNO. The key components in such a systems is the inverter, which converts the PV provided direct current (DC) electricity into 240 volts 50Hz alternatively current (AC), and does so in synchronism (Brinkley, 2006).

c. Solar thermal systems:

Solar collectors or panels absorb the solar radiation and convert it to heat which is transformed to a hot water cylinder by circulating fluid through a set of series of pipes to pre heat the water in the cylinder. This preheated water is then again heated to reach a certain temperature by auxiliary systems. Solar hot water systems do not usually contribute to the central heating systems. There are two main standards types of panels which are flat plate and evacuated tube. The flat plate collectors are simple but effective devices which comprise a dark plate with in an insulated box fixed with a glass or double plastic cover. The plate is usually coated with a selective coating to ensure that it has high absorption but low emissivity. In the evacuated tube collectors which are more sophisticated but with a series of metal strip collectors placed inside the glass vacuum tubes. Their efficiencies are usually higher and they are more effective in cold weather which is because of their low heat losses, but they do tend to be more expensive than flat plate collectors and succumb more easily to vandalism (Micropower, 2007). In these solar thermal systems both collectors' types can capture the heat whether the sky is cloudy or clear. Depending upon the UK location, 900-1100kWh of solar energy falls on each m^2 of unshaded UK roof surface annually. The annual energy captured by typical design which is flat plates has the efficiency of 380-450 kWh per m^2 of collector. Also the evacuated tubes: 500-550 kWh per m^2 of collector. The typical solar domestic features 4 m^2 of flat plate or 3 m^2 of evacuated tube, providing 50% to 65% of the energy required annually for water heating. Many domestic solar systems are known as indirect systems. The pipes are connected to the collector to the hot water cylinder connect to a heat exchange coil which is inside the cylinder. By this way the fluid which circulates inside the collector never comes into direct contact with the water in the cylinder and is therefore able to contain anti-freeze to protect the collector. The coil which is supplied by the solar systems which can either be in a dedicated to the solar cylinder which is built twin-could cylinder where the upper could is connected to the boiler to provide the top up when needed (Boardman, 2007).

d. Wind Power Systems:

The energy in the wind is converted into electricity by a wind turbine. Most domestic scale wind turbines are horizontal axis devices- that are miniature versions of wind farm machines. The turbine which is the head comprising the blades where the generator rotates freely at the top of the mast to align which itself with the wind. In high winds many turbine blades are designed to yaw (turn out of the wind) to prevent overloading. Masts need strong foundations. Some masts are free-standing; others use stay wires attached to ground anchors. Usually a buried cable transfers electricity to the house (Jowit, 2009). There are very few vertical axis turbines on the market, though machines are under development. Vertical axis wind turbines are inherently simpler because they do not have to move or turbo face the wind. But it is unlike horizontal axis machines- most designs do not self-start.

Houses mounted by the wind turbines have recently appeared on the market but concerns which have been expressed about the performance of such machines which is to be given the lower wind speeds and increased the turbulence in built up areas. One early study has shown that in large urban environments the micro-wind turbines may never pay-back their embodies carbon emissions. Also the taller the mast, the better: near the ground, friction effects slow the wind considerably (Lane, 2002).

RESEARCH METHODOLOGY:

A Research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. In fact, the research design is a conceptual procedure within which research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data. There are various types of research that can be used based on types of research problem. The types of research are applied research, Analytical research, empirical research, Quantitative research, Qualitative research, longitudinal research, historical research, exploratory type of research etc. According to Naoum (2007), deciding on the type of research depends on the purpose and type of the study and the availability of information. Though there are various types of research design, in this research study the researcher has proposed to use analytical and Qualitative type of research. The analytical type of research is adopted to compare and analyse various microgeneration technologies towards various parameters and the qualitative type of research is used to assess various benefits of using microgeneration technologies by household consumers (Naoum, 2007).

APPROACHES TO DATA COLLECTION:

There are various approaches for data collection, personal interview, telephonic interview, survey through structured questionnaire and case study approach. Though there are various approaches to collect data, in this study the interview approach to collect data from the respondents is chosen.

This method of collecting data involves presentation of oral verbal stimuli and reply in terms of oral-verbal responses (Yin, 2003). The researcher used this method through personal interviews. In this method the interviewer asks questions generally in a face to face contact with the builders. In this method the researcher who was the principle investigator was on the spot to meet the respondents from whom data was collected. This method is particularly suitable for intensive investigations. This method of collecting information through interviews was carried out in a structured way. The interviews involved the use of a set of predetermined questions related to microgeneration technologies and of highly standardised techniques of recording. Thus the interviewer in a structured interview follows a rigid procedure laid down, asking questions in a form and order prescribed (Naoum, 2007).

The data collected from the respondents will help to find out the most preferred Microgeneration technology by house owners and the reasons for preferring particular microgeneration technology. This survey also reveals facts like Capacity of microgeneration units, efficiency of microgeneration technology, level of emission of carbon from various microgeneration technologies, price of various microgeneration technologies and cost of microgeneration units that includes manufacturing cost, operation cost, maintenance cost and installation cost (Yin, 2003). The researcher can relate these facts with the objectives of the study. Both builders and respondents from housing sectors share their experience and ideas from their work place.

TYPES AND SOURCES OF DATA:

In this study the researcher uses both primary data and secondary data. The primary data is the first hand data which is not available, collected from the builders through a structured Questionnaire. Whereas the secondary data is the data which is already available collected through literature survey. The various sources of secondary data are research and academic journals, research papers presented in international conferences and published in journals, government publications and textbooks, company documents and websites. From the literature review, the researcher come across various variables like types of microgeneration technologies, level of carbon emission, cost of installation, cost of operation, capacity of the unit, power generated etc., which help the researcher to formulate the questions for the survey (Naoum, 2007). The intention of this research was to collect factual information as well as opinions of builders on selecting and installing suitable microgeneration technology that meet the requirement of users and government. Therefore, it was felt that the most appropriate method of data collection will be 'interview method'. Face to face interviews were conducted by interviewer with both the builders and household consumers in order to elicit their experience on using microgeneration technology (Yin, 2003).

Twenty builders and one thousand two hundred and eighty seven house hold consumers who were located near to the researcher were contacted for the research survey. They were personally met by the researcher as per his convenience and asked various questions on microgeneration technologies. From the reply of both the type of respondents the researcher felt that their view on various parameters of different microgeneration technologies satisfactorily represent the view of other builders and house hold consumers of Manchester city.

SAMPLING DESIGN:

A sample design is a definite plan for obtaining a sample from a given population. It refers to the technique or the procedure the researcher would adopt in selecting items for sample.

a. Type of universe:

The universe is finite. The construction companies in Manchester were taken as the population for the study.

b. Sampling units:

Electrical consulting engineers, Quantity surveyors and Head of departments of various construction companies in Manchester were taken as sampling units.

c. Source list:

It is also called as sampling frame from which sample is to be drawn. It contains names of all items of the population.

d. Sampling technique:

In this study the researcher used convenient sampling technique which is a non-probability sampling to arrive the sample size.

KEY INTERVIEW FINDINGS AND ANALYSIS:

Payback Assessment:

Initial assessments of the various systems utilises a payback method. The following Table (table 3- Capital costs) provides us with a base-line capital costs for the supply and installation of the proposed housing services.

Housing Services Capital Costs:

Costs based on a 3 Bedroom semi Detached 4 person Home of this technology by the construction companies.

System Ref Number	Heating Systems	No of Dwellings	Typical Supply Cost	Installation cost	Total Costs per dwelling
1.	Solar Thermal Systems and Solar Panels	1	£2,500.00	£1,000.00	£3,500.00
2.	Biomass or solar Hot water	1	£3,500.00	£1,500.00	£5,000.00
3.	Photovoltaic Panel per 1m^2	1	£1500.00	£500.00	£2000.00

4.	Wind Turbine (qty 1)	1	£3,000.00	£2,000.00	£5,000.00

Table 11 (Capital Costs for microgeneration technology)

<u>Note</u>:

Total Costs per dwelling = Typical Supply Cost + Installation Cost

<u>Sustainable Percentage of UK Electricity demands can be supplied by Microgeneration:</u>

The tables below summarises the microgeneration electricity production of 2030 and 2050 expressed as a percentage of UK electricity demands. This is different for microgeneration technologies which in the uptake model under different government intervention schemes (Cisco, 2005). By improving and increasing the use of microgeneration technology which can satisfy all the electricity needs in UK for the whole future.

	PV : 2.5 kWe	**Wind 1.5 kWe**	**Biomass V Elec. Heating**	**Solar Thermal V. Elec Heat**
2030				
No subsidy	0.0%	0.3%	0.6%	0.0%
Energy Export Equivalence	0.2%	0.9%	0.6%	0.0%
Capital Subsidy of 25%, Whilst Costs reduce.	0.1%	0.9%	0.6%	0.1%
Regulations to introduce tech. In all new build once cost effective	0.0%	0.3%	0.8%	0.0%

Table 20(Estimated Sustainable Percentage of UK Electricity demand 2030s)

2050	PV : 2.5 kWe	Wind 1.5 kWe	Biomass V Elec. Heating	Solar Thermal V. Elec Heat
No subsidy	0.0%	0.3%	0.6%	0.0%
Energy Export Equivalence	0.2%	0.9%	0.6%	0.0%
Capital Subsidy of 25%, Whilst Costs reduce.	0.1%	0.9%	0.6%	0.1%
Regulations to introduce tech. In all new build once cost effective	0.0%	0.3%	0.8%	0.0%

Table 21(Estimated Sustainable Percentage of UK Electricity demands 2050)

These tables show the use of different microgeneration technologies which they can supply the required amount of electricity to satisfy the UK in coming years. In this report the data is given till 2050. Most of the data is collected from the case study and interview.

Carbon Emission Assessment for Microgeneration Technologies:

System Carbon Savings Analyse:

Microgeneration Technology	Candidate Buildings	Prerequisites	Potential barriers	Annual saving per £100,000 of cost kWh	Annual saving per £100,000 of cost Kg Co2
Tower-mounted Wind Generators	Industrial, distribution centres	Average site wind speed minimum 7m/s	Environmental impact. Site space for large turbines	100,000	43,000*

Building-mounted "micro wind"	Most types of building	Average site wind speed minimum 3.5m/s	Environmental impact. Roof space for small turbines.	40,000	17,200*
Photovoltaic roof or panels	Most type of building	Roughly south-facing, unshaded	Available roof space	12,500	5,375*
Photovoltaic rain screen or glass	Prestige offices and retail	Roughly south-facing, unshaded	None	9,000	3,870*
Solar thermal or solar water heat	Residential and commercial, hotels and leisure.	Roughly south-facing, unshaded, requirement for hot water.	None	50,000	9,500+
Biomass systems	Most types of building and houses.	Space and convenient source of fuel. Requirement for heat in Summer.	Environmental impact and maintenance	100,000	19,000+

Table 17 (Microgeneration System Carbon Savings Analyse (Turnbull, 2000))

Percentage of Co2 Emissions Saved due to Microgeneration in 2050:

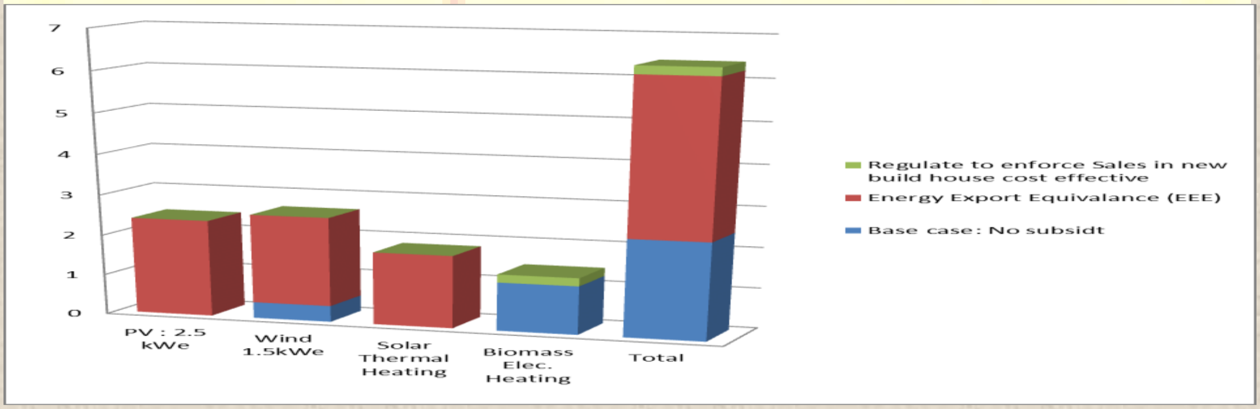

Figure 9 (Percentage of C02 emissions)

This graph is drawn to show the percentage of CO2 emissions (2005 figures) in the y axis and the various microgeneration technologies in the x axis. The graph shows the three different bars which it says no subsidy in the base case of the significant percentage of CO2. The second bar shows the energy export equivalence (EEE) and the third bar represent the regulate to enforce sales in new build once cost effective where the biomass produce some cost effectiveness. Data here is based on 198 MT CO2 arising from the domestic sector (UK Energy Sector Indicators, 2005). Domestic sector CO2 emissions are approx. 30% of UK emissions (including transport).

Percentage of Co2 Reduction by Microgeneration Technology by 2030 &2050:

The table below summarises results for CO2 emission avoided expressed as a percentage of UK domestic CO2 emissions* for different microgeneration technology in the uptake model under different government intervention schemes these results are not necessarily important (UK Energy Sector indicators, 2005).

	PV : 2.5 kWe	**Wind 1.5 kWe**	**Biomass V Elec. Heating**	**Solar Thermal V. Elec Heat**
2030				
No subsidy	0.0%	0.3%	0.6%	0.0%
Energy Export Equivalence	0.2%	0.9%	0.6%	0.0%
Capital Subsidy of 25%, Whilst Costs reduce.	0.1%	0.9%	0.6%	0.1%
Regulations to introduce tech. In all new build once cost effective	0.0%	0.3%	0.8%	0.0%

Table 18 (Estimated Percentage of Co2 Reduction 2030)

2050	PV : 2.5 kWe	Wind 1.5 kWe	Biomass V Elec. Heating	Solar Thermal V. Elec Heat
No subsidy	0.1%	0.4%	0.8%	0.0%
Energy Export Equivalence	2.7%	4.2%	0.8%	0.0%
Capital Subsidy of 25%, Whilst Costs reduce.	0.2%	4.2%	0.8%	0.1%
Regulations to introduce tech. In all new build once cost effective	0.1%	0.4%	0.8%	0.0%

Table 19 (Estimated Percentage of Co2 Reduction 2050)

These two tables show the amount of carbon reduction by various microgeneration technologies. The carbon reduction will be more on 2050 than 2030 if the increase in usage of microgeneration technology, which gives the lots of environment benefit to UK.

Energy Supply Assessment for Microgeneration Technologies:

Valuation for Electricity to Assist Microgeneration Technology Till 2050:

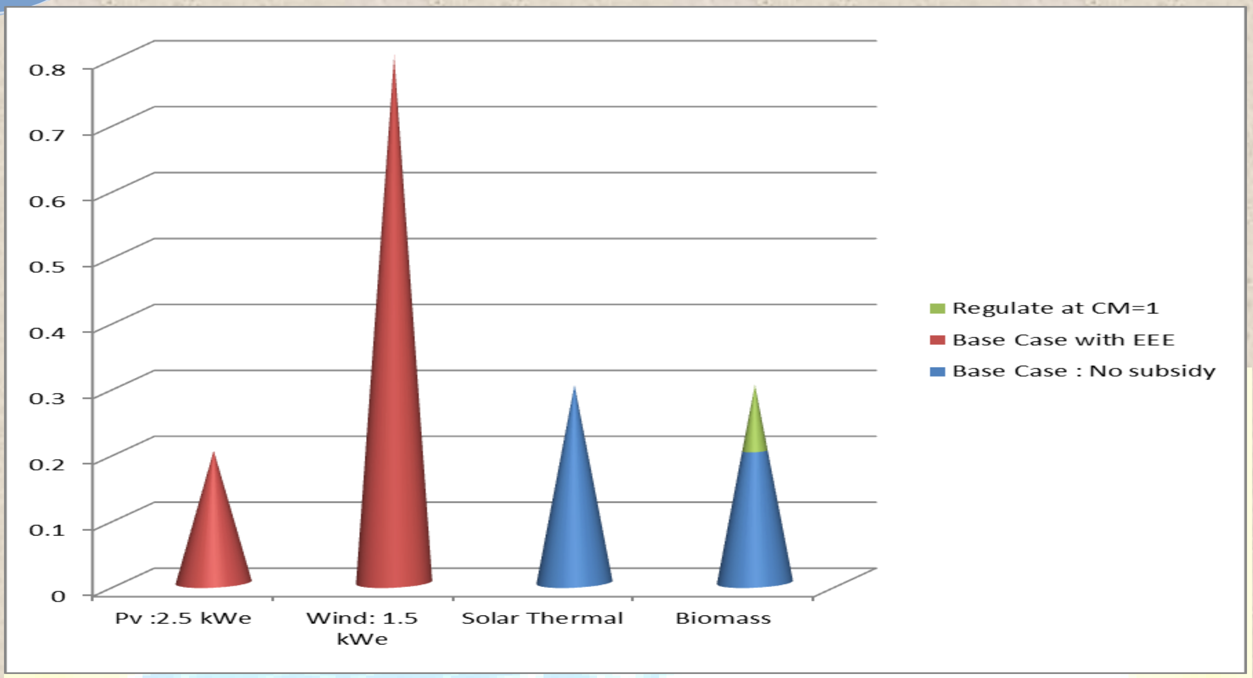

Figure 10 (GWh of energy generated due to microgeneration in 2050)

In this graph **y axis = 0.1= 50,000 GWh** of Energy Supplied by Microgeneration technology. 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 which electricity only. The capacity could be reached sooner subject to improved regulation and support.

Payback Period and Cost Management:

The microgeneration technologies has been analysed in this report with various key facts in terms of Lifer time energy, carbon and cost savings for the 3 bedroom house which they are described as follows from the pay back calculation result as follows.

a. Wind Turbine:

Electricity Generated : 40,000kWh

Carbon Savings : 17200kg

Home Cost Saved by Electricity

@ 8.5p/kWh : £3,400

Typical Costs and Installation : £5,000 per Kw

Cost Effectiveness (Payback) (New Homes)

2.5Kw Turbine : 15 years

Typical Life time : 22 years

b. **Biomass Systems:**

Electricity Generated: N/A

Carbon Savings : 4.5 tonnes per year

Home Cost Saved by Electricity

@ 8.5p/kWh : N/A

Typical Costs and Installation

(new build) : £5,000 per Kw

Cost Effectiveness (Payback): N/A

Typical Life time : 25 years

c. **Solar Photovoltaic Systems:**

Electricity Generated: N/A

CO2 displaced : N/A

Home Cost Saved by Electricity

@ 8.5p/kWh : £1,360

Typical Costs and Installation

(new build) : £3.500 per KWp

Cost Effectiveness (Payback) : N/A

Typical Life time : 25-30 years

d. **Solar Thermal (or) Solar Hot Water:**

Electricity Generated: N/A

Carbon Savings : 12 tonnes per year

Home Cost Saved by Electricity

@ 8.5p/kWh : £2,000

Home Cost Saved by Gas

@ 8.5p/kWh : £1,000

Typical Costs and Installation

(new build) : £1,000-£4000 per Kw

Cost Effectiveness (Payback) : 20 years

Typical Life time : 30 years

From the four microgeneration technologies the **solar thermal system** has been identified very cheaper compared to all other technologies in terms of installation, cost effectiveness, and CO_2 reduction.

CONCLUSIONS:

The key conclusions of this work are:

- A survey based on a set of questions that were used in interview format has been carried out in the City of Manchester that covers a select set of builders associated with microgeneration.
- Results have been presented of this survey, and an analysis has been done. This has been presented, and calculations shown.
- Four technologies were found to be used – Solar PV, Solar Thermal, Wind turbine, and Biomass.
- Solar thermal energy is found to be most attractive compared with the three other microgeneration technologies.

- For all four technologies, the analysis has shown the payback period, the Carbon emissions and the cost.
- A Case study of a microgeneration manufacturing and installation company was carried out.
- The results of the Case Study have been presented.
- The Case study identified lack of knowledge as a significant barrier.

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