Community Heat and Electricity

Engineering Sustainable Energy Systems

A response to the UK Energy Review from a community

Abstract

Energy Systems, principally for Heat and Electricity, work best if engineered at the right scale. Too big, and they are wasteful; too small, and they are inefficient. The right scale is a community scale, so involving a varied mix of uses and users and serving populations large enough to average out diversity in our behaviours.

Since we cannot produce Electricity from fuels without also producing Heat, our energy systems need markets for both. It is not enough to have distribution networks for gas, electricity and water, we also need them for Heat. Like other utilities, Heat distribution is a natural monopoly in its locale and so needs market regulation to ensure fairness and encourage investment. In contrast to the more established utilities, there remains huge opportunities for the investment in infrastructure to will deliver substantial carbon reductions. It is a Government role to define and nurture the markets that bring reward from this investment, and central to such markets is a weights and measures system. We suggest a framework for such a system.

Optimising the variable needs for Heat and Electricity across the day and across the seasons presents a complex problem of co-ordination across the communities and participants involved. It is a problem most readily solved by efficient trading among participants, so establishing the prices that encourage efficiency in both supply and demand, and allowing a rich diversity of generating and consuming devices, as well as people, to modify their behaviour to achieve optimum balance. We outline how this will work.

These community transactions also offer opportunities for people to engage in the energy issues of their neighbourhood, and so engage more deeply with their communities. We believe this will bring its own social rewards, reducing fuel poverty as well as enhancing energy and emissions efficiency.

In this context, we offer responses to the Energy Consultation Review Questions and Issues.

David Hirst 13 April 2006

On behalf of a community of entrepreneurs, consultants and academics listed in Appendix B.

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1 Introduction

Our energy systems play a central role in our civilisation but are also playing a central, damaging and destabilising role in our planetary system. In other words, current approaches to energy systems are unsustainable, and we have only a dangerously short time to fix it.

We will, soon, have to find ways of living without fossil fuels: the coal, oil and gas that has powered our lives and society also generates emissions that our atmosphere can no longer absorb. We will have to wean ourselves off it.

Some of the technologies that will enable us to do this are becoming apparent: wind, wave, solar, biomass, tidal will all play a role. Electricity will be central, and hydrogen may become the transport fuel. We need a vision for this future, and we hope this contributes part of it.

In the meantime, perhaps the most glaring shortcoming of the current approach is how little use we get out of the energy in the fossil fuels we burn. In making electricity, we discard as heat two thirds or more of the energy from coal, and about half of the energy from gas.[1] Yet heat is useful to us, and we use more energy elsewhere in our systems to make heat to keep us warm, washed and fed.

This paper discusses how we can do better, and how "community" scale holds out the best hope for long term sustainable energy systems.

It has been prepared by a self selected community of entrepreneurs, engineers, academic and others pursuing more sustainable ways of living. We list ourselves in Appendix B.

2 Executive Summary

The central theme of this paper that energy systems are best scaled around communities or neighbourhoods. Working at this scale enhances the security of energy supply, optimises economic and emissions efficiencies, widens the choices of technologies, and provides sensible, useful ways for individuals and families to engage with their community and the body politic. There will remain a need for large scale elements, as we will need the electricity harvested from ambient renewables in distant places, such as wind, wave and tidal, but these should be engineered to suit the many communities they will serve.

Two forms of energy, Heat and Electricity, are how most of us, most of the time, experience and use energy. We first (Section 0 Heat and Electricity) set our discussion in this context.

We then (Section 4 The Disbenefits of Large Scale in Energy Systems) show how large scale electricity generation systems, however appropriate they may have been for the times when they were conceived, no longer suit the needs of our age. Large scale fossil fuel generators are unable to make efficient use of all the heat that this technology liberates. Even before taking into account the losses in distribution and use, coal and nuclear technologies throw away twice as much heat energy as they make into electricity. Even the most efficient modern combustion conversion systems make use of little more than half the energy they liberate. Such loss is fundamental to heat engines, and cannot be sensible in a world whose atmosphere's capacity to accept more emissions is largely exhausted.

It has long been recognised that, if we can combine our need for heat with our electricity generation systems, we can achieve much higher thermal and emissions efficiencies, well over 90%. The Combined Heat and Power (CHP) community has long sought to encourage this approach. Section 5 Combined Heat and Power discusses the opportunity.

[1] In fact we lose even more in inefficient use, but that is not the topic of this paper.

Our challenge in the UK is to develop appropriate markets for the heat, and this requires a Heat Distribution infrastructure, just as gas, electricity and water need their distribution infrastructure. This, in turn, requires markets that appropriately reward those investing in the infrastructure.

Like other utilities, the local distribution infrastructure creates a "natural monopoly", which, to be fair and to work well, needs regulation by government. Part of this regulation needs to be a weights and measures system for the transactions involved. We suggest an appropriate market framework and pricing structure to encourage the building of local heat distribution infrastructures, and their possible aggregation into a larger scale market for transmission of heat from larger scale installations over longer distances.

Heat is far more amenable to storage [2] than electricity. It is easy to engineer systems in which we store heat, perhaps just as hot water, for use when convenient. Bringing Electricity, Heat and Storage into a coherent energy system we gain extra ways to manage our systems, and make our conversion processes more efficient and often smaller. Section 6 Storage and Flexibility explores the energy storage opportunities possible from smart use appliances and domestic infrastructure.

Section 7 Community Heat and Electricity brings together the arguments showing that the diversity and scale of community or neighbourhood systems gives the widest choice, offers the most flexibility and is most efficient, both in emissions and in resource use. We show how it minimises "a mis-match between economic and environmental efficiency [flows] from a number of energy pricing issues."[3] We see the Energy Review as providing an opportunity to address these (and related) market failures.

Section 8 Community Engagement opportunities explores the wider social opportunity that community energy systems can encourage. Energy is not the only system that optimised at the community level. For example, low heat loss housing is most easily achieved across large properties or groups of properties, and so can offer contributions to reducing fuel poverty. While energy need not be central, it can help support the social connectedness so critical to avoiding suffering and encouraging the sustainable Communities that are a major thrust of Government policy.

With this context set, the final section 9 Energy Review Questions & Issues, offers specific answers to the questions of the Energy Review Consultation.

The document is supported by Appendixes. Appendix A gives References, Appendix B lists Participants and Contributors and Appendix C Document Control gives the status of this document, and the uses to which it can be put.

3 Heat and Electricity

Energy is of use to us in our homes either as heat, which is great for keeping us warm, for heating our water and for cooking; or as far more versatile electricity [4], which we can use for a vast array of things we find useful, such as light, running TVs, appliances, PCs, hi-fi etc, as well as

[2] We define storage as "transport through time", as this broadens perception of how we can achieve storage.

[3] From the IEE FactSheet on Combined Heat & Power, [1]

[4] "Electricity" is a more precise and less ambiguous word than "power", so we are adopting this terminology in this paper. For further discussion see [2]

converting to heat. Some industries need some further forms of energy but this paper does not explore them [5].

Natural gas is broadly our chosen fuel for heat. From its ancient storage vaults deep underground, it is delivered to our homes by a vast, underground and largely invisible pipeline infrastructure. Partly derived from earlier local "town gas" distribution networks, partly built to carry North Sea gas to our homes, and now being extended to bring gas from further afield. It is very efficient, with around 99% of the gas reaching our shores being delivered to our homes and businesses. When it has reached our homes, only about 10% of it need be lost as waste up the chimney.

Oil and coal have largely disappeared from our homes: oil because it is more valuable as a transport fuel, and coal because it is inconvenient and smoky.

Electricity is our other "fuel" of choice. Except it is not a fuel, rather it is a carrier of the energy from fuels burned elsewhere, or captured from our environment.

To make electricity from fuels we use heat engines. That is, we make something very hot by burning the fuel [6], and then (simplistically) make electricity as it is cooled down. As technology has developed, we have got better at getting more of the energy into electricity, but the best we can achieve with modern machines is around 60%. Most of our generation operates at about half that. The energy we cannot make into electricity is heat, too often a waste product that is expensive and difficult to dispose of.

So why not use the wasted heat from electricity generation to feed our need for heat? Clearly, if we succeed, we can drastically reduce our need for heat. Combined Heat and Power – CHP – has long been recognised as a way of getting more out of our fuels.

But there are complications.

- The balance of our need for heat and our need for electricity varies in quite complex ways. It depends in part on the season and the weather: clearly we do not need so much heat if it is warm outside. It also depends upon the efficiency of our houses. Older, poorly insulated houses tend to need a lot of heat in relation to the electricity consumed. Well insulated, cosy homes need much less heat, and may keep warm just from the incidental heat of our technology – many offices keep warm from the computers they house.
- Our needs are constantly changing, sometimes quite rapidly. As in cooking, sometimes we need a short intense burst, but sometimes we need a long slow gentle heat. For electricity, in our homes, our peak consumption is around 15 times our average consumption.
- We cannot store electricity as such. We can store fuels and we can shift the timing of our electricity use, but we need the electricity NOW, whether or not the heat is of any value to us. So there are complex interactions between heat and electricity that we need to manage if we are to achieve our goal of avoiding waste.
- Heat distribution, like electricity and gas distribution, needs an infrastructure to open the market for the heat. Without this market, the heat cannot be used.
- Different technologies at different scales offer different balances between heat and electricity, and, unless we get the mix and scale right we will lose the promised efficiencies.

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[5] Strictly speaking, what we are concerned with is Exergy, the ability to extract use from the energy embodied in fuel. We commend an exploration of Wikipedia http://www.wikipedia.org/. But for policy purposes, heat and electricity are quite enough.

[6] This is true of nuclear "fossil" fuel also, although the burning is not combustion, and the waste products are not gas we can discharge to the atmosphere.

This is a difficult challenge, and will need a careful, sound and coherent framework for us all, in our different ways, to be able to make decisions that keep this mix efficient and effective, and maintain overall energy systems that meet our needs.

4 The Disbenefits of Large Scale in Energy Systems

The large generation plant that currently dominates our energy mix were conceived in the decades after the war and after many years of austerity, quite often imposed in the form of blackouts on cold winter evenings when there was just not enough electricity to go round. We appreciated the convenience of electricity, and found more and more uses for it, so demand was rising rapidly. The need was to build more generation as efficiently as possible, and a good way to do that was to exploit the economies that came with scale [3]. Larger plant was both a few % more thermally efficient and cheaper per unit of capacity.

The country, particularly London, also faced severe air quality problems. The Great London Smog of 1953 killed many thousands (although this was not really noticed at the time). Against this background, building large coal fired power stations in London faced planning obstacles, as well as facing difficulty with the logistics of coal transport. Coal by wire made sense when large power stations near the coal fields did not harm urban air, and faced less opposition.

There were and are downsides:

- The need for high capacity transmission lines – the supergrid. There was significant opposition to despoliation of the countryside, and the long distance transmission loses a few % of the electricity.
- The costs. Although dependent upon assumptions, the economics of long distance transmission are marginal, and, after it had been implemented, the view was that coal by rail would have been more economic[7] .
- Loss of markets for unwanted heat. City based plant could offer district heating services, such as the scheme at Battersea[8], but large remote plant needed reasonable rivers and large cooling towers, or needed to be by the sea. In coal plant operating at its optimum, over 60% of the energy embodied in the fuel is rejected as waste heat.[9]
- The need for high capacity backup when generators fail. A single generator set might be serving half a million homes, but was capable of intermittently "tripping out". To make sure this did not trigger a blackout, other plant had to be available to make up the loss. This, in turn, drives a need for the overall long distance grid system to be as large as possible. In the UK grid, the backup capacity today is driven by the need to protect against loss of Sizewell B – the largest single unit on the grid.

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[7] Quoting from [4] which reported on the study by which the approach was justified. "Subsequently the investigation has been repeated with more accurate modelling, and the advantage for electrical transmission has diminished. This has been identified as due to a more efficient loading and discharging of coal at pit head and power station, and the use of large trucks specifically designed for this work, reducing coal transport costs. Present indications are that there is no economic preference for the bulk transmission of electrical energy from generating stations sited on coalfields."

[8] Still in use, but having to generate its own heat from fuel.

[9] When quoting efficiency figures our figures are based on "rated" efficiency, that is the efficiency when running continuously at stable optimum output. In practice, short term variability, the need for reserve, and starting and stopping over the day or week significantly reduce this efficiency.

- The long lead time for building plant. With new plant taking a minimum of 5 years to build (and often more), forecasting demand so far ahead is particularly difficult. Some of the nuclear plant took over 10 years between commitment and commissioning.

These themes have been taken to the present day by Amory Lovins and colleagues in his exhaustive analysis: "Small is Profitable" [5].

Some of these disadvantages have been reduced, but not eliminated, by more modern gas fired plant. When operated at optimum, gas plant can achieve efficiencies of 60%, and the fuel is lower in carbon content. The "dash for gas" did, for a while, bring down the overall greenhouse gas emissions of the country. Today, the rising cost of gas, the declines in North Sea gas, and the lower costs of imported coal are reversing this trend.

5 Combined Heat and Power

Combined heat and power (CHP) is a broad set of technologies that aim to generate useful heat and electricity at the same time. The IET Fact sheet on CHP [1] is clear and helpful.

In part, CHP is attractive because it is impossible to generate electricity from fuels without generating more heat than can be converted into electricity. The core virtue of CHP is in organising things so that the heat you make is useful. For most existing CHP plant the electricity is a useful, but secondary, side benefit. When optimised an industrial plant that needs steam, for example, can make use of 90% or more of the heat in the fuel, with some proportion of this (usually around 30%) made into electricity.

Most CHP plant is "heat led". That is the system is controlled to meet the need for heat, so the electricity output varies broadly according to the heat demand changes. More flexible plant can change the proportion of electricity, but not usually by very much.

This feature is also reflected in domestic CHP equipment, which runs according to the needs of a household for heat (although the proportion of electricity, often 10% or less, is much smaller).

In the UK electricity market (or more strictly, the "Balancing Mechanism"), variation from the output predicted an hour or two earlier incurs extra costs and risks, so tending to lower the value received for the electricity output from CHP plant [6]. This tends to lower the rewards of CHP and make it less attractive to investors despite the substantially greater overall thermal efficiency.

The economics of CHP also depends upon a reliable and ideally stable demand for heat. If this is to be homes, then there needs to be a distribution network for the heat in the form of an infrastructure of insulated pipes, usually buried, that connect to the homes to be served. These are most effectively rolled out in the areas surrounding the source of heat, but once distribution networks exists they can be effectively serviced using high volume bulk transmission of heat from larger plant – a heat grid, conceptually similar to an electricity grid, but with lower energy losses.

There is a rich and complete literature on the virtues and economics of CHP [7-9], all suggesting that there is a huge and attractive potential for much wider adoption of what is a mature technology [10]. The Government strategy [10] recognises this potential and offers a range of incentives. Many dispute, however, that the analysis behind the incentives and the consequent market structures are well suited to the benefits and potential [11], and it is clear that many other countries, in Denmark, Lithuania, Russia, Sweden and the Ukraine have deeper heat distribution networks than the UK, despite us having a climate regime and housing stock that is relatively well suited.

[10] The EST web site http://www.est.org.uk/housingbuildings/communityenergy/ is a useful source for much of this literature.

The practical literature emphases the value of diversity among the users of heat. A mix of users will spread the time of use more widely, and avoid peaks and troughs of demand. A dormitory suburb, for example, will tend to peak at some times, but these times will not usually coincide with the demands of commercial offices, and a mix of the two provides a better balance.

There is also diversity from numbers. A few dozen or a few hundred users will have much steadier aggregate needs for heat than any individual user.

If there is no local heat distribution network, CHP is only possible when individual homes each have their own units, and this is the focus of a lot of investment and research effort. There is clearly a useful role for such equipment, but it is far from clear how soon energy systems can be optimised for CHP at this scale. There is evidence that the claimed benefits will be hard to deliver [12]. Small systems that can adjust to the variability of our individual needs are harder to engineer, harder to make efficient, and harder to maintain. At this small scale it is also harder to keep the emissions levels low, particularly of NOx, and many abatement technologies possible at larger scales become infeasible. This may be balanced by the quality and refinement possible with modern mass production. The heat distribution networks proposed can enhance the value, efficiency and reliability of service when small units are deployed.

Community scale, widely adopted, is better suited to our broader needs.

6 Storage and Flexibility

Energy storage, the shifting of energy through time, can greatly enhance the flexibility of our energy systems. Electricity as such, however, seems fundamentally incapable of storage. We can, with care, use our generators and our appliances to shift our conversion to or from electricity through time [13], and achieve storage in this way.

Heat is much more easily stored, most commonly in the form of hot water. We can and do store hot water in many tanks in our houses, and we have flexibility as to when we replenish the heat we use. At a larger scale it is easier to insulate better, so enabling heat storage to balance our needs across the day, or even across the week[11].

Since our electricity generation will normally make heat as well, a capacity to store the heat will give us the flexibility to generate to meet the demand for electricity, without incurring wasted heat when there is too much for our immediate needs. So some dynamic mix of generation, heat distribution and storage offers the opportunity for sustainable high efficiencies in our fuel use.

Storage will only be rewarded if the price paid at the time of putting it into store is less than the price received when it is released from store. To be profitable, the price must change over the time things are in store. With heat, the greatest usefulness is for storage over periods of hours, so we need a market transaction system capable of delivering price changes over periods of hours, perhaps even less.

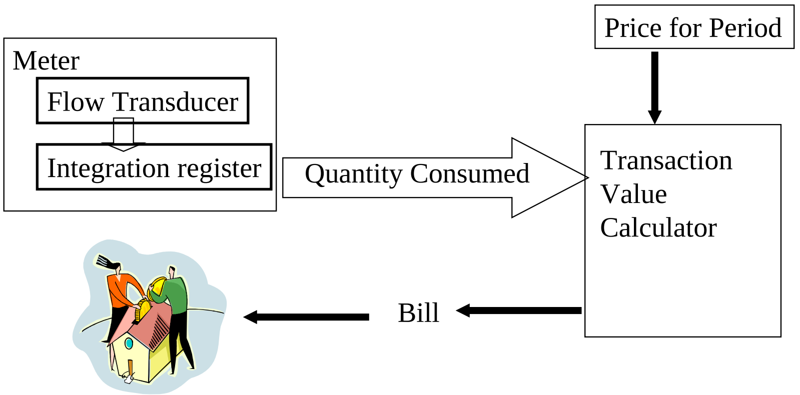
This implies that the measurement and pricing system needs to discriminate between use within quite small periods, perhaps as short as a minute or so. With access to a short term forecast, this will allow the domestic hot water systems to choose the time over the day when the can replenish most cheaply, and give opportunities for more central store to recover the investment by shifting heat between low price and higher price periods.

Even finer time discrimination is useful in electricity trading, such as that suggested for Neighbourhood Electricity Trading Schemes (www.responsiveload.com/nets.htm). This allows both

[11] Interseasonal heat storage may also become viable, achieving cooling by capturing heat in summer that we use in winter. This may be easiest with some form of ground source heat pump. However, biomass – classically the woodshed – looks to be hard to beat.

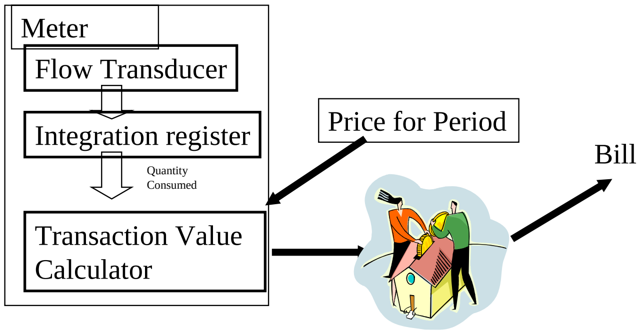
generation and demand, usually in the form of appliances, to react to the short term contingencies arising in the electricity networks, but to optimise their consumption to when electricity is most plentiful. This will often be when renewable ambient generation is most available: when the wind in blowing, the tide is running or the sun is shining.

With electricity such fine time discrimination needs change to current metering philosophies if the data processing burdens are to be manageable. Transmitting detailed consumption data to a central calculation site becomes unmanageable as the periods become shorter.



quarter	1
month	3
week	13
day	90
hour	2,167
half hour	4,334
minute	130,032
second	7,801,920

However, if we broadcast a price to all meters, they can themselves calculate the value of their imports (or exports) and so derive the values of the accumulated transactions over the periods of interest.



A recent submission to Ofgem [14] explains this in more detail.

Very similar arrangements are also possible for heat, but we do need a shared understanding of what it is we are measuring, and this needs to fall under regulatory oversight.

Once such measuring and trading systems are defined – clearly a government responsibility – then it is possible for players providing and consuming electricity, heat and storage to participate in a dynamic and continuous balance, each consumer (or their appliances) minimising their costs, each producer maximising their net income, and, as in Adam Smith's invisible hand, the system as a whole running optimally.

7 Community Heat and Electricity

The system as a whole will work best if the size of each components of the system is itself optimised. If things work most efficiently in each home, then the system should enable this. Similarly, if things work best at larger scales, then this also should be possible. We do not want to force things to an inappropriate scale.

If we do not have a heat distribution infrastructure, then we are forced to design devices for the smallest scale, the household. This is clearly appropriate for some appliances and services, such as kitchen appliances: fridges, freezers, cookers, dishwashers, and laundry related equipment.

It is less clearly appropriate for home generation. PV and domestic scale wind turbines can clearly make a contribution, but with other forms of electricity generation, it would be foolish to each try and have enough generation capacity to cope with our peak loads. Since individually our peak loads tend to be around 15 times our average loads, to become "self sufficient" would mean having capacity that most of the time would be wasted. If we size for average loads, we have the even greater expense of electricity storage, or we need to share with neighbours.

Sharing with neighbours brings benefits:

- By the physics of electricity our generation will tend to be used by our neighbours anyway.
- The community with which we share does not have to be very big for the average demand of all to be much smoother and us to gain the benefits of steadier demand. Indeed, once the community is above a few thousand, there is little further smoothing to be had.
- The scale of our generation is a reasonable match for the scale of our consumption, and so relevant to neighbours. It is less relevant to big gensets: a domestic 1kW is irrelevant to a power station exporting 1GW. It is a million fold difference in scale, and so below a threshold of awareness of a power station operator.

So the need is for structures and transactions that participants can see as fair and appropriate, and that do lead to the outcomes sought.

While "community sharing"[12] would be nice, each taking and giving as appropriate, this is an aspiration that few communities would trust to work. Certainly, any such community will need to be very carefully formed. A "market pricing" perhaps moderated by some bilateral barter, is a more realistic outcome.

One way in which this can work is for a "market maker" to broadcast a current price, updated perhaps very frequently. Each appliance and element in the system can see this current price, and use it to make decisions as to whether to consume, or generate, or not. In addition, meters would record the consumption (or export) at the price. One can expect a market maker to charge more for consumption than they will pay for exports – there would be a spread. It may well be that there are several market makers, so one can choose the one you deal with, in much the same way as today we choose electricity suppliers. If we choose to watch the price, we can also adjust our own consumption decisions, but we can probably assume this to be a minority pastime.

Similar schemes can operate for heat, with prices varying according to market circumstances. Some of the possibilities have been explored by the Design Council [13]. ResponsiveLoad propose Neighbourhood Electricity Trading Schemes [17]. Woking [18] has shown how some of these ideas work, and are being extended to London [19].

With such transaction systems in use, each player has an opportunity to optimise their own behaviour. A CHP system, for example, knowing its own costs of fuel, can choose the balance of across electricity, heat and heat storage. It is a tractable and autonomous optimisation problem, needing no external control, nor any complex analysis across the whole system. Similarly, an appliance can work out how best to use heat, hot water and electricity to minimise the cost to the household. Since this behaviour contributes to the wellbeing of the electricity system as a whole, and the turnover of appliances tends to be more rapid than that of network infrastructure, adding

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[12] To emphasise the social aspects I have chosen here to use names taken from a beautiful paper by Fiske [15], in which, he argues, all social transactions fall into one of four models: Communal Sharing (as in a family); Authority Ranking (feudal or military); Equality Matching (Polynesian shell gifting and, perhaps, dinner party mutual invitations), and Market Pricing. As children grow up, we become capable of operating the more sophisticated models (exchange of favours is a well defined teenage phenomenon). As we progress through these models we also need more sophisticated mathematical tools, from a simple ranking, to addition and subtraction to division and multiplication.

[13] See [16] and http://www.designcouncil.org.uk/futurecurrents/PP_energy_trading.php

appropriate smartness to appliances can, of itself, contribute to the evolution of the local electricity distribution networks.

We would expect all players, including CHP plant, to face costs for other externalities. Most relevant are costs of CO2 (under the EU ETS and Kyoto), and for NOx, where local Cap & Trade regulations can offer efficient ways of achieving air quality objectives, and balance the relative benefits of individual or community scale combustion.

It also presents opportunities for a diverse range of technologies that can match available local resource. If, for example, there is plentiful biomass, there are technologies, more widely used in Europe, that are excellent for serving communities with heat and power[14].

What we need from Government is the regulatory and measurement framework for electricity and heat trading within a community, so encouraging the investment in heat distribution investment that makes it possible.

8 Community Engagement opportunities

The case presented so far is based on engineering emissions efficiency and economic optimisation. Community engaging with the energy system enhances the energy system, and means it is nurtured [21].

It gives worthwhile opportunities for engaging with a local community [22]. This brings its own social and political benefits, and gives opportunities for contact with individuals and households who might otherwise be isolated, although the full implications are beyond the scope of this paper.

Several other energy and sustainability related services may also be better provided at a community level. There are significant efficiencies of scale if, for example, insulation, or double glazing or other property enhancing investments can be carried through on a community basis. The communities may become a suitable basis for a car club or other transport related initiatives. If a local wind farm brings a local benefit – lower local prices when the wind is blowing – then they will be more valued by the community, and objections more easily addressed or overcome.

So we hope the Government will take the opportunity of this energy review to encourage community involvement in our energy systems, establishing a sensible, fair measurement and transaction system, and bring heat into the regulation framework.

9 Energy Review Questions & Issues

This section offers specific answers to the Energy Review questions, now set in context.

9.1 What more could the government do on the demand or supply side to ensure that the UK's long-term goal of reducing carbon emissions is met?

The key need is to encourage substantial investment in heat distribution networks and infrastructure. The steps necessary are:

- Develop a regulatory ands measurement philosophy for the trading of heat;
- Integrate this with a refined regulatory and measurement philosophy for retail and so neighbourhood electrify trading; this may become easier with reform of the wholesale "spot pricing" systems;

[14] See, for example, Turboden [20]

- Provide incentives, commensurate with the social benefits, to encourage markets for heat, and provide disincentives, commensurate with the social costs, for heat that is wasted. These incentives can work through building regulations, planning guidance and taxes.

These measures should not divert us from stronger efforts to make our homes and appliances less wasteful of the electricity and heat they consume.

9.2 With the UK becoming a net energy importer and with big investments to be made over the next twenty years in generating capacity and networks, what further steps, if any, should the government take to develop our market framework for delivering reliable energy supplies? In particular, we invite views on the implications of increased dependence on gas imports.

The need for big investments in generation capacity is not proven or certain. Effective markets for heat and electricity at local level deliver reliability and security of supply, from diverse sources, at maximum efficiency, and with minimum dependence on critical centralised infrastructures.

Much of the evolution of local electricity networks can be achieved with active participation by smart appliances.

Government should ensure a framework that encourages the emissions efficiency offered by investment in plant of the "right sizing". Often this will also offer opportunities for community engagement with associated social benefits.

We note that gas imports, particularly of LNG, will incur substantially greater transport losses than the UK has faced from N Sea gas. We hope this will be reflected in the carbon costs deemed to be embedded in this fuel.

So long as sources are diverse, we should have no more reason to fear imports of gas than we do of other commodities, whether energy related or not.

9.3 The Energy White Paper left open the option of nuclear new build. Are there particular considerations that should apply to nuclear, as the government re-examines the issues bearing on new build, including long-term liabilities and waste management? If so, what are these, and how should the government address them?

The scale of current nuclear technologies is too big for the current heat transmission and distribution infrastructures, so will inevitably waste most of the energy they liberate.

9.4 Are there particular considerations that should apply to carbon abatement and other low-carbon technologies.

Efficient use of fuel sources requires the sort of flexible markets for heat and electricity we have explained.

Ambient generation, from wind, wave, tidal and solar renewables resources need electricity markets able to respond flexibly to their variable plentifulness. This needs local, active participation by appliances in the system as a whole.

9.5 What further steps should be taken towards meeting the government's goals for ensuring that every home is adequately and affordably heated?

Effective heat distribution networks will lower the cost of heat to all.

Community engagement can encourage efficient enhancement of homes in neighbourhoods, multi-occupancy properties, and offices.

Affordable heating is more a matter of the property than of the occupier The most efficient time to enhance the thermal behaviour and comfort of properties is during transitions between occupations. This is a good time for regulatory interventions and incentives to apply.

One possible intervention is to require properties to be sold with a significant element of their future running costs (such as a heating bill for a year or two) embedded in the sale price. This will make more apparent to buyers the costs of inefficient heating, and will encourage sellers to do something about it.

9.6 Issue i. The long term potential of energy efficiency measures in the transport, residential, business and public sectors, and how best to achieve that potential.

We hope the proposals outlined in this paper go a long way towards assisting energy and emissions efficiency in the residential, business and public sectors. It is possible that local community engagement could be geared to encourage greater opportunities for working close to home, and thus help reduce the need for commuting transport.

9.7 Issue ii. Implications in the medium and long term for the transmission and network networks of significant new build in gas and electricity generation infrastructure.

Our greatest need is for heat distribution networks.

Need for further growth in long distance transmission system and generation infrastructure is not proven, particularly if fossil fuel generation becomes, as we propose, far more decentralised and local. Some local problems remain (such as the England Scotland interconnector) but these issues arise more from the need to export electricity on a large scale from existing coal plant than from renewables.

9.8 Issue iii. Opportunities for more joint working with other countries on our energy policy goals.

Countries across N Europe, including Denmark, Sweden, Russia, the Ukraine, Germany and many others have extensive experience of heat distribution networks upon which we can draw to ensure our own become best in class.

9.9 Issue iv. Potential measures to help bring forward technologies to replace fossil fuels in transport and heat generation in the medium and long term.

Biomass has a long tradition of providing interseasonal energy storage and heat when we need it. It is well suited to continuing this role, providing a controllable and flexible source of heat and electricity for when other sources are scarce.

Appendix A. References

[1] IEE, 2003 *Combined Heat & Power (CHP). An Environment and Energy FactSheet provided by the IEE*, IEE http://www.iee.org/Policy/Areas/EnvEnergy/chp.pdf

[2] Patterson, W., 2005 *Getting Energy Right.* http://www.chathamhouse.org.uk/pdf/research/sdp/WPspeech1205.doc.

[3] Hannah, L., *Engineers, Managers and Politicians. The first fifteen years of nationalised electricity supply in Britain*. 1982 Macmillan. The Electricity Council, 0 333 22087 0.

[4] British_Electricity_International_Ltd, ed. *Modern Power Station Practice. Incorporating Modern Power System Practice. Volume K EHV Transmission*. Vol. K. EHV Transmission. 1991, Pergamon Press.0-08-040510-X (for set) 0.08-040520-7.

[5] Lovins, A.B., et al., *Small Is Profitable: The Hidden Economic Benefits of Making Electrical Resources the Right Size*. 2003 Earthscan Publications Ltd, 1881071073.

[6] ILEX, 2002 *Addressing the issues imposed by Electricity Trading Arrangements on the Development and Operation of Smaller Generation. A Report to the DTI*, DTI, Ilex Energy Consulting http://www.dti.gov.uk/energy/domestic_markets/electricity_trading/genissues.pdf

[7] Carbon_Trust and EST, 2005? *Community Heating for planners and developers. A guide to delivering sustainable communities using combined heat and power and renewables.* http://www.est.org.uk/uploads/documents/housingbuildings/GPG389_Comm%20Heating%20Mailer%20v11.pdf.

[8] EST, 2003 *Energy Efficiency Best Practice in Housing. Benefits of Best Practice: Community Heating. Advantages all-round. From a central source.*, http://portal.est.org.uk/uploads/documents/housingbuildings/ce13.pdf.

[9] EST, 2004 *Energy Efficiency Best Practice in Housing. Community Heating – a guide.* http://portal.est.org.uk/uploads/documents/housingbuildings/CE55%20-%20Community%20Heating%20-%20a%20guide.pdf.

[10] DEFRA, 2006, *The Government's Strategy for Combined Heat and Power to 2010*, http://www.defra.gov.uk/environment/energy/chp/pdf/chp-strategy.pdf

[11] Orchard, W.R.H. *Discussion of defects in current UK and proposed EU conventions for allocation of fuel burn for power and heat rejected in power generation*. in *BIEE Academic Conference St Johns College Oxford Supplementary Paper*. 2003: www.cleanheat.org http://www.cleanheat.org/PDF/1.pdf

[12] Carbon_Trust, 2005 *The Carbon Trust's Small-Scale CHP field trial update*, The Carbon Trust http://www.thecarbontrust.co.uk/carbontrust/about/publications/181105_01.pdf

[13] Hirst, D.R. *Demand Side - Teaching an Old Dog New Tricks*. in *Networks for Sustainable Power*. 2006. IEE London: IEE http://www.responsiveload.com/downloads/DemandSidedogHandoutPublish.pdf

[14] Hirst, D.R., 2006 *Domestic Metering Innovation. Consultation Response to Ofgem.* www.responsiveload.com/downloads/RLMeteringInnovationOfgemv10.pdf.

[15] Fiske, A.P., *The Four Elementary Forms of Sociality: Framework for a Unified Theory of Social Relations.* Psychological Review, 1992. 99(4): p. 689-723.

[16] Lockwood, M. and R. Murray, 2005 *RED Future Currents: Designing for a changing climate*, Design Council http://www.designcouncil.org.uk/futurecurrents/downloads/FutureCurrents-RedesigningEnergyPolicy-18-10.pdf

[17] Hirst, D.R., 2005 *ResponsiveLoad Consultation Response to DTI Microgeneration Strategy and Low Carbon Buildings Programme.* http://www.responsiveload.com/downloads/MicrogenandLowCarbonStrategyResponsev12.pdf.

[18] Jones, A., 2004 *Woking: Local Sustainable Community Energy.* http://www.mefl.com.au/documents/woking-1.pdf.

[19] Jones, A. *A Climate Change Agency for London*. in *RPA Micro Renewables Conference*. 2005. IEE London: Renewable Power Association http://www.r-p-a.org.uk/content/images/articles/Allan%20Jones.pdf

[20] *Turboden High Efficiency Rankine for Renewable Energy and Heat Recovery*. Turboden s.r.l. www.turboden.com.

[21] Vosseler, I., et al., 2004 *PV Hybrid Village Electrification in Spain. 6 Years Experience with MSG (Multi-user Solar Hybrid Grids).*

[22] Hirst, D.R., 2005 *The Neighbourhood Grid as a Community: Some Sociology of Electricity*. http://www.responsiveload.com/downloads/GridasaSocialActv10.pdf.

Appendix B. Participants and Contributors

Many individuals and companies have contributed ideas and support to this document. We have circulated drafts to a group, provoked some discussion and debate, and this has illuminated the submitted draft.

Here we list all those individuals and companies who have explicitly expressed their support, and offer our thanks to all.

Encraft Limited. "Low Carbon Wealth Creation". www.encraft.co.uk. Contact Matthew Rhodes: matthew.rhodes@encraft.co.uk

Hirst Solutions Limited. "Innovation Technology Sustainability". www.hirstsolutions.com. Contact David Hirst: david@davidhirst.com

John Prewer Associates Limited. Contact John Prewer: jprewer@hotmail.com

ResponsiveLoad Limited. "Innovative Energy Solutions". www.responsiveload.com. Contact David Hirst: david.hirst@responsiveload.com

XCO2. "low carbon engineering" www.XCO2.com. Contact Robert Webb: robertw@xco2.com

The opportunity to confirm support has been limited, so further expressions of support will be posted on the home page of this paper: www.davidhirst.com/CHE/CHEpaper.html

The primary author has been David Hirst, and he carries responsibility for errors, omissions and flaws.

While some cannot be named, thanks also to: Mark Barrett of Sustainable Environment Consultants (www.SENCOuk.co.uk), a reliable source of solid energy system information; William Orchard (www.cleanheat.org) for sharing knowledge and engineering expertise, and for supporting the objectives and principles; Alastair Martin for information; and to Professors Stephen Slater (of Edinburgh University); and Goran Strbac and David Fisk (of Imperial College) for thoughts and suggestions.

Appendix C. Document Control

This document is the final version submitted on the evening of 13th April to the DTI review team.

The document has a home page at www.davidhirst.com/CHE/CHEpaper.html. This is the best place from which to download a copy, as it will reference the latest version.

This document is also directly available at www.davidhirst.com/CHE/CommunityHeatandElectricityv10.pdf. Only in extremis will this version be withdrawn from this site, but there may be later versions.

If you wish to comment on the document, express support for the concepts, or wish to use it in other contexts, then please contact David Hirst – david@hirstsolutions.eu.