SIMPLIFIED STRATEGY FOR MODELING THE PERFORMANCE OF A NOVEL MULTI HOUSE HEATING SCHEMES

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ABSTRACT

Low carbon heating schemes frequently consist of a number of heat sources with different emission factors, a thermal store and heat distribution network. These need detailed models with short update periods to accurately predict their performance. However if you wish to establish the running patterns associated with the different heat source it can be assumed that tradition heat distribution networks work. This simplifies the modelling as the run period is dependent on thermal inertia of the heat store. This approach has been used to model the performance of a micro district heating scheme supplying three houses in the UK from a combination of a micro CHP unit, condensing gas boiler and solar water heaters. The model allowed each house to have variable heat loads and it was found that this combination of technologies produced a considerable reduction in annual CO_2 emissions.

Keywords: micro district heating, emission estimation, multi house heat load modelling, micro CHP with boiler and solar water heating,

1. INTRODUCTION

The need to reduce greenhouse gas emissions has now been generally accepted. This can be done by replacing some fossil fuelled power station by renewable generators and nuclear power station. An alternative approach is to improve the utilisation of our use of fossil fuels. The use of waste heat from electricity generation for space heating (combined heat and power CHP) is well established as a method of improving energy utilisation. A large industrial heat load or district heating scheme is needed to utilise the rejected heat from traditional utility scale generators. Micro CHP units designed to supply single households have been used as a way of over-coming the need for a district heating network. These have found to be effective in a number of countries. An extensive field trial carried out by the Carbon Trust in the UK found that they would only produce significant emission savings in houses with a high heating load (Carbon Trust 2007, 2011). An alternative would be to use a single micro CHP unit to heat a few houses in a micro district heating scheme. It is common practice in district heating CHP schemes to use a combination of a CHP engine and auxiliary boiler. With the CHP plant sized to supply a typical load and the auxiliary boiler rated to top up the capacity on the coldest days. This arrangement improves the capacity factor (the ratio of equivalent full load running hours to hours in a year) of the CHP plant and hence the economics of the scheme.

The advantages of using thermal stores to improve micro CHP unit efficiency has been well reported (Haeseldonckx, Peeters, Helsen, and D'haeseleer 2007; Beyer and Kelly 2008). Traditionally in the UK the critical load for sizing boilers is the need to replenish domestic hot water (DHW) tanks after a bath is taken. A well insulate modern thermal store can store sufficient water for several baths can be taken in succession (The Hot Water Association, 2010). This allows the store to be reheated over a longer period which enables a smaller heating system to be used. Consequently the heating system can be sized for its longer term space heating duties rather than short duration DHW ones.

Thermal stores are also key components in solar heating systems so it was decided to look at the impact of adding solar water heaters to the system to see if this would meet requirements for 10-15% of primary energy generated from onsite renewable energy generation in the "Code for Sustainable Homes" (DLCG 2006).

Studies that have looked at the energy used in identical houses have shown wide variation between properties (Kane, Firth, Lomas, Allinson, and Irvine 2011; Carbon Trust, 2011). Although some of the variation can be accounted for by factors like degree of shading much of it appears to be a matter of occupier's lifestyle and preference. To take account of this it was decided to model three houses with average heat loss coefficients then independently vary the coefficient by ±30% to see what the performance is likely to be in a real installation.

It was decided to model the performance of one of the micro CHP unit used in the Carbon Trust field trial to heat three average houses with the assistance of a natural gas booster boiler for use on cold days. Each house had its own thermal store. The stores were connected in series and each store had a bypass value. The bypass valves were automated such that the two warmest stores were bypassed (Figure 1).

It was found that this arrangement coped well with unbalanced heat demands and could produce primary energy savings of 20-23% when compared to heat supplied by a condensing boiler and electricity generated by a gas fired combined cycle gas turbine (CCGT) supplied through the electricity grid. The savings could be increased to 30% by the addition of solar water heating and seasonal adjustment of heating system running temperatures. Large solar water heating installations can also meet the onsite renewable generation requirements of the UKs sustainable homes standard.

2. DESCRIPTION OF MODEL

It is possible to produce detailed models of building using tools like ESP-r and TRNSYS but this requires detailed information about the building being modelled. Although these tools can give accurate results for a single building they may be unnecessarily complex to estimate the performance of average houses with conventional heat distribution systems. We know that householders are satisfied with the performance of conventional heat distribution systems so it is only really necessary to consider the heat flows in and out of the thermal store. As the thermal inertia of the thermal store is much higher than that of the air enclosed in the house a lower model update rate can be used when compared to a full building simulation programme.

For the multi house model each house has its own thermal store. This means that any heat loss from the store heats the house and is not necessarily wasted. The micro CHP and boiler plants are run if any of the stores is below the appropriate cut in temperature and will run until all the stores are above the cut out temperature.

The three houses were initially modelled with a simple series connection but this was found to produce unacceptable thermal store temperature with some load distributions. This was overcome by including store bypass valves which were operated so that the coldest store received all the heat in a given period as shown in Figure 1.

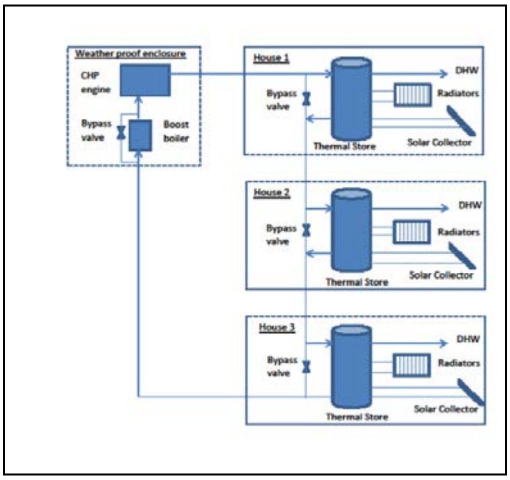

Figure 1: arrangement of micro district heating scheme

This arrangement maintained all the stores at an acceptable temperature throughout the year over the tested permutations of heat loads. It would also enable the running cost to be apportioned according to the total length of time that each houses bypass valve was closed thus removing the requirement for individual heat meters.

The model operates at a 6 minuet time interval for every fifth day throughout a year using the Weather data for Cardiff a city has an average UK climate (Exeter University 2011). The model follows typical UK practice of switching off the heating systems are overnight. This means that the inherent discontinuities associated with not considering every day occur when the heating system is off. It has been assumed that the houses are occupied throughout the year.

When the heating system is enabled it is assumed that the internal air temperature is maintained at a uniform 20°C. This is used to calculate the losses. The houses are assumed to have brick faced cavity walls with solid block inner skins. Each house is considered to have a thermal mass equal to the total thermal mass of the building structure within its insulated envelope. This is assumed to be the inner skin of the cavity wall which has a thermal mass of 8,333 kJ/K. The heat stored in the thermal mass is calculated from the inside air temperature and the thermal conductivity of the inner skin of the cavity wall (this assumption is only valid for this type of construction). The heat required to satisfy the losses and heat storage requirements for each period is subtracted from the heat accumulated in the store.

When the heating is switched off the internal temperature is assumed to be the mid wall temperature of the thermal mass and this is used to calculate the losses for the period. These are subtracted from the heat stored in the thermal mass.

For the solar heating option each thermal store is connected to a bank of vacuum insulated heat pipe thermal collectors which can operate at elevated liquid temperatures. To maximise the heat collection from the solar collectors the operating temperatures of the micro CHP engine and boiler are reduced during the summer.

2.1. Heating system input

2.1.1. µCHP unit

In the proposed arrangement the micro CHP engine is housed in a separate enclosure and is not in any of the houses. This means that it is possible to use a unit based on an internal combustion engine rather than a quieter but less efficient commercially available Stirling engines.

It was decided to use the commercially available Senertec Dach micro CHP unit for the model as its performance is typical for commercial IC engine based micro CHP unit and it has been widely studies (Beausoleil-Morrison and Kelly 2007). In its low NO_x form this engine can produce 12.3 kW of heat and 5 kW of electricity. It was assumed that the engine would take 6 minutes to warm up to a temperature where it produces utilisable heat (Beausoleil-Morrison, Kelly 2007).

2.1.2. Boiler

The micro CHP unit cannot supply all the heating or electricity demands of the houses. Additional heat is provided by a 12 kW condensing boiler. The boost boiler is connected in the return line to the micro CHP engine; this ensures that the inlet temperature to the boiler is low enough for it to operate in condensing mode.

2.1.3. Distribution system losses

An allowance of 5% was made for heat loss in the distribution system between the 3 houses. An allowance of 300W was made for the pumping power required by the distribution system.

2.1.4. Back up heating

The heating capacity of the radiator system is a function of the hot water supply temperature i.e. the thermal store temperature. This was allowed to vary over a wider temperature range than in conventional installations consequently the available heat output from the radiators was calculated for each period. If it was found to be below the thermal load for the period it was assumed that the occupants will switch on electrical heaters. The power that these consume was taken from the net generation of the CHP plant.

2.1.5. Solar water heaters

The model was run for houses with or without solar water heaters. Estimates of hourly beam and diffuse solar irradiation that would have been received at Cardiff for a year in the period 1961 to 1990 have been taken from Exeter Universities (2011). These have been used to calculate the hourly solar irradiation on an inclined solar collector. To maximise the use of solar energy it was decided to collect more solar energy than required for the DHW load on sunny day and store it for use on cloudy ones. This meant that the solar collector would have to operate efficiently with a high collection temperature. A collector that uses vacuum tube heat pipes would be suitable for this duty and it was decided to model the performance of the Sunnpro series of solar collectors as they appeared to be typical of this type of collector (Kramer 2007). The collector was assumed to be optimally mounted and the area adjusted such that the store temperature did not exceed 90°C at any day over the year. This is not a safe temperature for DHW but the building regulations require that thermal stores are fitted with temperature control valves that dilute the stored water so that the DHW is at a safe temperature. The amount of energy that can be stored on a sunny day is naturally a function of the store size. A larger collector area is needed to collect more energy consequently the size of solar collector that can be installed increases with store size.

This style of solar water heater uses a circulating pump. It has been reported that the electricity these use is equivalent to an average of 5% of the energy they collect (Martin, Watson 2001). The annual electricity consumption has been increased for the houses with solar water heating to take account of this increase in load.

2.2. Control Logic

2.2.1. Systems without solar water heating

The heating plant operates following the following control strategy:

- The CHP engine and boost boiler are constrained to only operate between 06:00 and 23:00.
- The CHP engine starts if any of the thermal store temperatures drop below 60°C.
- The CHP engine stops when all the store temperatures are above 75°C.
- The boost boiler operates if the return temperature is below 50°C.
- The boost boiler is bypassed if it is not running.
- The thermal store bypass valves are open except for the thermal store with the lowest temperature where it is closed.

2.2.2. Systems with solar water heating

For the days of the year where space heating is likely to be needed the control setting described in 2.2.1 were used. But solar water heaters should be able to provide most of the DHW demand over the summer period (day 100 to day 250) when there is little demand for space heating. The amount of energy storable in a thermal store depends on the difference between its maximum and minimum operating temperatures. To allow the maximum amount of solar energy to be stored the control temperatures were lowered to so that the CHP would only cut in if the thermal store temperature dropped below the minimally acceptable DHW supply temperature. This gave revised settings of:

- The CHP engine starts if any of the thermal store temperatures drop below 40°C.
- The CHP engine stops when all the store temperatures are above 50°C.
- The boost boiler operates if the return temperature is below 30°C (in practice this would only happen if the CHP engine was not available).

2.3. Individual house energy requirements

2.3.1. Electricity

Electricity consumption varies considerably between households and building types. The standard 30 minute demand profiles for domestic consumers used by the electricity balancing market administrators (UKERC,2012) was used to estimate the hourly electricity consumption which equates to an annual consumption of 3500 kWh.

2.3.2. Heat losses

Loss through the buildings fabric

The most common type of house in Britain is a three bedroom semi-detached or terraced house with a floor area of $82m^2$ (Anon 2009, Utley and Shorrock 2008). There is a wide range of construction techniques used so the thermal conductivity and thermal mass will vary between houses. This study considered a typical mid-20th century construction of facing brick, air cavity, and inner cinderblock skin with a plaster facing. There have been a number of government schemes to improve the insulation standard of houses and it has been assumed that the houses would have had the loft insulated to a depth of at least 100mm, cavity wall insulation injected and double glassing fitted over the last 30 years.

It is assumed that a typical house is a cube with a pitched roof that is joined to a similar house by a common wall. Glazing fraction and material U values were taken from the government's Standard Assessment Procedure (SAP) manual for the energy ratings of dwellings (BRE 2011). This gave a heat loss of 167 W/K. An allowance for ventilation loss has also been included. Test on a range of property types in Scotland found ventilation rates in mid-winter ranging from 2.15 to 0.05 air changes per hour (AC/H). Some of this variation can be accounted for by building type, and age however there was also a wide range of values within each type of building indicating differences caused by location, or user preference (Howieson 2003). It was decided to use 1.0 AC/H which corresponds to an average loss of 73 W/K. This gives the total losses for the house as 240 W/K which gives a specific heat loss of 2.93 W/m^2K (this is similar to the average value for the UK housing stock of 247 W/K from Utley and Shorrock (2008)).

Domestic hot water

The Energy Saving Trust (2008) carried out a survey of DHW usage in the UK which gave averages for the volume used, delivery temperature, and incoming water mains temperature. This has been used to derive the following equation for the average daily DHW energy requirement:

$$Q_{dhw} = 4.56 + 6.53N \text{ MJ} \qquad (1)$$

Where N is the number of occupants.

80% of English households have less than 4 occupants (Anon, 2009) so it was decided to assume an occupancy level of 3 for calculating the metabolic gain and DHW demand. As the houses were fitted with large thermal stores that buffered the DHW demand it was considered acceptable to assume that the DHW load was uniformly distributed between the hours of 07:00 and 23:00.

2.3.3. Heat gains

Solar Gain

The solar energy received per square meter of south facing window for each day has been calculated using the hourly solar data for Heathrow and the following factors from the SAP procedure (BR 2011): frame factor of 0.7, transmittance 0.76, solar access factor 0.9 glazing fraction of 17%. It was assumed that the house would have the equivalent of one south facing wall and that the solar gains through the windows in other walls would be negligible.

Metabolic and cooking

Metabolic gain is the heat given off by the occupants of the dwelling. The SAP procedure (BRE 2011) assumes that 100 Watt per person is dissipation to the surroundings. The SAP procedure uses equation 2 for average cooking gain

$$Q_{cooking} = 35 + 7N \text{ kWh/day} \qquad (2)$$

It is unlikely that this will be a steady load so it was assumed that cooking only take place in the hours 12:00 to 13:00 and 18:00 to 19:00.

Lighting and appliance gain

It was assumed that eventually all electrical power used in the home would end up as heat.

Thermal Store losses

As the thermal store is assumed to be in the heated area of the house the heat loss from it is a heat gain for the house. The following equation for calculating the maximum permitted 24 hour heat loss is given in The Hot Water Association (2010):

$$Q_{HL\text{-}MAX} = 1.28 \times (0.2 + 0.051 \, (VT)^{2/3}) \qquad (3)$$

Where $Q_{HL\text{-}MAX}$ is the maximum permitted daily heat loss from a thermal store in kWh and VT is the total storage capacity of a thermal store in litres. It is measured with an initial store temperature of 75°C, and an ambient air temperature of 20°C. This will give the store temperature after 24 hours as:

$$T_{24} = T_0 - \frac{Q_{HL\_MAX}}{C_P VT} \qquad (4)$$

Where C_p is the specific heat of water, T_0 is the store temperature at the start of the test and T_{24} is the temperature 24 hours later.

In practice for modern thermal stores the difference between T_{24} and T_0 will be less than 10°C and it is acceptable to assume a linear heat loss such that :

$$T_{Average} = \frac{(T_{24} + T_0)}{2} \qquad (5)$$

Consequently a linear heat loss coefficient K can be defined as

$$K = \frac{Q_{HL\_MAX}}{24(T_{Average} - T_{Ambient})} \qquad KW/K \qquad (6)$$

This was used to calculate the heat loss from the thermal stores.

3. RESULTS

3.1. Energy Savings

Comparison of the emission associated with a gas fire CHP scheme with those from an independent heating system and grid electricity are likely to show emission savings simply because gas is being used as a primary fuel rather than the grid mix of coal, gas, nuclear and renewables. To get an assessment criteria which is independent of the grid mix it was decided to compare primary fuel usage by the micro district heating scheme with a benchmark of the same houses using the best economically available gas fired technologies i.e. gas fired condensing boilers and grid electricity from a gas fired combined cycle gas turbine (CCGT) power station. It is worth noting that this benchmark case would emmit 32% less CO_2 than would have occurred for the same load in 1990 (the Kyoto protocol base data) with the 1990 grid mix and non condensing boilers. So a 30% primary fuel saving against this papers benchmark is a 52% saving against the Kyoto protocol baseline.
The heat load for each house was varied for -30% to +30% with different combination of high and low load houses used the resulting energy supplied by the system is shown in Figure 2

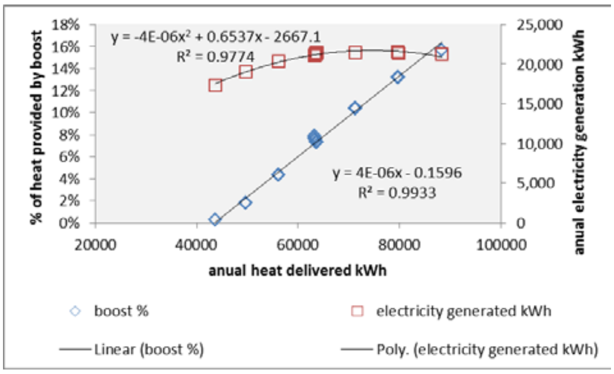

Figure 2: Energy supplied by micro district heating scheme

This gave rise to the primary energy savings shown in Figure 3. The boiler that is used to boost the CHP output has the same efficiency as the base case and so it is to be expected that the primary fuel saving will fall with increase boiler usage.

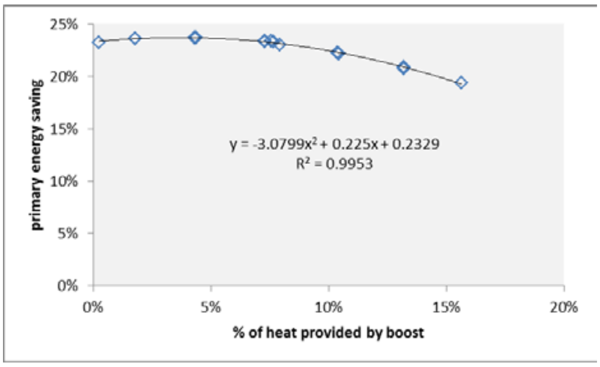

Figure 3: primary energy saving

It was found that changing the loads of the various houses had little impact on the thermal store temperatures of the individual houses. However at higher loads there were a few occasions where electrical back up heating were required. In the worst case when each house was taking 130% of the design heat load 3% of the heating was provided by the backup electrical heaters which would need to have an output of 3kW to cope.
The impact of different size solar collectors was investigated with each house fitted with a 700l thermal store and with equal heat load. The results are shown in Figure 4. There is not much solar energy available in the winter when the booster boiler operates consequently the solar water heating displaces micro CHP operation.

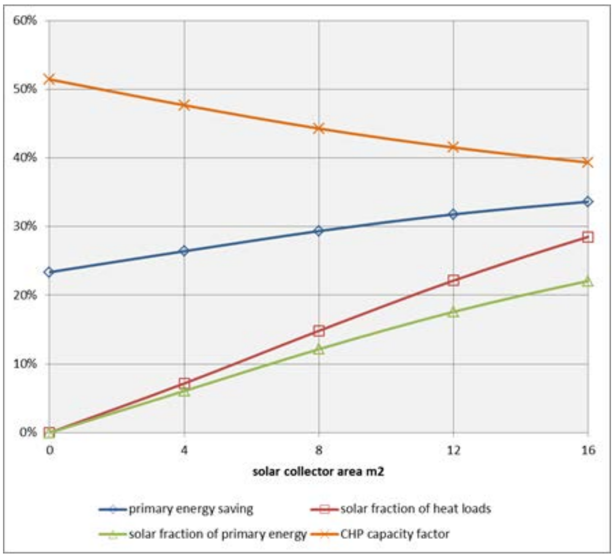

Figure 4: Impact of adding Solar Water Heating

3.2. Economic analysis

A full economic analysis is outside the scope of this study. If it is assumed that all systems have the same operational life and that the energy demand does not change between years a simple payback period calculation should give an indication of the most profitable option. Payback periods are simple to understand and are frequently used in promotional literature. The calculation is not subject to the underlying assumption involved with setting discount

rates or valuation of environmental impact used by more sophisticated techniques like net present value and environmental cost benefit analysis.
A simple payback period calculation has been carried out to allow the relative costing of a multi house system to be compared with a single house installation. To do this the model was reconfigured as a single house installation.
It was recognised that the Dach unit is not designed for single households and is oversized for this application. So the single house was also run using a Honda Ecowill unit which is designed for single households and has rated outputs of 1kW electrical and 2.8 kW thermal.
The basic procedure was to estimate the annual gas and electricity bills for the house using a condensing boiler and grid electricity. Calculate the annual net saving made by using the micro CHP systems and their capital costs. Then calculate the simple payback period.
The electricity generated is treated by considering the amount of the CHP generation that would displace grid electricity (own use) and surplus CHP electricity sold to the grid (export). Electricity used when the CHP plant is not running is supplied by the grid. Payments under the UK feed in tariff scheme are allowed for.
Operation and maintenance cost of 0.036 Cent/kWh for the Econwill and 0.026 Cent/kWh were taken from (Pehnt et. Al. 2004). The net impact of electricity sales and imports is calculated and an overall annual operational savings calculated.
The installed costs were taken from the following papers and consumer information sources:

- Micro CHP units - Angrisani, Roselli, Sasso (2012),
- Thermal stores - www.stovesonline.co.uk/wood_burning_stoves/Akvaterm-Standard-Thermal-Stores.html
- Solar water heaters – theecoexperts.co.uk
- Condensing boilers – Wich.co.uk

Prices in pounds Stirling have been converted at the average 2012 exchange rate of 1.1776 €/£ (taken from www.currency.me.uk/convert/gbp/eur). The solar water heater cost is for a collector with an effective area of $12m^2$ and is net of a £600 grant available under the government's renewable heat incentive scheme.
The costs have been taken from single sources to try and eliminate errors resulting from different geographic location, dates, exchange rates and assumptions about installation costs. As such they do not represent a considered estimation of the cost but should only be taken to be indicative of the relative costs that may be experienced in real installations.
Domestic electricity consumption is highly stochastic in nature. A stochastic load estimation tool has been produced by Loughborough University (Richardson I, Thomson, Infield, Clifford, 2010) this has been used to generate load profiles for 3 occupants during January. A sample of these is shown in Figure 5.

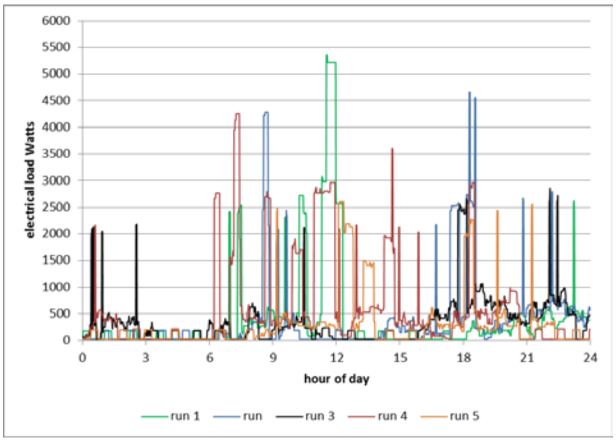

Figure 5: simulated daily electrical load profiles

From analysis of 40 runs it was concluded that 50% of the electricity consumption took place at times when the load was less than 1kW (which was about 92% of the time). The rest occurred in short duration peaks 99% of which were less than 5 kW. A 1kW micro CHP unit will be able to supply all of the loads below 1 kW and 1kW of the peak load this mean that on average overall it can supply 71% of the domestic electricity requirements when it is running. Likewise a 5 kW system can 99% of the domestic electricity requirement. However as the micro CHP plant does not operate all the time the amount they actually produce is dependent on their capacity factor. The operational performances of the systems are listed in Table 1.

Table 1: Operational Parameters

	Ecowill	Own Dachs	Shard Dachs	shared Dachs with SWH
Heat supplied kWh	19,448	19,631	19,516	19,449
boiler %	19.0%	0.0%	7.6%	7.7%
CHP	80.4%	100.0%	92.4%	70.1%
SHW				22.1%
CHP capacity factor	59.4%	18.9%	51.8%	41.5%
hours run / start	14.25	1.52	9.07	8.56
CHP heat efficiency	62.5%	58.7%	58.9%	58.9%
CHP electricty effiency	22.7%	24.9%	23.4%	23.4%
primary energy saving	20.3%	29.2%	23.4%	31.8%
solar % of primary energy				17.6%

The heat supplied is different for the different installations as the heat losses from the thermal store will be a function of its temperature which will differ between the systems. As predicted the use of a Dach unit in a single house results in a lower capacity factor and lower number of running hours per start. The electrical efficiency is higher on the Dach used on a single house as the electrical generation is net of the

power used by the installation which is higher for the shared units.
The payback period has been calculated on the basis of current UK feed in tariff (FIT) payments for micro CHP of 0.1289 £/kWh generated and export payments of 0.0464 £/kWh (www.energysavingtrust.org.uk/Generating-energy/Getting-money-back/Feed-In-Tariffs-scheme-FITs). At present the 5 kW systems are too large to qualify for these payments but would be eligible for other subsides however as the aim of this study is to compare systems not support mechanisms it was decided to use the FIT payments in all cases.
The electricity and gas cost of 0.1318 £/kWh and 0.0443 £/kWh are the 2012 average domestic price from DECC (2012).
The key data for the payback calculation are shown in Table 2. The data for the boiler system is shown in order to demonstrate where the additional costs and operational savings are made. As it is the reference system there is no payback period associated with it.

Table 2: payback period

	boiler	Ecowill	Own Dachs	shared Dachs	shared Dachs with SHW
gas used kWh	23504	29229	33418	32356	25994
gas bill €	1226	1525	1743	1688	1356
electricty used kWh	3500	3500	3500	3500	3688
electricity generated kWh		5,345	8,320	7,111	5,705
own use kWh		1476	656	1793	1516
electricty from grid kWh	3500	2024	2844	1707	2172
electricty bill €	543	314	441	265	337
O&M cost €	100	187	216	185	148
FIT payments €		811	1263	1079	866
Electricty export kWh		3,869	7,664	5,318	4,189
Electricity sales €		211	419	291	229
annual operating cost €	1869	1003	719	768	747
Savings €		866	1150	1102	1123
Capital cost per house €					
CHP		6000	15000	5000	5000
thermal store		2341	2341	2341	2341
distribution pipes etc				1000	1000
saving on boilers				-550	-550
Solar water heater					6948
total		8341	17341	7791	14739
payback period years		9.6	15.1	7.1	13.1

The nominal target payback period used to design the UK FIT scheme was 10 – 15 years (Brown, Omom, and Madden 2009). It would appear that the Ecowill and shared Dachs with solar water heating fall inside this target, the single Dachs does not meet it and the shared Dachs exceeds it.

4. DISCUSSION

It has been shown that the use of micro CHP units can give a significant emission saving over separate electricity and heat generation using the best commercially available technology. In common with most generation technologies micro CHP units show a considerable economy of scale (Simader, Krawinkler and Trnka 2006; Angrisani, Roselli, and Sasso 2012). It has been shown that it is possible to take advantage of this by using a micro CHP unit to heat a small number of properties. This is likely to be a more realisable option for retrofitting existing houses to a CHP network than implementing a new large scale district heating scheme.
The control system described in this paper copes with unbalanced loads and has the following features:

- requires very little on site adjustment,
- low data processing requirements,
- no need for heat meters,
- still maintains acceptable store temperature.

There could be an issue with the frequent operation of the bypass valves and further work is needed to optimise the operating period for different thermal store sizes.
The estimation of the optimum size CHP unit is a complex mater (Haeseldonckx, Peeters, Helsen, and D'haeseleer W,2007; Bianchi, De Pascale, and Spina, 2012), too large a unit involves unnecessary capital expenditure and it runs infrequently which can lead to inefficiencies unless large heat stores are used; too small a unit runs efficiently for long periods but requires frequent running of an auxiliary boiler to boost its output. Unfortunately there is a limited range of units on the market so in practice it is a matter of finding one which will do the job rather than the optimum sized unit. The option of sharing a unit between properties increases the size range of systems available for the system designer.
From Table 2 it appears that sharing the load between a micro CHP unit and booster boiler improves the scheme economics but Table 1 indicates that this results in a significant reduction of the primary fuel savings achieved by the scheme. This is due to the fact that although a condensing boiler and a micro CHP unit have similar overall efficiencies the electricity produced by the micro CHP unit is displacing electricity which is generated at a much lower efficiency. This effect can also be seen with the solar water heating where the SWH provides 18% of the primary energy but only increases the primary fuel saving by 8.4%.
As the efficiencies of internal combustion µCHP units are broadly similar a SWH system should provide the same order of primary energy saving on any installation.

The primary energy savings achievable are in the region of those has been targeted for 25 years time which is also close to the end of the life of the micro CHP engine. It should be noted that if the micro CHP engine is replaced with a fuel cell based unit further primary fuel savings will be achieved.

5. CONCLUSIONS

Sharing a micro CHP unit between a number of houses is a realistic option that give flexibility to the system designer to optimise the size of each houses effective CHP unit.

The use of series connected thermal stores with heat distribution controlled by two state bypass valves is a simple method of implementing a robust small scale heat distribution network.

The economic case for micro CHP is dependent on the installation being able to receive FIT payments or other similar value subsidies.

The use of gas fired micro CHP units result in significant primary fuel savings when compared to the best available gas technology for local heating and gas fire centralised generation.

The addition of solar water heating further improves the primary fuel saving but increases the payback period under current subsidy arrangements.

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