The impact of the GB Feed-in Tariffs and Renewable Heat Incentive to the economics of various microgeneration technologies at the street level

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Abstract: England, Scotland and Wales planning regulations require zero carbon homes by 2016. This can be expected to accelerate the uptake of microgeneration technologies. To incentivise small low-carbon generators the UK Department of Energy and Climate Change (DECC) proposed two new systems: the Feed-in Tariffs (FIT) and the Renewable Heat Incentive (RHI). This paper investigates the impact of these two systems on the carbon performance and the economics of various microgeneration technologies under two scenarios: (a) at the single dwelling level and (b) a local microgrid at the street level. The economic implications of combining a number of houses to form a local microgrid are assessed and expressed in terms of percentage of capital investment outstanding. The paper concludes that the current structure of the FIT and RHI does not incentivise microgeneration technologies according to their carbon performance and does not favour street-level schemes such as the one investigated in this paper. However it is sufficient to drive the market forward.

Keywords: Microgeneration, Microgrid, FIT, RHI, Residential, Renewables, Economics

1. Introduction

England, Scotland and Wales planning regulations require zero carbon homes by 2016 [1]. For large-scale residential developments, this implies the use of biomass combined heat and power (CHP) systems with potential contributions from photovoltaics or solar thermal systems. Micro wind power is unlikely to be suitable for the majority of developments due to the poor wind resource in the urban environment [2]. Smaller-scale developments and notably individual houses will be dependent on a combination of microgeneration technologies to meet their demand in heat and electricity. Undoubtedly the main barrier to the microgeneration technologies to date has been the high capital costs. In order to support and incentivise small low-carbon generators, the Department of Energy and Climate Change (DECC) in the UK proposed two new systems: The Feed-in Tariff (FIT) and the Renewable Heat Incentive (RHI).

A zero carbon home as defined in the “Code for Sustainable Homes”, takes into account energy efficiency usage within the boundaries of the house. However, Department of Communities and Local Government (DCLG) recognise that there may be cases where it is not reasonable to expect zero carbon to be achieved through on site measures alone [3]. This means that policies will set out a series of solutions that can deal with the emissions that cannot be dealt with on the site of the development (’allowable solutions’).

This paper considers a slightly less restrictive definition of the “zero carbon home” where various microgeneration technologies are directly connected to and operating for small-scale developments of fewer houses than would be typical for a developer-driven housing development (Figure 1). The impact of linking a number of houses at the street-level to the economics of various microgeneration technologies is investigated and compared with the economics for the single house case.

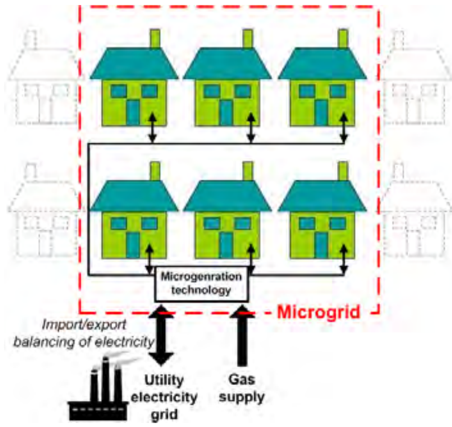


Fig.1 Conceptual combined thermal and electrical microgrid at the street level

2. Assessing the thermal and electrical demand of a residential housing cluster

For the prediction of the thermal heating demand (space heating and domestic hot water) the dynamic simulation package *TRNYS* [4] was used. Figure 2 illustrates the relationship between the main parameters used in *TRNSYS* to predict the thermal demand.

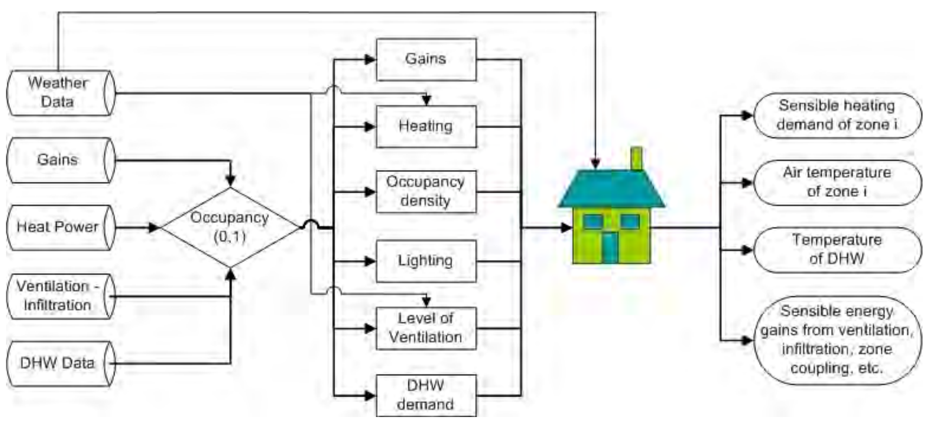


Fig. 2 Schematic illustration of the main signal flows used in TRNSYS for predicting the thermal demand

2.1. Space heating demand

The study considered a notional detached house constructed post-1965, which essentially represents ~17% of the total UK building stock [5]. Three user occupancy profiles were used: (a).Retired couple, (b).Professional working couple and (c).Family with 2 children.

2.2. Domestic hot water demand

Load profiles developed by Ulrike and Klaus [6] were used for the domestic hot water demand. Domestic hot water data and occupancy profiles were synchronised with a Fortran routine developed within *TRNSYS*, effectively operating as a load buffer [7].

2.3. Electrical demand

For this study real data was used for the generation of the electrical demand profiles; this had the form of five-minute interval data from an eco-home development of 9 low energy houses in Havant, near Portsmooth, UK [8]. Three datasets were chosen from the Havant trial to represent the three occupancy profiles in this study. Table 1 summarises the demand levels for the three occupancy profiles and the cluster of 10 houses.

Table 1. Demand profiles in kWh for the 3 occupancy profiles and the cluster [7]

	Retired couple	Working couple	Family	10 house cluster
Space heating	12,178	8,161	10,287	118,008
DHW	3,006	3,002	5,230	36,706
Electrical	2,800	3,500	4,000	33,700

3. Clustering approach - Microgrids

The energy consumption of ten detached houses was modelled. Detached houses were chosen as they are a common house type of the UK building stock, accounting for more than 20% of the total UK building stock [5] and they are more likely to adopt any of the technologies considered in this study due to the availability of space as required by some technologies.

The clustering of ten houses at the street level to form a local microgrid was chosen as the basis of this study to assess any potential financial benefits. The reasons for adopting such an approach are:

(*a*) Smoother demand profile with less distinctive peaks, for both heat and electricity, maximizing the local use of the energy generated. More continuous thermal demand is expected to result in fewer losses from the thermal storage and buffer tanks and less volatile electrical demand is expected to result in lower levels of electricity export.

(*b*) Increased thermal load, allowing CHP technologies to operate under better regime.

(*c*) Proportionally smaller peak demand of a cluster compared to a single dwelling, which translates to smaller total installed capacity for the microgeneration technologies.

(*d*) Lower capital and maintenance costs for the microgrid compared to the single house.

The short proximity of the houses within the residential cluster implies a small electrical network, where distribution losses may be ignored. The heat network was assumed to be equally small and highly insulated, therefore heat losses were also considered to be negligible.

4. Microgeneration technologies

Four types of microgeneration technologies were considered and modelled in *TRNSYS* at the single house level and the street-level microgrid [7]: Solar thermal, Photovoltaics (PV), Ground Source Heat Pumps (GSHP) and Combined Heat and Power (CHP).

4.1. Solar thermal

A typical active, indirect, flat plate solar thermal system of 4.4kW_p capacity was modelled for the single house and the street cluster (x10). A 300 litre stratified thermal storage tank was assumed per house. For the street-level cluster the same thermal storage tanks were assumed to be linked, essentially operating as a common thermal storage.

4.2. Photovoltaics (PV)

A monocrystalline PV module of 1.8 kW_p manufactured by Suntech Power [9] was modelled for each house, requiring 13m^2 total roof area [7]. The main limiting factor for sizing the PV system was the available roof space with right orientation and the minimum shading. This size is of a typical domestic application which may vary from 1.5kW$_p$ to 2kW$_p$ [10]. For the 10 house cluster the PV arrays were linked to form a local microgrid. Each house within the cluster was connected to a local distribution grid, allowing electricity to be transferred from one house to another and excess generated electricity to be exported to the utility grid.

4.3. Ground Source Heat Pumps (GSHP)

A single ground source heat pump system per dwelling was modelled to meet the space heating demand. To maximise the heat pump's thermal performance, heat storage was also considered. For intervals where heating demand could not be met by the heat pump, a backup boiler delivered any heat shortfall. GSHPs were modelled for 45°C output temperature, essentially modelling high temperature underfloor heating and low temperature radiators. For the single house a GSHP of 6.4kW$_p$ rated heating output was modelled, whilst for the cluster at the street-level two large heat pumps of 32.6kW$_p$ rated output each operating in series were considered [11].

4.4. Combined Heat and Power (CHP)

In terms of using fuel more efficiently, the concept of a CHP system was considered. Small CHP systems are commonly high heat:electricity ratio systems (>3:1) and as stated in the government's standard assessment procedure (SAP) [12], are assumed to be heat-led, meaning that they are allowed to operate only when there is demand for heat. On the grounds of economics, the installation of a CHP unit with a secondary back-up boiler would be unattractive. CHP units were therefore examined as an alternative to condensing gas-fired boilers.

For the single house a stirling engine micro-CHP system from Whispergen [13] was modelled, whilst for the residential cluster two options were investigated:

(a). a mini CHP operating as common facility for the microgrid and;

(b). three CHP units of different capacities (7kW$_{th}$/1kW$_e$, 14kW$_{th}$/5.5kW$_e$, 30kW$_{th}$/15kW$_e$) operating in series to provide the same peak thermal and electrical output as the single mini-CHP (51kW$_{th}$/21.5kW$_e$).

A thermal storage tank of 150 litres per dwelling was considered. Multi-stage operation involves the problem of scheduling the CHP devices operating in series. For this reason a heuristic, greedy construction algorithm was designed and incorporated in the CHP model.

5. Feed-in-Tariffs (FIT) and Renewable Heat Incentive (RHI)

In order to support and incentivise small, low-carbon generators and also make low carbon generation more cost effective to communities and householders, the UK Department of Energy and Climate Change (DECC) proposed two new support systems: the FIT and the RHI. With the FIT and RHI the UK Government introduces clean energy cash-back for renewable electricity and heat. Table 2 presents the tariffs for generated electricity and heat as proposed by DECC.

For electricity generation technologies, electricity exported to the national grid will be incentivised by an extra 3p/kWh$_e$.

Table 2. FIT and RHI generation tariffs for the UK, as proposed by DECC in February 2010

	FIT or RHI tariff (p/kWh)	
	Single house	**Cluster**
Solar thermal (kW_{th})	18.0	17.0
PV (retrofit) (kW_{el})	41.3	31.4
GSHP (kW_{th})	7.0	5.5
CHP (kWh_{el})	10.0	0

6. Results

At the first step, the carbon emissions from the 10-house cluster were estimated for the business as usual scenario (BaU) of a 90% efficient condensing boiler and electricity from the national grid. The BaU carbon footprint was then compared with the carbon footprint after deploying the microgeneration technology at (A) the individual house level and (B) the microgrid level. Results are summarised in Table 3 and clearly illustrate the improved carbon performance of the microgrid. It should be noted that micro-CHP for the single dwelling was the only technology with poorer carbon performance than the BaU scenario. PV system for the microgrid achieved a higher utilisation factor of the generated electricity, with 6% lower import and 15% lower export. However, in terms of carbon performance, the two schemes were equivalent as the system effectively displaces electricity with the same carbon intensity as the electricity imported. CHP's improved carbon performance for the microgrid was mainly due to lower electricity import from the national grid (13% for the mini-CHP unit and 24% for the 3 CHPs in series). For the carbon emission analysis a carbon intensity factor of 0.19kgCO_2/kWh was used for natural gas and 0.43kgCO_2/kWh was used for electricity imported from the UK national grid [12].

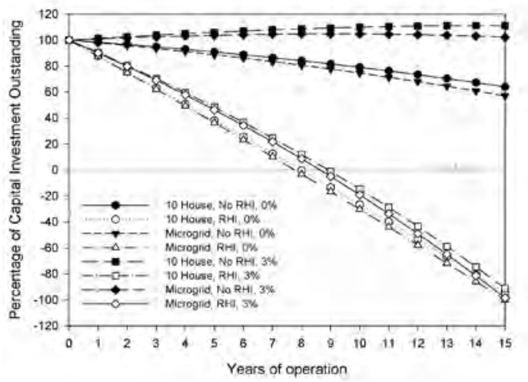
Table 3. Estimated tnCO_2 savings per annum compared with the BaU scenario

Tones CO_2 saved compared with BaU	**Solar thermal**	**PV**	**GSHP**	**micro-CHP**	**1 mini-CHP**	**3 CHPs in series**
10 non linked houses (A)	3.8 (48%)	8.0 (54%)	10.3 (41%)	-2.2 (-4.7%)	-	-
Microgrid (B)	4.3 (55%)	8.0 (54%)	11.5 (46%)	-	7.0 (15%)	7.8 (17%)
Difference (A-B)	0.5	0	1.2	-	-	-

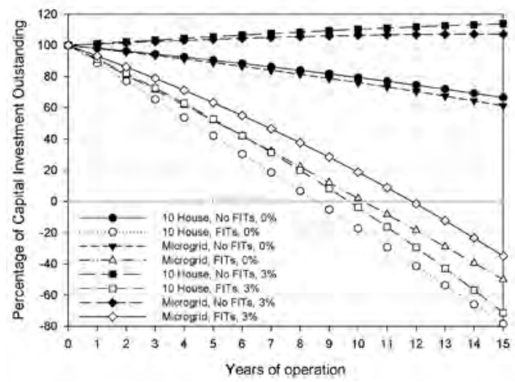
The costs of the generated energy from each technology were estimated for a 15-year period, for the 10 non-linked houses and for the microgrid. The impact of the FIT and RHI schemes was assessed for each technology. For each case, both 0% and 3% interest rate was investigated for the capital investment. The prices used for gas and electricity were: 5p/kWh for gas and 16p/kWh for electricity (£1=100p) assuming a 3% annual increase over the 15 year period. Figure 3 illustrates the predicted cost of ownership for all the microgeneration technologies assessed in this paper.

For solar thermal the single house system was priced at £3,000 with maintenance cost £50 per annum to cover engineering inspections. For the microgrid the total investment, including the piping to connect the houses, was priced at £36,000. Without the RHI support the savings achieved by the system were negated by the interest rate and the system's economics diverged. Taking into account the RHI tariffs, the system achieved a financial break-even after 10 years of operation. Financially the microgrid scheme performed better, achieving 10% greater savings on energy bills compared to the 10 non-linked houses.

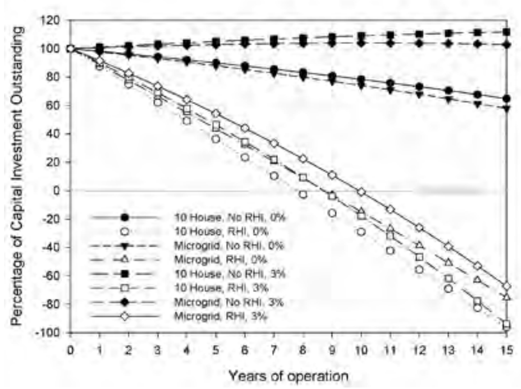
The main benefit of forming a microgrid when considering PV, was the increase of local utilisation of the electricity generated by the system. With the current FIT structure, the PV microgrid scenario was predicted to have worse performance than the standard single-house installations. Due to the very high tariff for generation and the additional export tariff, savings from the avoided import were insignificant compared to the savings due to generation. Assuming 3% interest rate, the financial payback period was predicted to be ~10.5 years for the 10 non-linked houses and ~13 years for the microgrid. Assuming no FIT the microgrid performed marginally better than the single-house case. The capital cost used for the analysis was



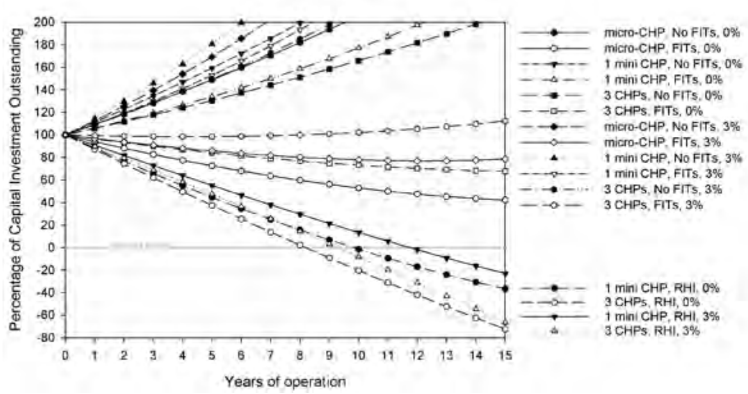
a. Solar thermal



b. Photovoltaics (PV)



c. Ground Source Heat Pumps (GSHP)



d. Combined Heat and Power (CHP)

Fig. 3 Cost of ownership profile for all microgeneration technologies considered in this study, assuming a 3% annual increase in the energy prices.

£4,500 per kWp installed and an annual OPEX of 2% of the initial capital cost was assumed for maintenance and the replacement of the system's inverter.

The improved carbon performance of the microgrid with GSHP systems was also followed by improved financial performance. With the current RHI tariffs microgrid was estimated to perform better than the 10 non-linked houses, with payback periods of ~9.5 and ~11 years respectively, despite the lower tariff offered for larger systems. Without the RHI support, all systems were far from the financial breakeven point. The capital cost assumed for the GSHP system was £1,000 per kWp [14] installed and a 1% maintenance cost was allowed for an annual inspection.

CHP units were examined as an alternative to boilers; hence the economics were calculated against the BaU scenario of a 90% efficiency condensing boiler, priced at £900 per unit with an annual maintenance cost of £50. Capital costs used were £26,000, £45,000 and £50,600 for the micro-CHP scheme, the mini-CHP scheme and the 3 CHPs in series respectively, including the heat piping network. A 2% of the capital cost was allowed for annual maintenance. As seen in Figure 3d, none of the three CHP schemes modelled reached the financial breakeven point within 15 years of operation, even when taking into account the current FIT. It should be noticed that despite its poor carbon performance, micro-CHP performed financially better, followed by the 3 CHP units in series and then the mini-CHP operating for the microgrid. The lower part of Fig. 3d illustrates a hypothetical scenario where the communal CHP units are supported through the RHI scheme. A price of 3.5p/kWh$_{th}$ would be required for these systems to reach the financial break-even point after 8-10 years of operation assuming 0% interest rate, whereas when a 3% interest rate was assumed breakeven took an additional 2 years.

Figure 4 shows a summary of the financial performance of all the microgeneration technologies considered for the residential cluster at the street level, with the current FIT and RHI tariffs, assuming 3% annual increase in energy prices and a 3% interest rate for the capital investment. It is shown that CHP technologies can not be economically viable if not incentivised. Current support for solar thermal, GSHP and PV proved to be sufficient to drive the market forward, even for the case of a 3% interest rate for the capital investment.

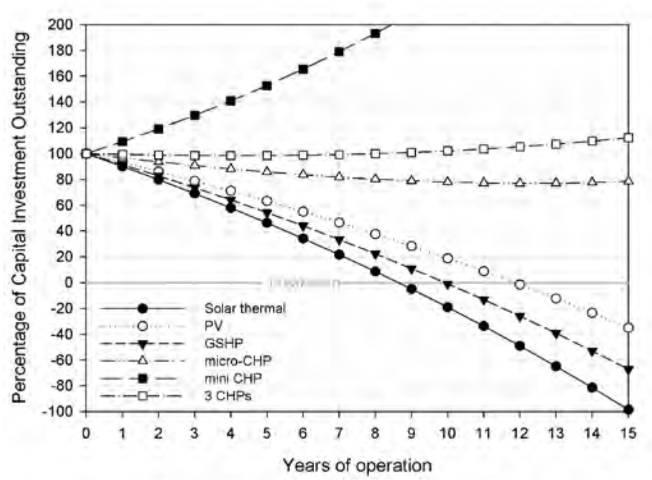


Fig. 4 Cost of ownership profile for all microgeneration technologies for the residential cluster, under the current FIT and RHI structure, assuming a 3% annual increase in the energy prices and 3% interest rate for the capital investment.

7. Conclusions

This paper investigated the impact of the UK FIT and RHI tariffs on the economics of various microgeneration technologies when they operate as common facilities for a cluster of houses at street level. It was shown that the carbon performance of these technologies was not followed by similar financial performance. A comparison between the individual house level and the cluster of 10 linked houses showed that there are potential carbon benefits and better matching of the generation-consumption profile. In some cases, however, the benefits are almost negated by the current FIT and RHI structure, due to the lower tariffs offered for larger installations and because of the high tariff offered for generation which overshadows the financial benefits from local consumption/avoided import. For this work, linked microgeneration technologies have been regarded as one larger installation, but financial benefits could further increase if each unit could be incentivised individually. The clustering approach proved to benefit CHP technologies more than any other, delivering 7-8tnCO_2/year per cluster. With no support from the Government such schemes were not predicted to reach the financial breakeven point within their lifetime. As heat-led processes they could be supported through the RHI scheme. With a generation tariff of 3.5p/kWh_{th}, CHP technologies could breakeven financially after 8-12 years and proliferate in the residential sector.

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