EPRG WORKING PAPER NON-TECHNICAL SUMMARY

UNIVERSITY OF CAMBRIDGE
Electricity Policy Research Group

Making Combined Heat and Power District Heating (CHP-DH) networks in the United Kingdom economically viable: a comparative approach

EPRG Working Paper 0925

Cambridge Working Paper in Economics 0945

Scott Kelly and Michael Pollitt

This research suggests that under the present regulatory and economic paradigm, the infrastructure required for DH (District Heating) networks remains financially prohibitive; the implementation of government policies are complicated and impose high transaction costs while engineering solutions are frequently not implemented and economically optimised. If CHP-DH is going to play any part in meeting climate change targets then collaboration between all parties involved in all three of these key areas will be required. This then highlights a major barrier related to the co-ordination of implementing CHP-DH networks in general and highlights the need for entrepreneurial development in major infrastructure. It is clear from the analysis presented that within the present regulatory and policy regime in the UK strong Local Authority involvement is required for the co-ordination, leadership and infrastructural deployment of CHP-DH.

Scandinavian countries have a history of supporting CHP-DH. For example, district heating now forms the backbone of the Danish energy system with almost all heating networks served by CHP plant with the majority owned by local authorities and co-operatives. Sweden and Finland are also leaders in this regard but instead of the regulatory route imposed in Denmark a more market based, municipally lead approach was implemented to great success. In Sweden upto 47% of domestic energy demand is met through CHP-DH. In the UK, central government are beginning to realise the important role that renewable heat will play in meeting carbon targets as indicated by the heat and energy saving strategy. Yet, despite this renewed interest, the number

E·S·R·C ECONOMIC & SOCIAL RESEARCH COUNCIL of operational CHP plants have stagnated since the year 2000 and today only contribute less than 1% of heat demand to the domestic sector.

From the six UK based CHP-DH schemes compared in this study, total heat and electrical capacities varied considerably. Sheffield has the largest electrical capacity; while Nottingham has the largest heat generation capacity and both schemes are powered from municipal waste. The overall profitability of these schemes appears to be marginal and largely depends on how the engineering and economic operating principles were originally established. A more thorough analysis of these critical success factors for CHP-DH networks is included in this analysis.

It is also shown that ESCO's (Energy Service Companies) provide a number of organisational, legal and economic benefits (by reducing risk) that are advantageous to the development of CHP-DH. In all the schemes studied, ESCO's contribute an important part to the organisational structure of managing, owning and protecting the interests of contractual parties. Several different models exist for establishing an ESCO but in general they are used as an entity to hold a contractual relationship between a municipality (or non-profit organisation) and a profit motivated company.

In conclusion it is shown that CHP-DH has good potential to meet at least part of the UK's long term energy goals. Such heating networks have the potential to future-proof the delivery of energy through versatility, energy efficiency and the alleviation of fuel poverty. Realising these goals will ultimately require the development of a robust regulatory environment, consisting of rigorous market based instruments that support the future development of ESCOs. Policy measures, which foster the development of relationships between public bodies and private companies are also necessary. An advantageous environment for CHP-DH networks will include an open market for heat, adequate support for decentralised energy and the internalisation and appropriate pricing of externalities such as carbon emissions. In sum, CHP-DH can make a lasting contribution towards improving resource efficiency, reducing fuel poverty, minimising pollution, improving energy security and providing increased competition for the delivery of energy.

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Keywords ESCO, Combined Heat and Power (CHP), Co-generation Energy Service Company, District Heating, Community Heating, Renewable Energy, Energy Efficiency, Private Wire Network (PWN)

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Making Combined Heat and Power District Heating (CHP-DH) networks in the United Kingdom economically viable: a comparative approach[1]

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October 2009

Abstract

As global fuel reserves are depleted, alternative and more efficient forms of energy generation and delivery will be required. Combined Heat and Power with District Heating (CHP-DH) provides an alternative energy production and delivery mechanism that is less resource intensive, more efficient and provides greater energy security than many popular alternatives. This article presents a comparative analysis between several operational CHP-DH networks across the UK, these include: Aberdeen, Barkantine, Woking, Southampton, Nottingham and Sheffield. It will be shown that the economic viability of CHP-DH networks depends on several principles, namely: (1) the optimisation of engineering and design principles; (2) organisational and regulatory frameworks, and finally; (3) financial and economic factors. It was found that in the long term DH is competitive with other energy supply and distribution technologies such as electricity and gas. However, in the short to medium term it is shown that economic risk, regulatory uncertainty and lock-in of existing technology are the most significant barriers to CHP-DH networks. This research suggests that under the present regulatory and economic paradigm, the infrastructure required for DH networks remains financially prohibitive; the implementation of government policies are

[1] The authors wish to thank those people working in district heating in the UK who generously agreed to be interviewed for their valuable insights. They also acknowledge the financial assistance of the EPSRC Flexnet project at the EPRG. All errors remain their own.
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complicated and impose high transaction costs while engineering solutions are frequently not implemented and economically optimised. If CHP-DH is going to play any part in meeting climate change targets then collaboration between all parties involved in all three principle areas will be required. This then highlights an over-arching barrier related to the co-ordination of the system in general and a lack of entrepreneurial development of major infrastructure. It is clear from the analysis presented that strong Local Authority involvement is required for co-ordination, leadership and infrastructural deployment of CHP-DH.

Key words: CHP, Combined Heat and Power, ESCO, Energy Service Company, District Heating, Trigeneration, Co-generation, Community Heating, Renewable Energy, Efficiency, Private Wire Network, PWN

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1 Introduction

It will be shown that CHP-DH networks in UK towns and cities have not experienced diffusion as they have in several other European cities such as Berlin, Copenhagen, Stockholm, Hamburg and Rekyavik. However, several schemes are now operating in the UK using the structure known as the Energy Service Company or ESCO model. In order to better understand the critical success factors and barriers to wider adoption of these schemes a comparative analysis was undertaken on six CHP-DH networks within the UK. It will be shown that the economic viability of CHP-DH networks depends on several areas, namely: (1) the optimisation of engineering and design principles; (2) organisational and regulatory frameworks, and finally; (3) financial and economic factors. Barriers and opportunities in each of these areas are identified, and recommendations are made for how policy levers, market based instruments and system design principles can be used to improve the economic viability of CHP-DH networks in general. It was found that in the long term DH is competitive with other energy supply and distribution technologies such as electricity and gas. However, in the short to medium term it is shown that economic risk, regulatory uncertainty and lock-in of existing technology are the most significant barriers to CHP-DH networks. District heating networks therefore face an uncertain future unless perverse policy incentives are removed and replaced with mechanisms that encourage private enterprise to make bold long term investment decisions in efficient and more sustainable infrastructure.

1.1 Outline

The paper begins with a short analysis of the benefits of CHP-DH technology. This is then followed by a brief historical account for the development of district heating in the UK up to the present day. The next section introduces six different CHP-DH schemes by providing a thorough review of the similarities and technical differences between them. This then leads to a discussion about the different factors contributing to CHP-DH economic viability. The paper then concludes by providing targeted recommendations.

1.2 Combined Heat and Power

In the UK, aggregate thermal power generation efficiency is approximately 40% (Figure1.2 (DUKES, 2008). If, however, low-grade heat is not dumped and CHP is used to capture waste heat energetic efficiencies often exceed 80% (aggregate CHP efficiency in the UK is 70% Figure 1.2). Final use of this low-grade energy is generally used for space heating, steam production, hot water production and even cooling using absorption chillers (Trygg and Amiri, 2007). By contrast, the vast majority of power stations do not attempt to capture low-grade waste heat, thus resulting in large system inefficiencies contributing to the accelerated depletion of fossil fuel reserves and greater pollution to surrounding environments.

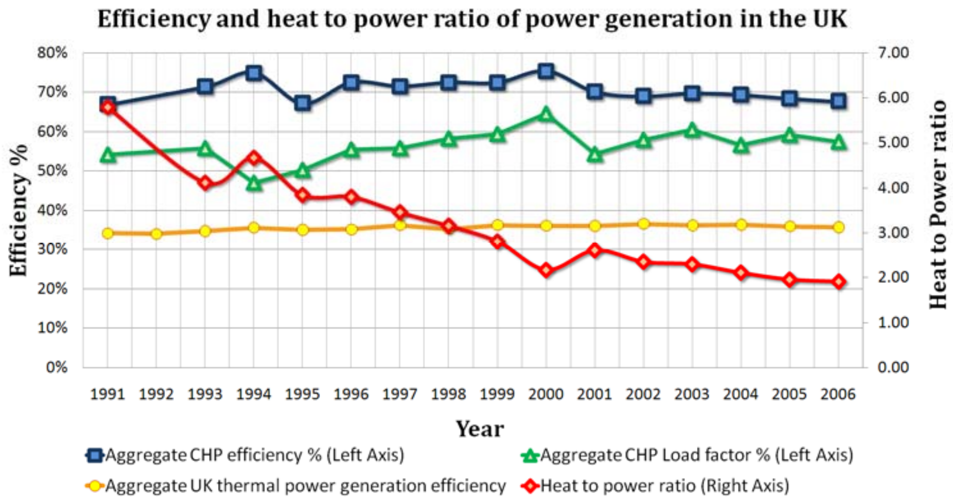

Figure 1: Aggregate energy efficiency comparisons of CHP and thermal generation (1991-2006) Source: Graph created from published data (DUKES, 2008)

It is well accepted that the amount of electricity produced by a CHP plant (as opposed to an electricity only plant) decreases when both useful steam and electricity are produced simultaneously (MacKay, 2008). Opponents of CHP-DH argue that as electricity is a more valuable commodity than heat, the resulting loss in electrical output decreases the benefit of CHP plant in favour of other competing technologies. It is argued here however that these drops in power efficiencies (sometimes as much as 10%) are only applicable for large industry that require high pressure and high temperature steam, in these circumstances requiring a sacrifice in the creation of electricity. Power efficiency losses for district heating systems that only require temperatures of around 100°C have correspondingly much smaller power losses. Furthermore, it has been shown by DECC (2009) that CHP-DH networks have some of the highest technically possible CO_2 savings and some of the lowest costs per tonne of CO_2 saved when compared against competing technologies (Figure 2). For example, it is shown in the Heat and Energy Saving Strategy (DECC, 2009) that CHP-DH using biomass could save approximately 19.3 $MtCO_2$ annually compared with individual ground source heat pumps saving just 2-3 $MtCO_2$ per year when connected to the same homes[3].

[3] This is based on the carbon intensity of the UK electricity grid in 2008.

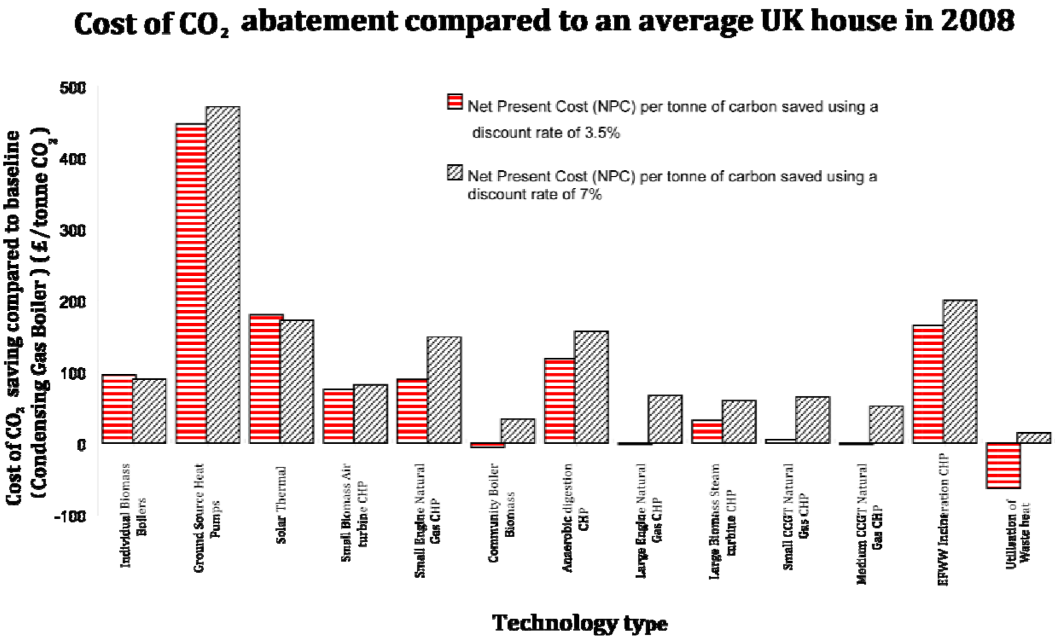

Figure 2: Cost of CO_2 abatement by technology in £/tCO_2[4]
Source: (Koehler, 2009, DECC 2009)

1.3 *Advantages of CHP-DH for sustainable development*

There are many benefits for sustainable development offered by CHP-DH networks. CHP is a proven technology that can significantly contribute to increasing energy efficiency and the mitigation of carbon emissions (Torchio et al., 2007, DTI, 2007, IEA, 2008). Furthermore, DH networks can also reduce energy costs for the end consumer and therefore contribute to the alleviation of fuel poverty (BERR, 2008). As CHP is a form of distributed generation and can be operated in 'island mode', that is, independent from the national grid, it also has potential to offer increased security of supply while providing guaranteed back-up power when required (Werner and DHCAN, 2004). In addition, system reliability is increased because CHP-DH ESCOs are able to professionally manage and operate the district heating network thereby providing continuous monitoring of efficiencies in heat production and distribution systems.

Aside from increased energy efficiency and related cost savings, communities also benefit from CHP-DH. In the first instance, electricity and heat can be generated from local renewable resources such as biomass and waste thus minimising transport distances and therefore CO_2 emissions (Action Energy, 2004, Carbon Trust, 2005, DEFRA,

[4] The baseline represents conventional heating systems using an average UK generation mix which uses individual gas boilers and electric heating. Net Present Costs have been calculated using discounted cashflows over a 30 year period.

2007). Furthermore, jobs are created to manage and maintain local power stations along with newly created waste and biomass industries; this in turn contributes to local economic growth and employment for the community. Households experiencing fuel poverty also benefit because municipalities have identified that CHP-DH networks are a cost-effective way of providing affordable heating to low income households. In addition, by using local, more affordable fuels more efficiently, district heating allows flexibility in the choice of fuels being used. For example, dual-fuel or multi-fuel CHP systems provide choice amongst different fuel types for the generation of energy. Such systems can alleviate the effects of ever increasing and volatile fossil-fuel prices that are increasingly caused by exogenous economic and political factors (EDUCOGEN, 2001).

District heating networks also provide future proofing against uncertain future energy supplies. At present, the vast majority of UK's heat demand relies on natural gas supplies, like all fossil fuels this is a finite resource. As a DH network relies only on the production of hot water, any number of fuels can be used within the thermal network including: industrial waste heat, solar hot water, biomass, combustion of household waste and geothermal energy. Such systems offer an opportunity to future-proof and improve national energy security by providing an alternative energy delivery option for when fossil fuels are either too expensive or simply unavailable.

District heating systems also offer the opportunity to use Energy Recovery Centres (ERC) for the incineration of waste and the creation of both heat and power. When waste incineration is closely monitored through a clean and filtered burning process, it has the added benefit of decreasing the volume of landfill sites whilst simultaneously decreasing a community's reliance on fossil fuels (Veolia Energy, 2008). A community based energy system encourages individual awareness about energy issues, which may also contribute to further efficiency gains (BERR, 2008).

There are also several economic benefits. For example, when heat production is centralised, cost savings are made in the operation, maintenance and cleaning of heat systems while also providing higher overall efficiencies when compared to conventional domestic natural gas boilers (Future Cogent, 2001). CHP-DH networks also offer increased competition arising from an increased choice of energy delivery methods.

Benefits accruing to the operation and balancing of the power grid are also advantageous. As CHP-DH networks usually operate sporadically during the summer months and continuously over the winter months, winter peak demands are reduced by the utilisation of heat from a CHP, therefore curbing pollution from marginal coal and gas power plants. In addition, when heat accumulators are incorporated into the network it becomes possible to produce power at times of peak electricity demand-maximising the revenue potential of electricity by creating the ability to store heat for later use. The corollary of this is to utilise abundant cheap electricity to energise electrical resistance heating coils within the heat accumulators thereby creating a thermal energy-battery that can be used when there is an increase in the demand for heat. In Denmark, this technique is being used as a means to balance the national grid during system over-burden, but also to provide a mechanism to utilise abundant cheap wind power produced at times when there is limited power demand. This situation is likely to increase as the percentage of wind influencing the system continues to increase (Palsson, 2000, EcoHeatCool, 2006, Lehtonen and Nye, 2009).

By economic and engineering necessity, CHP plants typically need to be located close to areas of high heat demand, a measure that usually corresponds with high population density. In general, these areas also have an equivalently high electrical power demand. Electrical power produced by the plant is therefore consumed in the immediate vicinity of the CHP, thus minimising transmission and distribution losses that account for some 7-9% of power consumption in the UK (DUKES, 2008). It is also possible to improve the power quality by using decentralised CHP to correct for other power system anomalies. Harmonic distortions, transients, voltage dipping and power surges all occur on a typical power network. The ability to maintain good power quality is therefore very important for the working life and efficiency of all electrical appliances drawing power from the network. CHP plants have potential to be used as a means to correct for such power anomalies thereby decreasing further losses in the system and increasing the life of equipment (Action Energy, 2004). Most notably, decentralised CHP-DH networks have the ability to prevent the development of capital-intensive large, centralised plants, the upgrading of national grid infrastructure, and the construction of new natural gas storage facilities.

In conclusion, heat distribution networks which utilise CHP therefore offer the following benefits: increased energy efficiency; minimisation of pollution; lower fossil fuel consumption; increased employment and other economic benefits for the community; a capacity to use local renewable energy resources; and finally they provide opportunities for intelligent system balancing.

1.4 Leading international experience

Scandinavian countries have a long history of support for CHP and district heating. Denmark's rapid deployment of CHP-DH during the 90's can largely be attributed to pro-active energy policy that encouraged energy saving, technological development and the early involvement of energy distribution companies (MURE Network 2002). Strong policies supporting CHP-DH were triggered by the oil crisis in 1973-4 and the late 70's at which time over 90% of energy demand was met by oil imports. District heating now forms the backbone of the Danish energy system with almost all heating networks served by CHP plant with the majority owned by local authorities and co-operatives. With so many people reliant on the Danish heat networks, heavy regulation of heat prices ensures consumers are protected. For example, the heat supply law stipulates that DH networks must operate on a non-profit basis and heat and electricity prices must be cost reflective (IEA 2009). The Danish Energy Board and the Danish Board of District Heating now aim to transfer their knowledge and technology to other countries now representing 5.5% of the countries exports (IEA 2009).

Sweden and Finland are also cited as leading examples for the implementation of CHP and district heating. In 2007, Finland generated 65% of its thermal electricity production from CHP and in Sweden 47% of its residential energy demand is supplied through DH networks (IEA 2008; Knutsson et al. 2006). Unlike Denmark's heavily regulated approach, Sweden and Finland adopted a more market based and Local Authority lead approach that is not underpinned by a strong central government incentive regime. In Sweden for example Local Authorities brought together the owners of high energy consuming buildings such as apartment blocks and company owned office buildings in a bid to collaboratively invest in DH. In Sweden during the early 1970's DH networks were heavily dependent on fossil fuels but now over 70% of fuel for DH comes from renewable feed-stocks such as biomass and municipal waste. Aside from a small initial tax rebate to kick-start the sector, there has been minimal regulation supporting CHP in Finland. Electricity taxation is focused on end use - not on production, therefore providing fair conditions for electricity production optimisation. Fuels used for energy generation are however subject to excise taxes. The Finnish Government has also maintained low barriers to entry for producers wishing to enter the electricity market. Any competitor that conforms to the necessary safety legislation can connect to the grid, paving the way for large CHP schemes that would have traditionally taken years to get approval. And finally competition legislation protects consumers against district heating utilities, however, only three to four annual complaints are made each year insufficient to warrant changing the system (IEA 2008).

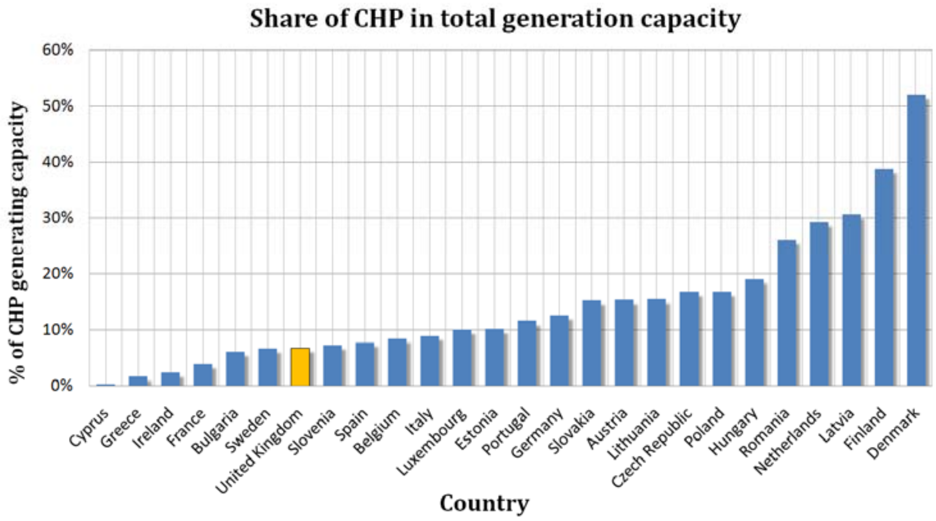

Figure 4: The EU share of generating capacity coming from CHP Source: IEA data and analysis; data merged from years 2001, 2005, 2006.

1.5 A brief chronicle of district heating in the UK

The first attempts to install a heating network in the UK occurred in 1742, however, it was not until 1791 when the first patent was granted. Manchester was one of the first places to build a large scale CHP-DH network where one was commissioned in 1911. Over the next 50 years, several schemes were constructed including one at Whitehall that still supplies heat for all the government buildings in the area. The largest of these early schemes was built at Pimlico, commissioned in 1950 and designed to supply waste heat to some 11,000 households, it was subsequently decommissioned in 1983 along with the Battersea power station (Babus'Haq and Probert, 1994). Between 1960 and 1970 several other schemes were built in Derby, Billingham and Nottingham.

During the 1970's, following political pressure arising out of the fossil-fuel price crisis the government established a CHP committee chaired by Lord Walter Marshall who first identified the potential for large-scale CHP- DH (Marshall, 1977, 1979). These reports identified that CHP-DH could be a viable economic option for providing heat to areas of high-density heat demand, particularly in the long term (Boyle and Everett, 2006). Marshall (1979) estimated that some 30% of high-density heat demand areas in the UK could be met by CHP-DH, thereby avoiding the use of 30 million tonnes of coal equivalent (approx 9% of 1977 primary energy use). The reports emphasised, however, that in the short term CHP could not be expected to take off on any scale, largely due to competition from other fuels, particularly natural gas. Marshall (1977) summarised, "if nothing is done to encourage CHP-DH now, we shall not, because of long-lead times, have CHP-DH networks when we need them". The report concluded with a recommendation that a heat strategy be implemented and a heat board established to oversee CHP-DH networks in the UK. Commitment to develop a national heating strategy has only recently been forthcoming in the Heat and Energy Saving Strategy (HESS) published to meet tough new CO_2 targets. (DECC, 2009, BERR, 2008)

In 1982, five years after the first Marshall report, the Government offered £750,000 to meet half the costs of developing schemes first identified in the 'Lead City Study'. Together these schemes have contributed to the majority of CHP capacity in the UK today, namely: Sheffield, Leicester, London, Belfast, Edinburgh and Newcastle (Budden, 1988). The Energy Act of 1983 came with mixed support for CHP-DH networks requiring area boards to 'adopt and support' small scale CHP and offer 'avoided costs' for the purchase of their exported electricity, reflecting the Seasonal Time of Day tariffs (STOD) (Boyle and Everett, 2006). Due to the lack of CHP statistics collected over this period, the success of this measure remains difficult to assess. Nonetheless, with later privatisation of the electricity sector in 1989, CHP- DH suffered a series of major setbacks, explicitly: the government failed to establish a market for heat as it did for electricity; the government with- drew CHP obligations on industry under the Energy Act (1983); and, the government initially refused to put CHP into the Non-Fossil-Fuel-Obligation (NFFO). Subsequent changes to taxation favoured separate burning of gas for heat rather than CHP. For example, there were taxes on power station fuel but not on natural gas burnt in homes.

In the years after privatisation, regional electricity companies concentrated on building large, non-CHP, principally gas-fired power generation plant and later CCGT (Combined Cycle Gas Turbine). Principally due to the growing competition in the electricity sector there was a necessity for large power stations constructed as quickly as possible which favoured quick build CCGT plant. The increasingly competitive environment in the energy sector required power stations to be made as cheap as possible to both construct and run with minimal capital and operating expenses. Plants were increasingly located on main gas lines outside town centres, as land close to main centres tended to be more expensive and usually involved longer planning delays. Thermal power generating facilities located at large distances from town centres make DH unviable, as DH networks require proximity to heat demand. Furthermore, building up a sizeable heat demand for a potential DH network took time, organisation and extra capital - expenditure that may not have been fully realised for many years. Finally, using waste heat from power stations would have displaced electric heating, which could have been seen as cutting into the revenues of existing generating plant revenues.

In the early 1990's, quite in contrast to previous historical trends, the government began to recognise the benefits of CHP and subsequently set a target in 1993 as part of the climate change programme to reach 5 GW installed CHP capacity by the year 2000 (DTI, 2007). This target was not achieved. In 2000, the government set a target to reach 10 GW of Good Quality CHP (GQCHP) by 2010, a target that, yet again, is unlikely to be met (Cambridge Econometrics, 2006). The Government has however put in place mechanisms to assist CHP-DH schemes. In 2001, the CHP Quality Assurance (CHPQA) programme was established to certify and monitor good quality CHP within the UK (CHPQA, 2000a,b, DEFRA, 2004). Schemes meeting these requirements are exempt from the Climate Change Levy (CCL) and are issued Levy Exemption Certificates (LECS), however, electricity outputs under CCL are only guaranteed until 2013. In monetary terms this represents just 0.43 p/kWh for electricity (sold domestically at 12.63 p/kWh incl tax in 2008) and 0.15 p/kWh for gas (sold domestically at 3.88 p/kWh incl tax in 2008) (DUKES, 2008) which is less than a 5% subsidy in final price. Schemes eligible for CCL exemption are also eligible for Enhanced Capital Allowances (ECA) for the investment in new energy technologies, and are exempt from paying business rates on electricity generating plant and machinery (DTI, 2007).

Between 2001 and 2005, the government implemented the Community Energy Programme (CEP) that invested £50m in government grants for the promotion of community heating. Further mechanisms include biomass grants; inclusion of CHP plants in the EU-ETS for plants over 20MWe; the adoption of a 15% target for all government departments to use electricity generated from CHP; and new banding of the Renewables Obligation (RO) for GQCHP that use biomass and waste as fuel. Such banding will mean dedicated biomass plants (with or without CHP) will receive 2.0 ROCS (Renewable Obligation Certificate) per MWh of electricity generated. Co-firing of energy crops for CHP will receive 1.5 ROCS and CHP plant using regular biomass (non energy crop) or energy from waste plant will receive 1.0 ROC/MWh. ROCS are given to renewable generators and can be traded with licensed electricity suppliers who are required to source a specific and annually increasing percentage of the electricity they supply from renewable sources. The current level is 9.1% rising to 15.4% by 2015/16. Until recently generators with capacities less than 50 kW were excluded from receiving ROCS, Ofgem are now allowing small generators to aggregate their supply to meet this minimum threshold, ultimately beneficial for small scale CHP (Ofgem, 2009a). In 2004 Defra published the governments CHP strategy (DEFRA, 2004) which outlined possible market incentives, financial assistance and legislative action to support the growth of CHP in the UK. More recently, the Heat and Energy Saving

Strategy identified crucial role of renewable heat and CHP for meeting renewable energy and climate change targets (DECC, 2009).

1.6 CHP investment trends

Despite measures implemented to support CHP by the government, growth has stagnated (Figure 3). Many factors have contributed to this downturn but probably the most significant is the price of heat not reflecting the infrastructure and fuel costs required for its delivery. For example, in 2007 the domestic price for natural gas was 3.24 p/kWh (incl. tax) (DUKES, 2008) while delivered heat was sold at 3.5 p/kWh (incl. tax) leaving little margin to cover the cost of infrastructure required for its delivery (Chan, 2008, Lyon, 2008). On a more positive note, although there has been a decline in heat capacity from the mid nineties, electricity capacity has been steadily increasing due to ever improving power to heat ratios of CHP plant.

Energy infrastructure in the UK remains inefficient and wasteful when compared to countries such as Denmark - ranked the second most energy- efficient country in the world with over 50% of electricity delivered from CHP plants (Figure 4) (Zumbrun, 2008). Within the UK CHP accounts for just 6% of total UK generating capacity, and less than 2% of all CHP capacity is used for community heating schemes. Furthermore, in the UK over 50% of final energy demand is used for space or water heating, and the majority of this is used in the domestic sector (Figure 5). Despite this, DH networks supply less than 1% of final heat demand in the domestic sector (Radov et al., 2008).

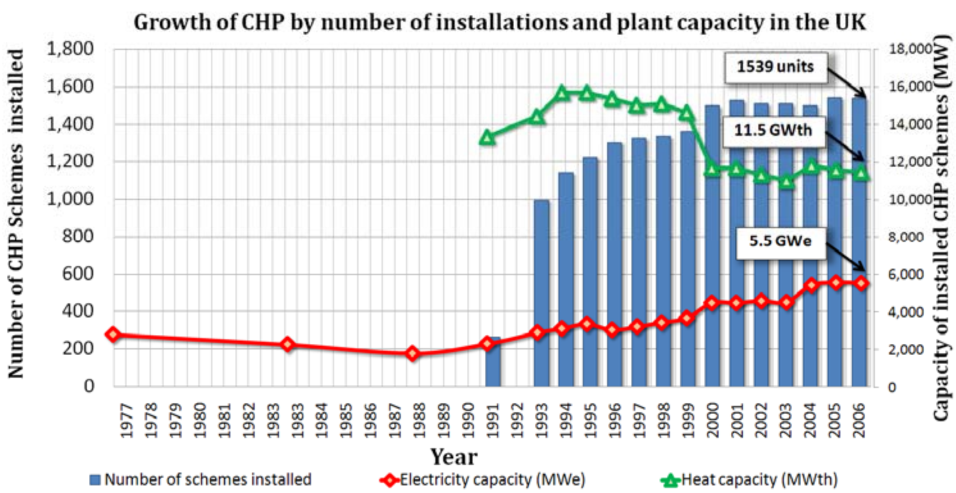

Figure 3: Growth of CHP capacity in the UK (1977-2006) Source: Graph created from (DUKES, 2008)

As the UK is bound by the EU's 2020 targets that mandate the UK must meet 15% of its primary energy demand from renewable sources and a 34% cut in emissions by 2020 - significant progress in the sustainable delivery of transport, power and heat is therefore required. These facts are emphasised in the recently published Renewable Energy Strategy (RES) (BERR, 2008) and the UK Low Carbon Transition Plan (Government, 2009) which set out, in principle, how the government plans to achieve reaching these targets. It is suggested that renewable sources will need to meet 37% of electricity demand, 10% of transport demand, and 14% of heat demand.

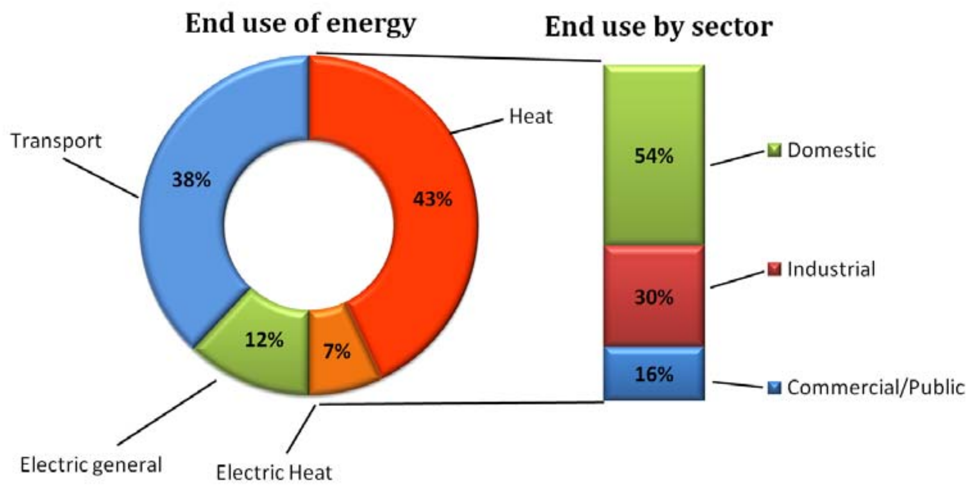

Figure 5: End use of energy in the UK by type and sector Source: (BERR, 2008, DUKES, 2008)

1.7 CHP-DH scheme analysis

There are many small and medium DH schemes operating within the UK. Six such schemes were chosen for this analysis, specifically: Aberdeen, Woking, Barkantine, Southampton, Sheffield and Nottingham. For the schemes analysed the total heat and electrical capacities varied considerably. Sheffield has the largest electrical capacity; however, Nottingham has the largest heat generation capacity. Woking is the most capital intensive ESCO with over £13m in fixed assets, while Veolia has the largest turnover increasing from £10m in 2001 to £25m in 2002 (the year after it took control of the ESCO). Of the schemes under analysis, two used heat accumulators for storing hot water, two schemes had access to private wire networks, and two schemes generated heat and power from waste.

Table 1: Comparison of heat and power generation capacities for the six DH schemes analysed (data reported in 2008)

	Electrical capacity kWe	Heating capacity kWth	Chilled water capacity kW	Annual heat generated MWh	Annual electricity generated MWh
Barkantine	1,300	1,600	No	8,000	5,500
Woking	1,352	1,623	1200	8,733	7,031
Aberdeen	1,510	2,560	No	16,660	9,800
Southampton	6,400	7,800	7000	40,000	26,000
Nottingham	14,400	82,000	No	230,000	60,000
Sheffield	19,000	60,000	No	86,000	106,000

Table 2: Comparison of engineering components and qualities (2008)

	Heat store m^3	Private wire network MW(e)	Backup boilers MW(th)	Waste incineration tonnes/year
Barkantine	210[1]	×	✓	×
Woking	163[2]	1.3	✓	×
Aberdeen	×	×	✓	×
Southampton	×	×	✓	×
Nottingham	×	5.0	76	150,000
Sheffield	×	×	87	196,505

Table 3: Financial comparisons of schemes for the 2006 financial year

	Cost to build CHP-DH (£ million nominal)	Present day value of fixed assets (£ million)	Annual turnover (3 year avg) (£ million)	Profit(loss) before tax (3 year avg) (£)
Barkantine	£6.0	£3.4	£1.1	£96,000
Woking	£4.2	£13.0[1]	£2.3	**(-£41,000)**
Aberdeen	£6.5	£5.4	£0.23	£14,522
Southampton	£8.0	£6.2	£2.8	£33,509
Nottingham	unavailable	£1.2	unavailable	unavailable
Sheffield	unavailable	£6.5	£25.6	£2,890,000

1.7.1 Financial comparisons between schemes

Care must be taken when using these figures to compare the financial performance of the different schemes. For example, the finances for the Sheffield ESCO (Veolia ES) also includes a waste contract, which significantly increases annual turnover. Likewise, the ESCO for Woking (Thameswey Energy Ltd) is involved in several renewable energy initiatives such as PV arrays and a large fuel cell skewing the total capital value of assets.

1.7.2 Other general comparisons between schemes

Two of the oldest district heating schemes in the UK are Nottingham and Sheffield and the engineering plant in both have recently been upgraded and re-commissioned to plant of much larger capacity. Both of these schemes use Energy from Waste (EFW) technology and both have much larger capacities relative to the other schemes studied.

Table 4: General comparisons between ESCOs (As reported in 2008)

	Commissioned	Number of Dwellings	Carbon Savings (tonnes)	Length of pipe work (km)	NFFO
Barkantine	2000	600	1700	4	-
Woking	2003	900	650	-	-
Aberdeen	2003	987	411	-	-
Southampton	1986	7000	11000	11	-
Nottingham	1972 & 1996	5000	58000	56	Expired
Sheffield	1970 & 2005	19000	34000	-	Operating

2 Viability of CHP-DH networks in the UK

Three main areas were identified that affect the viability and implementation of DH schemes namely: engineering and design principles; financial and economic factors; and the regulatory and organisational frameworks of CHP-DH networks (i.e. ESCOS).

2.1 Improving the economic viability of CHP-DH Schemes

Since privatisation of the electricity sector in the early 1990s competition in the wholesale electricity sector has developed significantly. Industrial, commercial and residential energy customers have had a variety of energy suppliers to choose between. Under the arrangements for wholesale electricity markets (NETA) small, variable and unpredictable power generators appear to have been disadvantaged. Meanwhile, transmission and distribution use of system charges do not reflect the benefits of local generation (Grubb et al., 2008, Ofgem, 2002). One direct example of this was the collapse of the Leicester citywide district-heating scheme that failed to secure a supply contract for the sale of its electricity. Guaranteed income from long-term energy supply contracts are essential if a DH scheme is to be a competitive energy producer under the present economic and political system. Liberalisation of the power sector is frequently blamed for the demise of the Leicester scheme because a relaxation in electricity regulation shifted negotiating power away from CHP-DH schemes to larger decentralised power plants. Despite this, Leicester still has, albeit significantly reduced, a heating network incorporating approximately 700kW of independent heating schemes with the aim to one day connect them under a single network (Bulkeley and Betsill, 2005).

The total generation capacity of a power station coupled with an ability to match periods of peak demand affect the wholesale price that can be received for the electricity produced. Furthermore, electricity is approximately three times the price of heat per kWh, but because CHP-DH systems are predominantly heat-led systems, the technology is 'locked-in' to producing a low value commodity. Therefore, CHP-DH networks have to satisfy demand for a low value commodity compromising its ability to satisfy higher returns for the delivery of electricity. Improving the profitability will thus require maximising revenues from the electricity generated rather then heat produced. Another complication is that periods of high heat demand do not necessarily coincide with periods of high power demand and therefore the final price (/kWh) paid for energy. Thus, power produced by a CHP is usually unpredictable, making electricity less valuable to a licensed supplier. CHP schemes utilising heat accumulators or variable heat to power ratios have much greater flexibility when meeting peak (energy) demands and therefore have a stronger negotiating position with electricity suppliers when negotiating long-term contracts.

CHP in the UK is predominantly gas fired making the 'spark-spread' an important indicator for determining economic viability (AEA Technology, 2004, IPA, 2005, Bonilla, 2006, EAC, 2006). The spark-spread as shown in (Figure 6) is the difference between the wholesale gas price used for electricity production and the cost of electricity sold to domestic consumers, both inclusive of taxes. Not only does Figure 6 show the spark spread closely following the price of electricity but also that the spark-spread narrowed during the 1990's, most likely due to privatisation of the energy sector (De Paepe and Mertens, 2007, DUKES, 2008). However, from 2004 onwards, the spark spread has begun to rapidly expand and is now at its highest level since 1978. If the rate of increase in electricity price is faster than the rate of increase in gas price, then the financial viability of CHP-DH networks improves; however, this same phenomenon will also increase the financial viability of CCGT. It is argued here that a more accurate measure for the viability of CHP-DH is the difference in price between gas sold for domestic use and gas sold for the generation of electricity. Figure 6 shows the spread between domestic and industrial gas prices increases dramatically from 2004 onwards representing a far clearer indicator of a schemes competitiveness. As with CCGT plant CHP-DH schemes purchase gas at the industrial gas price yet when that energy is sold, it is sold as heat a commodity that competes directly with domestic gas price, therefore the difference between these two measures represents the competitiveness of selling heat to end consumers (Figure 6).

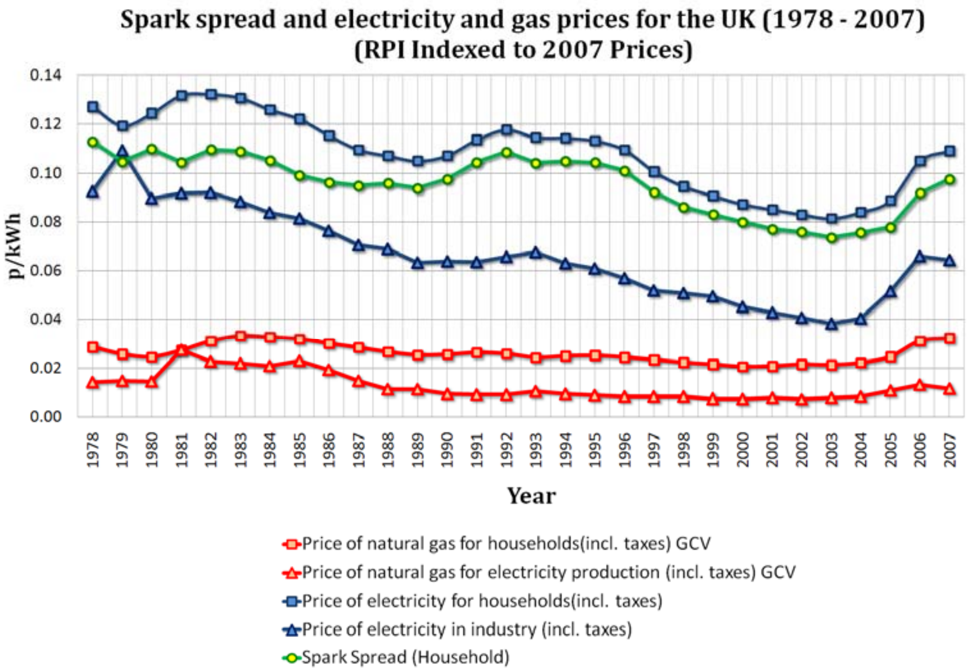

Figure 6: Spark-spread, electricity price and gas price for the UK (1978-2007)
Source: ENERDATA 2008

The present electricity network was established for a centralised system, disadvantaging Distributed Generation (DG). For example, use of system charges (TUoS and DuOS) and triad charging is calculated by the National Grid using three half-hour periods of peak demand between the 1st November and the 28th February (the winter months). An electricity supplier purchasing power from an embedded generator (a generator connected to the local distribution network) is therefore able to offset power that would otherwise have to be imported from the national transmission grid at a premium. However, this benefit is rarely passed onto distributed generators such as CHP-DH and the occasions where this does happen it is only accrued to large schemes with minimum generating capacity. Offsetting the importation of power from the grid offers a significant opportunity for DNO's to reduce operating expenses (Ofgem, 2002). TUoS charging is calculated using two components, a locational element which allows for the costs of transmission infrastructure due the placement of the generation station on the network where zonal marginal Km are converted into a cost using the National Grid's DCLF ICRP transport model (National Grid, 2004). Secondly, a non-locationally varying element related to the provision of residual revenue recovery is calculated to ensure that a generation and demand split of 27:73 is maintained and total revenue recovery for the National Grid is achieved. Between April 2008 and May 2009, small-embedded generators were eligible to receive a discount pursuant to License Condition C13 for a rebate of 25% of the combined residual charge for generation and demand, this has now been temporarily extended to 2011 but beyond this date uncertainty for small-embedded generators remains.

At present, it is prohibitively expensive for small to medium scale CHP plants to connect and export power onto the national transmission grid. Costs for connecting to the grid vary across the UK and there are large differences in connection costs depending on where the power station is located, presently there are seven different cost zones (Figure 7). If the connection charges are averaged across all seven zones it can be shown that it is more then four times as expensive for small plant (50MW) to connect to the grid then large plant (1000 MW) for every MW of installed capacity (Ofgem, 2009b).

TuOS and DuOS tariffs are also an unfair charge for CHP-DH networks. Considering that electricity produced by CHP is usually consumed where it is produced tariffs levied on energy producers to use the transmission and distribution network are likely fail to reflect the true (lower) network costs for CHP- DH development. One solution would be to initiate cost reflectivity on network costs. This in turn would lead to CHP-DH schemes being rewarded for minimising transmission and distribution losses and provide a competitive advantage for generation located close to demand. Furthermore, the 3MW minimum capacity requirement to participate in STOR should be restructured allowing small-distributed generators to be aggregated to meet minimum participation thresholds. This would provide small electricity producers with additional income and provide incentives for participation in system balancing.

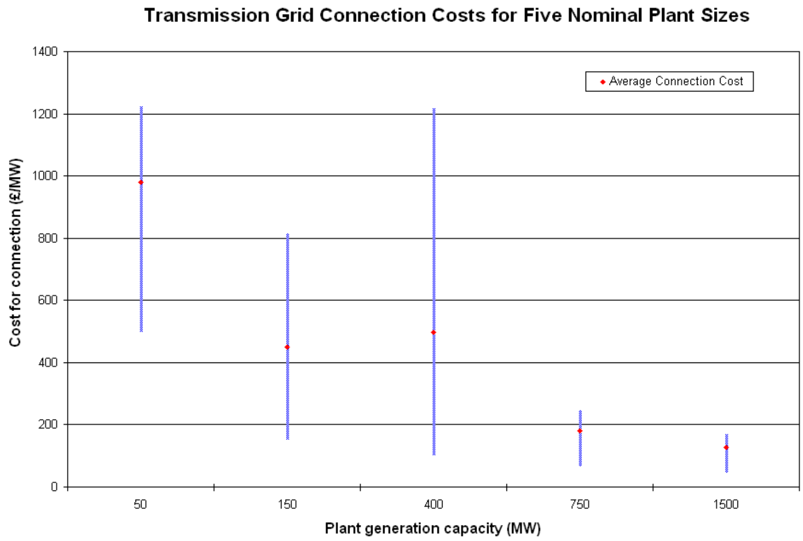

Figure 7: Connection costs for distributed generation Source: (Ofgem, 2009b)

One way to minimise this connection tariff is to install a Private Wire Network (PWN). Under the present Electricity Supply Order Exemption (2001) generators, distributors and suppliers can, supply electricity directly to customers within specified limits and allow them to avoid the full costs of applying for a public electricity supplier (PES) licence (London Development Agency, 2006). The upper limit for supplying power to domestic customers over private and public networks is presently set at 1MW and 2.5MW respectively (Figure 7). Larger schemes above the thresholds in the 2001 Order must apply for a PES licence. It is claimed the main reason for limiting the size of PWN's in the UK is to prevent ESCO's gaining a monopoly over the sale of electricity to customers on the PWN. A recent EU legal case, known as the "Citiworks Case" (European Court of Justice, 2009), has ruled that access to a private wire network must be granted to third parties, arguing that the competitiveness of the energy sector depends on open markets. This requirement for small networks to provide access does raise transaction costs but in practice could be handled by appropriate charging.

As identified by Pollitt (2009) when the distribution network costs of the electricity supply industry are compared to the unbundled local loop (LLU) costs in the fixed line telecommunications sector, the percentage of costs associated with duplicating local distribution networks appear to be much lower. Furthermore, the competitive benefits provided by LLU in the telecommunications sector are widely considered to outweigh the added costs of the stranded assets. Taking this analogy one-step further it is also possible to conceive how unbundling local distribution electricity networks could provide efficient incentives for competition based on DG based ESCOs getting non-discriminatory access to local wires to encourage innovation and lower electricity prices. This is similar to what has been achieved already in the telecommunication networks (see Pollitt 2009).

Ofgem (together with BERR) have conducted a significant review of the regulatory regime around distributed energy (Ofgem, 2007, 2008, 2009a). A major concern of this review was whether the regulations for connection of distributed generation within small supplier schemes were too onerous. The review (Ofgem2008a) made a number of suggestions. First, there were a number of recommendations on how the wholesale market arrangements might be altered in order to reduce the transaction costs on small-distributed energy suppliers making use of the wholesale market to buy and sell power (see EU legal case Citiworks). A number of work areas have also been identified which will introduce reflective charging to reduce distribution system charges for small-embedded generators like CHP, and in some circumstances may provide a net positive income for DG. Consequently the changes should encourage more local, low carbon generation to connect closer to the demand at distribution level. Finally, the latest price distribution and control review is looking at the role DNOs can play in facilitating DG specifically relating to connections and commercial arrangements for distributed generation. Indeed in February 2009, the Department of Energy and Climate Change (DECC) launched consultations on a Heat and Energy Saving Strategy (HESS) and on the Community and Energy Saving Programme (CESP) which among other things would examine the possibility of a renewable heat incentive and a feed-in tariff for small scale electricity generation.

2.2 Engineering and design principles affecting economic viability

When selecting CHP plant, an engineer must first decide how best to match the demand requirements of the end user with the supply capacities of the plant. The scale of a DH scheme is also very important. Large (>200MW) power-stations such as Combined Cycle Gas Turbines (CCGT) and nuclear power plants have been used for CHP (EcoHeatCool, 2006). Such schemes are economically viable at generating electricity alone leaving income generated from heat to be used as the finance for the DH infrastructure. Large schemes are frequently used by the industrial sector where there are requirements for continuous high temperature heat loads (DTI, 2007). Medium scale systems range from 1MWe to 50MWe and are usually fuelled by gas, but also by diesel, biomass and the incineration of waste (Future Cogen, 2001). Small-scale schemes can be classified as systems operating between 40 kWe and 1 MWe, and are used for heating hospitals, small communities, public buildings and estates. Micro-CHP is a relatively new technology; operating at around 1kW, Micro-CHP plants are designed to provide enough power and heat for one family home (Carbon Trust, 2007). A summary of different CHP technologies for small to medium plants (Table 5) and medium to large plants (Table 6) are presented below.

2.2.1 *System balancing techniques*

CHP-DH networks operate best with uniform heat demand. There are two fundamental demand cycles for CHP-DH networks, a daily cycle and a seasonal cycle. Both cycles need to be understood so the system can be most economically balanced. As would be expected, demand for heat at night is less then demand during the day. The most straightforward approach to balancing system demand is to connect constant heat loads to the system; for example, hospitals, universities, public buildings and shopping centres all require relatively constant heat profiles. Swimming pools also provide the ability to dump excess heat at most economic times. Diversifying heat loads with retail and commercial premises is also good for balancing supply loads and can have the effect of increasing potential revenues. Figure 8 shows differences in demand by sector for the UK as a whole.

Table 5: Small to medium CHP

	Cogeneration Technology	Gas Turbine	Gas Engine	Heating oil engine	Steam turbine	Sterling engine	Fuel Cell
Fuel type	Natural Gas	✓	✓	✓	✓	✓	After process
	Biogas	✓	✓	✓	✓	✓	After process
	Heating oil	✓	✓	✓	✓	✓	×
	Vegetable oil	×	✓	✓	✓	×	×
	Wood	×	✓	✓	✓	✓	×
Energy carrier	Hot water	✓✓	✓✓	✓✓	✓✓	✓✓	✓
	High Pressure Steam	✓✓	✓	✓	✓✓	×	×
	Low Pressure Steam	✓	✓	✓	✓	×	×
	Hot Air	✓✓	✓	✓	✓	×	×
	Electrical Power Output (kWe)	28-250	5-250	5.3-250	~500	1-7.5	1-200
Efficiency	Electrical Efficiency	26-30%	26-36%	30-37%	10%	11-24%	38-36%
	Thermal Efficiency	40-47%	53-62%	47-59%	70%	70-79%	39-47%
	Overall efficiency	66-77%	79-95%	77-96%	80%	81- 97%	77-83%
	Thermal Power (kWth)	52-330	12-368	10.5-314	3,000	7-22	1.2-217
	Investment (£ / kW)	2000-1500	2300-630	2300-630	Varies	4700-2000	50000-4000

Source: (ETSU, 1999, Cogen Europe, 2001, Berta et al., 2006, Intelligent Energy, 2006)

Table 6: Medium to Large CHP

	Cogeneration technology	Pass Out Steam Turbine	Back Pressure Steam Turbine	Combined Cycle Gas Turbine	Open Cycle Gas Turbine	Compression Ignition Engine	Spark Ignition Engine
Fuel type	Gas	✓	✓	✓	✓	✓	✓
	Biogas	✓	✓	✓	✓	✓	✓
	Gasoil	✓	✓	✓	✓	✓	×
	LPG	✓	✓	✓	✓	×	×
	Naphtha	✓	✓	✓	✓	✓	✓
Energy carrier	Hot water	✓	✓	✓	✓	✓	✓
	High pressure steam (+2 bar)	✓	✓	×	✓	×	×
	Med pressure Steam	✓	✓	✓	✓	×	×
	Low pressure steam	✓	✓	✓	✓	✓	✓
	Hot air	✓	✓	✓	✓	✓	✓
	Electrical power output (MWe)	1-100	0.5-500	3-300	0.25-50	0.2-20	0-6
Efficiency	Electrical Efficiency	10-20	7-20	35-55	25-42	35-45	25-43
	Thermal power (kWth)	3-800	1.5-5000	3-900	1-250	0.1-60	0-18
	Overall efficiency	~80	~80	73-90	65-87	65-90	70-92
	Heat to power ratio	3:1 - 8:1	3:1 - 10:1	1:1 – 3:1	1.5-1 – 5:1	0.5-1 : 3-1	1:1 – 3:1
	Maintenance Costs (p/ kWh)	1.8 – 1.18	1.8 – 1.18	4.25 – 3.62	4.25 – 3.62	7.24 – 4.56	7.24 – 4.56

Source: (ETSU, 1999, Cogen Europe, 2001, Berta et al., 2006)

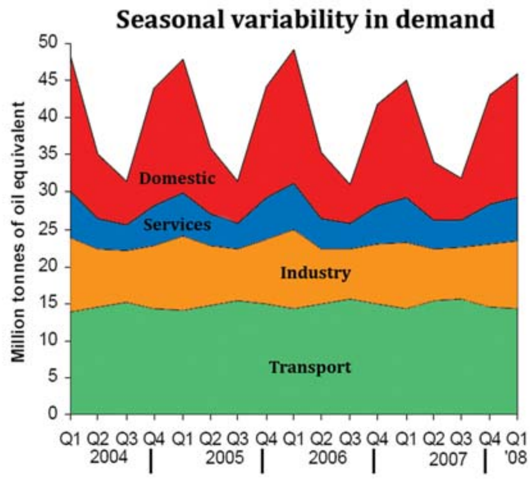

Figure 8: Seasonal variability in demand between different sectors for the whole UK economy Source: (BERR, 2008)

The seasonal cycle is much more difficult to balance. Figure 9 shows how CHP can be sized for base summer load, while back-up boilers (Boiler 1 and boiler 2) provide additional heat during the winter for seasonal balancing. A common approach involves adding chillers to the system to provide cooling in summer months. This technique is often called tri-generation and can be achieved using either absorption chillers, which take heat from the CHP as an energy source or, more conventionally they can run entirely on excess electrical power produced by the CHP (e.g. Southampton). The combined effects of climate change and increased affluence may also increase the desirability of citizens to install air conditioning systems that may also be fuelled by heat and/or power from the DH network.

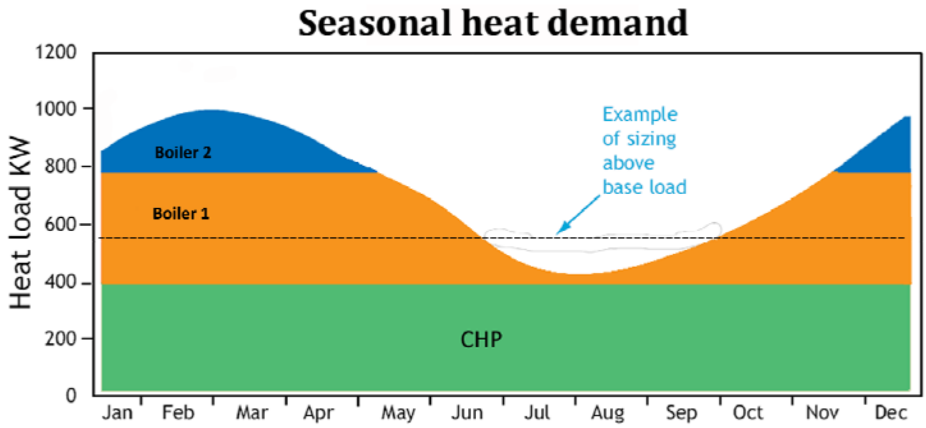

Figure 9: Seasonal heat demand profile for a typical CHP-DH network Source: (Action Energy, 2004)

There are three distinct ways to design a CHP-DH network, namely:

- Summer heat lead system with back-up boilers accommodating peak winter demand. This is the most common and risk free approach, but the disadvantage of this method is that total CHP heating capacity is minimised. Furthermore, as electricity is the most valuable commodity the amount of electricity capacity is also reduced and overall revenue potential is minimised (e.g. Aberdeen).

- Winter heat lead systems on the other hand have unused capacity during summer months. The advantage here is that the CHP provides heat for the majority of winter demand; however, the assets are under-utilised during summer months. Still, such a system will also benefit from increased revenues from selling larger quantities of electricity (e.g. Southampton).

- Electrically lead systems enable the CHP unit to operate at times of peak power demand and maximise the revenue generated from the electricity produced. Heat accumulators are required for this approach to store the heat produced by the system for when it is needed (e.g. Woking and Barkantine).

The approach finally decided on needs to take into account such factors as the ability to dump unwanted heat (if required), the ability to sell excess power, and the relative levels of revenue generated from selling different forms of energy.

As CHP is a bespoke technology, an engineer must always carry out a full economic and technological appraisal and feasibility study before construction. It is always necessary to analyse the energy demand profiles of the area being served in order to gain an understanding of peak energy requirements as well as daily and seasonal load patterns (Cogen Europe, 2001, Action Energy, 2004, Intelligent Energy, 2006). Careful consideration must be made of supply and return temperatures, heat to power ratios, as well as the physical limits and boundaries of the scheme. There have been a number of studies that model heating networks in order to optimise capacities and efficiencies of the system (Palsson, 2000, Future Cogen, 2001).

2.3 Organisational frameworks that affect economic viability

ESCOs are created for a number of reasons, namely: to minimise risk; increase revenues; appropriately apportion ownership rights; and to create a special purpose vehicle capable of delivering on specified targets. Energy Service Companies (ESCOs) have been operating in various capacities around the world for a number of decades. Still, the definition of an ESCO is loosely defined as any company that offers expertise or service for the supply or use of energy, therefore widely incorporating any organisation from a consultancy, service provider or a large asset owner (Future Cogen, 2001, Werner and DHCAN, 2004).. There are presently more than twenty ESCOs operating in the UK (Vine, 2005) and most were established to supply energy in the form of heat; increasingly ESCO's also offer services to improve household efficiency or provide finance for the development of district heating networks. ESCOs are often created in relation to heating networks designed to operate at arm's length from a parent company or organisation in order to maximise returns and minimise risk. Because of their organisational structure ESCOs can offer significant benefits through economies of scale for both capital and equipment.

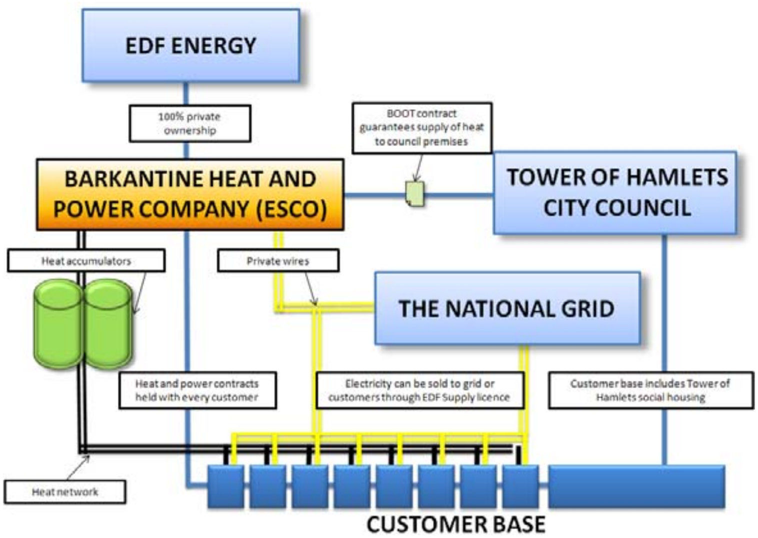

Figure 10: Seasonal heat demand profile for CHP-DH network Source: (Action Energy, 2004)

ESCOs can also offer increased incentives to improve efficiencies because of greater energy management expertise achieved through industry experience and specialization, long-term capital investment and contractual guarantees with suppliers and customers. The organisation of ESCO's can be placed into five categories: solely public, solely private, public-private-partnership (mixed ownership and management), not-for-profit and community owned co-operatives. The complicated organisational structures often associated with ESCO's can be illustrated by the Barkantine ESCO structure (Figure 10).

Within the aforementioned categories there are various contractual relationships used, namely:

- operating and management contracts;
- leasing arrangements;
- public service concessions;
- only privatisation of heat generation;
- selected private minority equity partnership;
- minority private equity invited through the stock market;
- majority private equity ownership; and,
- full private ownership with municipal support.

The details of each model are outside the scope of this article but can be reviewed in the relevant literature (Zeman and Werner, 2004, Carbon Trust, 2005, Smith, 2007, TNEI, 2007, EuroHeat and Power 2005). A more relevant analysis will be to discuss the different contracts used for public-private partnerships, as these are the dominant form for establishing ESCOS in the UK. Within public-private partnerships there are two major contract relationships ESCOs can fill: Energy Supply Contracting (ESC) and Energy Performance Contracting (EPC). Energy Supply Contracting (ESC) is the most commonly used contract and has many advantages; however, there is less motivation for the company to improve demand side energy efficiency, particularly when it is receiving an income for the energy it sells. These contracts generally operate on a low-margin, low-risk basis; with business, models often focused on securing long term operation, supply and/or maintenance contracts. Two such contracts are the Chauffage contract, where the ESCO is completely responsible for supplying energy services to customers and the Build Own Operate Transfer (BOOT) contract where the infrastructure is transferred back to the client (usually a municipality) at a pre-determined future date.

Energy performance contracting (EPC) can be defined as a form of 'creative financing' enabling investment in energy efficiency. Using EPC methods, the costs that will be saved from the energy efficiency upgrade provide sufficient finances to invest in the energy efficiency measures to be installed. ESCOs using this form of contract are thus able to provide energy performance guarantees for the provision of energy, the cost of energy, and any energy savings that may come about. These savings can then be shared between the ESCO, the public body and even the customer. This approach differs from pure energy supply contracting because savings in production and delivery are targeted. There are two main variations of energy performance contracting (Zeman and Werner, 2004, Carbon Trust, 2005): shared savings, where profits are shared between the parties (TNEI, 2007) and guaranteed savings where the ESCO takes the profit from energy savings after first guaranteeing the energy savings to be made.

An important finding is that none of the networks we looked at was developed independently and in isolation within either the public or private sectors. All schemes studied were developed as a joint project between the public and private sector. This one factor may be contributing to the slow growth of CHP-DH in the UK. Companies and municipalities wishing to operate CHP-DH networks therefore require parallel long-term strategies that must be captured within legally binding contracts. Drafting such contracts tends to be a complicated, long and expensive process thus adding large transaction costs to an already expensive undertaking. With correct market incentives and appropriate use of regulation, private initiatives would be able to undertake CHP-DH developments without being partnered with a local municipality and vice versa for municipalities.

The dominant model for successful CHP-DH networks is with direct municipal involvement and under the present political and economic environment this is almost essential in order for a scheme to be successful. However, in the longer term it is also possible to transfer the ownership of a scheme into private control, as has been achieved in Sheffield. Municipalities have been shown to assist DH schemes in many ways; for example they have:

- connected their own buildings to the scheme;
- leased or given buildings and equipment to the ESCO;

- guided customers and provided information and incentives to connect to the scheme;
- provided financial assistance for dwellings in fuel poverty;
- developed long-term mutually beneficial relationships with ESCOs, sometimes with agreements for service provision that span more than 25 years;
- instigated new planning arrangements to assist DH; and,
- prepared town developments plans and long-term heat strategies central to the long-term success of CHP -DH.
- offered long term guarantees to take heat and/or power from the system as and when required, and importantly;
- allowed the expropriation of property, roads and highways needed for pipelines and heat supply equipment to be installed;

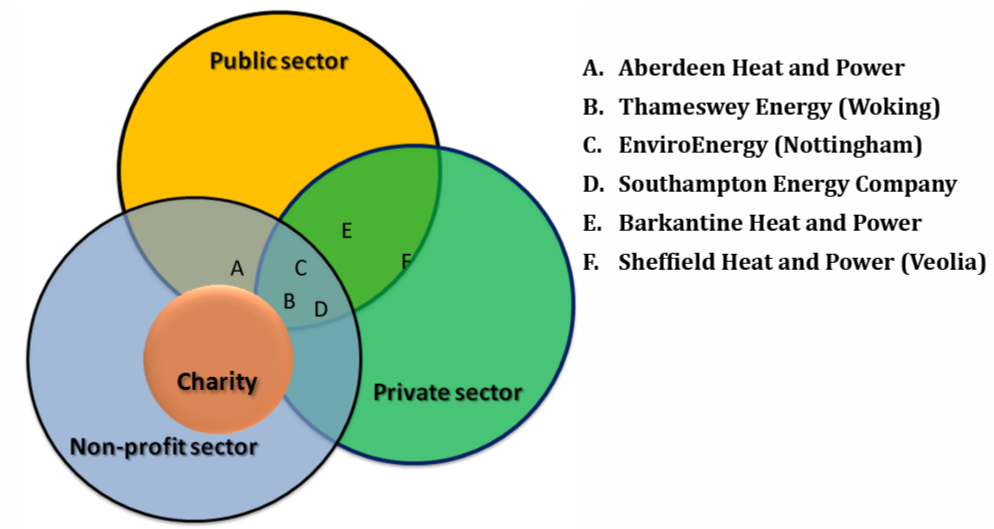

Figure 11: Sector placement of ESCOs studied Source: updated from Smith (2007).

Because of the benefits and long-term relationships offered by public-private partnerships, ESCOs can usefully be categorised into three sectors: Private Sector, Public Sector and non-profit/community owned (Figure 11). The ESCOs closest to operating unassisted in a privatised market are Barkantine, Sheffield and Southampton, all of which are wholly owned by the private sector but still require long-term heat supply contracts with a local authority.

A key question is why so few local authorities are willing or are able to successfully support local DH CHP schemes. Our discussion so far has highlighted the difficulties they would face in creating a viable scheme. However one might equally well ask what might explain why some UK Local Authorities *have* implemented District Heating schemes. Various possible explanations exist such as the presence of particularly motivated or well informed council officials or popular political support or deeper financial resources to risk up front in the project.

A possible source of an explanation is the prevalence of the right type of local "social capital" (following Putnam, 1993). Although the meaning of "Social Capital" continues to be debated within literature, there is some consensus that it consists of several important indicators typically including social relations, formal and informal social networks, group membership, trust, reciprocity and civic engagement (see Pollitt, 2002). Higher amounts of local social capital would aid the formation and financing of local working groups to assess and promote DH CHP (Scandanavia is thought of as having such social capital). It is worth noting that voter turnout – a standard measure of social capital - in Tower Hamlets (where Barkantine Power is located) is significantly higher than in the rest of London (voter turnout was 53.3% against 37.9% for London as a whole) (Electoral Commission 2005). However this measure is not consistently higher for the other five schemes we examine. A deep analysis of the particular localities behind the six schemes we discuss is beyond the scope of this paper, but would be a worthwhile exercise.

3 Discussion and Recommendations

3.1 Financial and economic recommendations

Gaining insight into the financial viability of the six ESCOs studied was completed through an analysis of their financial accounts. Not only are some ESCOs failing to submit complete and accurate financial accounts but also due to complex organisational structures the flow of money between inter- related organisations remains difficult to trace. Additionally, company assets may be owned by the ESCO itself, another holding company, the local authority, or a combination of these, making capital asset and therefore overall wealth difficult to apportion. Furthermore, the goals of an ESCO such as the delivery of affordable heat to the poor, and its non-profit status also affect what is finally charged for energy making it difficult to assess the scheme's commercial performance. Overall, the profitability of ESCOs appears to be marginal. Regulations that require ESCOs to submit complete and transparent accounts are therefore necessary so that conclusions that are more accurate can be made.

Thus far it has been shown that the financial economic viability of CHP-DH depends on several factors, namely:

- initial financing for the capital investment and the operation of the scheme over its lifetime;
- the influence and viability of market prices for gas and electricity;
- the ability for an ESCO to maximise revenue potential from electricity generation (Cambridge Econometrics, 2006, IEA, 2008); and,
- the regulatory benefits and limitations of private wire networks.

It can be seen that financing CHP infrastructure is the first and greatest obstacle to the implementation of viable CHP-DH networks. Supplemental revenues such as government grants, subsidies and tax relief (CEP, LECS, RO, CCL, and ECA) have not had the effect hoped for (Ofgem, 2008). It is therefore argued that barriers to the uptake of CHP-DH networks are systemic and further government grants and subsidies may not accelerate further CHP-DH diffusion. Instead, it would be better to focus efforts at mitigating the cause of the problem, specifically: the risks with long-term infrastructure directly caused by high upfront transaction costs, market volatility and long payback periods. A system in which companies are rewarded for long-term investments where financial investments may not be recouped for many years is thus required. This brief assessment explains why municipalities are frequently found to be at the core of the ESCO organisational framework; explicitly, they mitigate risk for the ESCO as a long-term anchor customer guaranteeing long-term future revenue streams.

It has been shown that increasing the revenue potential from electricity is one of the best ways to maximise CHP-DH profitability. Under the present policy regime there are several ways to maximise revenue from power; first, large generating plants such as in Nottingham and Sheffield benefit from triad avoidance and STOR (Short Term Operating Reserve) because they generate power above the minimum threshold (3MW) enabling them to earn significant additional income. Second, schemes that can balance demand using technology like heat accumulators can produce power at peak periods maximising revenue from electricity when there is a higher price (e.g. Barkantine and

Woking); and third, the installation of private wire networks minimises use-of-system charges levied by DNO's, while also providing a guaranteed base of customers and thus income from the power that is produced (Woking and Nottingham). A further way to overcome the 1MW limit for exemption from the need to have a supply licence is to sell power over private wires to a large single customer where the regulatory limit is increased to over 100MW (Southampton).

In conclusion, private companies wishing to install CHP-DH face consider- able risk due to the overall volatility of the electricity markets, inadequacies in the contracting environment and constantly changing policy objectives from the government. Such an economic environment favours quick build, low capital-cost solutions which do not provide the long-run incentives for CHP-DH development.

3.2 Engineering and design recommendations

Cold climates offer the best locations CHP-DH profitability because of the long operating hours and subsequent high demand for the heat produced. Areas of high-density heat load are also beneficial, which minimise network length (capital costs) and losses in the heating network. A CHP-DH system has two critical demand cycles: daily and seasonal; balancing the system over these two cycles requires different strategies, both essential for economic competitiveness. Southampton, Woking and Barkantine are three examples that have successfully implemented system-balancing techniques. Balancing daily demand can be achieved with heat accumulators, variable heat and pressure ratios, and a diverse cross-sectoral heat load incorporating many demand types. Balancing seasonal demand can be achieved using a winter heat lead system; tri-generation technologies; and again, a diverse cross-sectoral heat load. In the past CHP-DH networks in the UK have received a negative image because of inadequately designed systems not meeting user and design specifications. Latest control technologies are more than capable of meeting today's comfort levels and should alleviate historical concerns about the performance of DH networks.

3.3 Regulatory and organisational recommendations

There are three core strategies leading to investment in CHP-DH. One strategy is through the public sector the other is through the private sector and the third is a combination of both through partnerships. It could be argued that CHP-DH networks are a 'public good' and because market failures prevent private enterprise from making such long-term investments, public money is therefore required to build the infrastructure necessary for CHP-DH networks. This is similar to the development of the national gas and power grids where investment in infrastructure was largely paid for through public finances. A second alternative is to use the private sector to develop the infrastructure that requires creating the right regulatory and economic environment necessary for private investment to be competitive with other energy options. As discussed previously, the main barrier in this strategy, because of high infrastructure costs and long payback periods this increases risk that necessitates a need for higher returns adding further to the un-competitive of CHP-DH networks. Regulatory instruments such as NFFO for heat, a CHP obligation or a feed in tariff could significantly reduce risk by providing a faster repayment schedule on the capital infrastructure. More direct measures such as the requirement for all public buildings to use CHP, or minimum efficiency standards for power plants (i.e. 70 %), could also be considered as a way to encourage CHP-DH development. Another option is to continue using the present public-private partnership structure but at- tempt to streamline this process by removing barriers and transaction costs.

At present Government interventions do not appear to be having the desired effects for the development of CHP-DH. Uncertainty over long-term government policy is one of the primary cited explanations by owners of DH networks. There are many policies and market based instruments being used, and most are complicated and difficult to interpret, which may act as a barrier for new entrants into the market. By combining the many government initiatives into a single framework, industry participants will be in a much better position to understand the opportunities available to them and act upon them.

There is also an obvious need for government to introduce adequate environmental policy and sustainability reporting methods to the energy sector, which fairly account for externalities such as pollution (CO_2), resource depletion, biodiversity loss and environmental degradation (Pearce et al., 2000) and for these to be appropriately priced at their long term values. Appropriate and transparent financial accounts and sustainability reporting for ESCOs is also necessary in order to measure carefully their performance and impact.

4 Conclusion

CHP-DH is a promising technology in the UK that has the potential to future-proof the delivery of energy through versatility, energy efficiency and the alleviation of fuel poverty. DH networks have potential to use local biomass and offer a local supply of renewable electricity and heat as well as having synergistic benefits with demand-side management. Because of these facts, CHP-DH could potentially play a significant role in meeting the UK's long-term energy goals. Realising these goals will ultimately require the development of a robust regulatory environment, consisting of rigorous market based instruments that support the future development of ESCOs. Policy measures, which foster a symbiotic relationship between the public and private sectors, are therefore necessary. Such an economic environment will include an open market for heat, adequate support for decentralised energy and the internalisation and appropriate pricing of externalities. Society therefore has a distinct opportunity to capitalise on a frequently over-looked but powerful solution that can make a profound and lasting contribution towards improving resource efficiency, reducing fuel poverty, minimising pollution, improving energy security and providing increased competition for the delivery of energy.

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