ResponsiveLoad Limited

Innovative Energy Solutions

The regulatory implications of domestic-scale microgeneration

ResponsiveLoad Consultation Response

Abstract

ResponsiveLoad Limited (RLL) welcome the opportunity to respond to Ofgem's consultation, and shares a desire for a regulatory environment that fosters and encourages microgeneration. Microgeneration gives opportunities for civilised low carbon living that climate change demands.

The current regulatory approach enforces complex processes and structures on current market participants, leading to some perverse incentives. We explain how this happens.

We articulate how we believe competitive markets can be harnessed to align market incentives with societal imperatives, sharing a vision that we hope will find support.

Our vision anticipates change from where we are, with evolution as the anticipated technologies roll-out. This document makes recommendations as to the first steps of that evolution, but leaves most to the imaginations and knowledge of others to build on.

Author:	David Hirst
Contact:	david@responsiveload.co.uk

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1 Introduction

ResponsiveLoad Limited welcomes the opportunity to respond to the Ofgem consultation [1]. Ofgem are right to recognise the profound regulatory implications of domestic-scale microgeneration. We believe such microgeneration to be a key element of society's response to the critical challenges of climate change. We consider current regulatory structures to present barriers to the growth of the industries and services we need to deliver this component, and so welcome this opportunity to suggest regulatory change. We hope Ofgem understand the scale of the change needed, and that this response will enlighten their strategies and plans to pursue the change.

2 Executive Summary

Domestic-scale microgeneration, although not yet mature, has many and clear environmental and societal attractions. In Section 3 The Microgeneration Challenge we explore the potential benefits and the specific challenges to be addressed for microgeneration to be successful.

The regulatory structure should impose no avoidable burdens on any participants who become involved in its adoption. Current structures and processes, in part driven by the regulatory framework, can lead to opaque decision-making and some perverse incentives on players. We analyse how this happens in section 4: Current Structures and their Impact.

Alternatives are possible and attractive. In Section 5: Participatory Electricity Markets, we put forward a vision of how effective markets could work, showing how this addresses the need, and enables efficient participation of microgeneration in our electricity networks. We analyse the technologies and regulatory regime we need for these to become achievable. Essentially, this is a believable real time electricity market price, and a change in metering philosophy.

Finally, we make recommendations:

- For an in depth study of the vision proposed, its benefits, risks and opportunities
- For a radical review of metering philosophy in the light of a shift from central generation

In the context of this response, ResponsiveLoad Limited does not have any specific contribution to the consultation questions raised. Rather, ResponsiveLoad Limited wishes to raise broader principles of regulation, and attaches two documents in support: A Technical Architecture Discussion Paper on the ESI Mission & Principles, and an extract of the proposed text of the Mission & Principles in a form suitable for debate and enhancement.

3 The Microgeneration Challenge

Domestic-scale microgeneration, although not yet mature, has many and varied attractions, for the environment, for consumers, and for society. These include:

- Local generation of electricity from natural gas allows a very high proportion of the energy embodied in the fuel to be useful, either as electricity or as heat. As gas is also relatively low in carbon, the benefit to emissions ratio is vastly greater than for conventional coal fired central generation. It exceeds the emissions efficiency of even the best gas fired central generation technology.
- Local generation avoids the losses arising from transmission and distribution. In general, it costs more (in capital and losses) to transmit electricity than to transmit gas.
- Ambient sources of energy, such as solar panels and rooftop wind generators, consume no fuel and so form no direct emissions. The costs are overwhelmingly capital costs, which can be expected to fall with increasing scale.

- Local generation can reduce dependence on distant infrastructure, and so increase the reliability and availability of electricity service to the consumer.

There are however issues:

- The operation of domestic gas-fired generation will generally be driven (despatched) by the domestic need for heat, not by the need for electricity. While the needs for heat and electricity do overlap, they do not coincide, and so create a greater variation in the demand that has to be met by the Electricity Supply Industry (ESI). This presents both local challenges (from voltage variation), and wider scale issues in matching demand and supply.
- Ambient sources, such as solar and wind, are essentially uncontrolled: How much and when they generate is a function of the ambient conditions, uninfluenced by demand or need. In the traditional ESI vocabulary: "It cannot be despatched". Again, there is some overlap between generation and need, but no coincidence.
- Peak household demand is a multiple of average household demand. Thus if each household is to meet its needs by microgeneration, most of the installed capacity will be unused for most (or nearly all) of the time. Unless capacity becomes very cheap indeed, it will be more economic for households to pool their generation and demand, so evening out fluctuations in demand by the diversity within a number of households. Thus an overwhelming majority of households will gain benefit from a shared (and preferably local) electricity network, rather than aiming for self sufficiency.

The regulatory challenge of domestic-scale microgeneration and indeed smaller scale generation in general is:

- To facilitate ways to influence the timing of microgeneration so that it is more likely to generate when needs are greatest, and less likely to generate when needs are smaller or when the local distribution network is under greatest strain.
- To facilitate ways to influence demand so that it is more likely when ambient generation is greatest and less likely when ambient (or other) generation is scarcest.
- To facilitate ways in which natural electrical "neighbourhoods" can pool their generation and consumption and so optimise their demands upon the infrastructure and services beyond their neighbourhood.

The current regulatory infrastructure, which evolved from quite different technology imperatives, offers no clear philosophy for addressing these challenges. We explore the background and need for evolution in the next section.

4 Current Structures and Their Impact

To provide a context for exploring the implications on domestic-scale microgeneration, it is helpful to explore the models of electricity generation that drove them. The first subsection (4.1 Current Regulatory Structures) provides such a context. The next subsection (4.2 Implications on microgeneration) then explains how they fall short of what is needed.

4.1 Current Regulatory Structures

Current regulatory and market structures derive from a centralised model of electricity generation, itself evolved from a more distributed model by the economies of scale once achieved by central power station technology, and the linking of locally oriented distribution networks by of a national transmission grid.

Basic features of this model are:

- A limited number of large generating power stations, operated, at least at a minute by minute level, by a central co-ordinating role who has an understanding of the operational constraints of the power stations.
- Essentially uncontrolled demand[1]. Demand is broadly statistically predictable, particularly when taking into account weather and seasonal factors and with sensitive awareness of synchronised behaviour by

[1] Except in extremis, when demand can be reduced by broadly undiscriminating blackouts, imposed on a town or a region.

many people (such as commercial breaks on popular TV shows or sporting fixtures). There is, however, constant variation in the demand, usually, but not always, quite small[2].

- Central optimisation (or balancing) of the generation and transmission function, tempered by a variety of mechanisms, such as wholesale electricity markets, so that generation is always available to meet the demand, at the places where demand arises. The Transmission & System Operator is responsible for the various ancillary services that enable this role to be fulfilled[3].

It is the capacity of the System Operator to carry out sensible optimisation, balancing and fine tuning of the system that limits the numbers and types of power stations that can participate in the optimisation (or balancing) processes, and places limits the minimum scale of the plants that can be involved.

This basic model may be enhanced by features to influence demand:

- Wholesale and industrial markets to provide price differentials between different periods of the day and night. These do reflect the different costs generators incur for different periods, as, at higher demand times, higher cost generators will be needed. Consumption at low demand periods is met from the cheapest "baseload" plant. These variable prices serve to influence investment by industrial consumers to prefer consumption at low cost periods rather than high cost periods. It is difficult to exploit these differentials in operational decision-making, so the influence on demand tends to be long term rather than operational.

- Domestic tariffs to create additional demand during the expected off-peak periods. The classic UK case is the White Meter and Storage Heating. These create demand to occupy "base load" (particularly nuclear) at otherwise low demand periods. Although there is now some remote (and so near real time) control of the timing, these primarily influence long term demand.

On this basic centralised model various further regulatory structures are built:

- **Suppliers (retailers)**. These are the participants that sell (metered) electricity to consumers (their customers), and buy electricity from Generators, their suppliers. From a regulatory perspective, their primary role is to provide a competitive market to generators, so that suppliers have a market choice of generators to buy from, and generators have a market choice of suppliers to sell to. For generators, the credit-worthiness of suppliers is pertinent to their market behaviours.

- **Consumers** have a choice among the suppliers who compete for their business. In practice, the grounds upon which suppliers can compete are limited to the accounting and billing service and, within constraints of standardised metering, the tariff charged. Brand image and ethical / environmental stance are other features on which suppliers compete.

- **Distribution Network Operators (DNOs).** The DNOs are the monopoly providers of the local distribution network. Their role is to provide (all) suppliers with the distribution service that carries electricity from the transmission network (or locally embedded generation) to the consumers who buy electricity from the suppliers. They have no direct commercial relationship with the consumers, as their (regulated) tariffs are paid by the suppliers (strictly the customers of the DNOs). However, it is the DNOs that most directly influence the reliability, stability and quality of electricity supply to consumers, and who are involved if there is any interruption or break in service. Since these are matters of great concern to their regulator (Ofgem) and is most directly measured, DNOs tend to think of and refer to consumers as their customers, (although they are not!) This can make it hard for consumers to understand the markets in which their microgeneration will participate.

- **Wholesale Metering**. In the wholesale markets of Generators and Suppliers electricity is traded for each half hour period[4]. Suppliers buy electricity to meet their expected demand, and generators commit to providing that electricity. The electricity leaving a generator is metered for each half hour, and the

[2] The greatest source of unexpected variation that needs to be covered is failure within the ESI infrastructure, such as loss of a generator, a transmission line or a major load area.

[3] In many countries, this role is embedded within a central generation organisation.

[4] In some countries different periods of quarter or whole hours may be used

electricity distributed to a DNO is similarly metered. Larger consumers also have their consumption measured each half hour (so are Half Hour, or HH consumers). Most consumers, however, only have meters that measure the electricity consumption over a longer period, such as a month, a quarter, or even longer (and are NHH consumers.)

There is therefore no direct way or relating the meter readings for a particular half hour to the demand for which a supplier has assumed responsibility. The suppliers demand occurred across many DNOs and, within each DNO, the metered electricity is the responsibility of many suppliers.

In practice rules of thumb, based on historical evidence, are used to decide a set of preliminary allocations of metered totals to suppliers for each half hour, and these are used for settlement with generators within the wholesale markets. These allocations are later refined and corrected as further evidence from Domestic Metering (see below) becomes available.

- **The Balancing Mechanism.** In a real electricity network, which needs to be maintained in balance at all times, various possibilities arise:
    - Demand over the half hour varies from that anticipated and bought by suppliers;
    - Generators do not precisely match the generation they sold;
    - Limited capacity (constraints) on parts of the transmission network make it impossible to meet the contracts, so generation from different generators needs to be sold and bought to overcome the constraints;
    - Failures of part of the infrastructure occur;
    - Demand and generation within the half hour varies from the nominal contracted amount, with (perhaps) more demand early in the period and less later.

  The National Grid Company, as Transmission and System Operator, compensates for these variations through operation of the balancing mechanism. It accepts bids and offers for change in generation from players in the balancing mechanism and "despatches" the necessary change in generation. Since the scale of imbalances to be corrected can be quite large, and the timescale in which to achieve the change is short, NGC is able to cope only with a small number of large players able to deliver big change.

  The costs incurred by NGC in operating the Balancing Mechanism (principally in payment for bids and offers from generators) are then allocated across suppliers and generators. Currently, the allocation is made according to the difference between the contracted electricity flows (as notified at "gate closure" a bit before the half hour starts) and the actual flow during the half hour.

  This particular form of Balancing Mechanism and charging for it is believed to be unique to the UK.

- **Domestic Metering**. As mentioned above, domestic (NHH) metering is designed to measure the consumption of the consumer over the period between meter readings. While notionally every quarter, actual meter readings vary in frequency and timing, and self readings or estimates are often used.

  The domestic meter reading is the basis of customer billing by the supplier.

  Somehow, the consumption by the consumer over the period has to be allocated to the supplier for each half hour of the period. This is done by using "profiles", derived from detailed metering of a sample set of "standard" consumers. As meter readings become available, the profile is used to allocate consumption to each half hour, and this is reconciled against the wholesale metering allocation of the supplier. Eventually, the reconciliation process is closed, and the suppliers wholesale allocation becomes fixed, and any settlement adjustments are made.

4.2 Impact on Domestic-Scale Microgeneration.

This structure has adverse impacts on all ambient and most distributed generation, as well as suppliers and consumers. Since these impacts also apply to domestic scale generation, they are explored before examination of the adverse impacts specific to microgeneration:

- The Balancing Mechanism imposes costs related to imprecision of prediction, which are unrelated to underlying market fundamentals (such as scarcity or energy cost).

  - For ambient renewable generators, costs are incurred if the actual generation departs from that predicted at gate closure. Since ambient renewable generation is inherently less predictable than despatchable generation (regardless of its emissions performance) this penalises such ambient generation, and presents costs they can do nothing to control.
  - For the most emissions efficient generation, such as Combined Heat and Power, the primary driver of the plant is the heat demand, so generation is inherently less controllable and so less predictable than a less efficient process driven solely by electricity contracts.
  - Suppliers have no direct control over their demand, so face risks of potentially large balancing mechanism costs over which they have no control.

  A further consequence of this charging structure is that there is no reliable price indicator or index as to the actual price within the delivery period. The best index that can be achieved is from the (relatively illiquid) contract price just before gate closure, but as this does not reflect actualities that occur in the system, so there is no reliable price to indicate particular scarcity or oversupply.

  The absence of a reliable price indicator deprives the market of an accepted and acceptable index that can be used to settle futures and other hedging contracts. This makes long term contracting harder.

- The supplier demand predictions are inherently less reliable than predictions of the system as a whole. This is because the predictions have to be made for smaller numbers of consumers so with less statistical smoothing. If, in addition, the predictions have to discriminate across different geographical zones and or DNO territories, the predictability is further reduced. This introduces risks to suppliers costs, although not necessarily to the system as a whole.
- The costs of failures of generators cause imbalance prices that are unpredictable and uncontrollable. To avoid these uncontrolled costs generators cover their risks by operating additional plant less efficiently so that they can cover possible imbalances. Thus economies of scale from shared cover are lost.
- These uncontrolled risks can, in part, be counterbalanced by common ownership of both generation and supply businesses. Such consolidated businesses have reduced need to trade on the wholesale markets, thus weakening their liquidity and undermining the competitive element that the markets exist to encourage.
- There is no incentive on a supplier to encourage their NHH customers (the consumers) to modify the timing of their consumption to reduce demand at high price times or encourage it at low price times. Indeed, if they did so, the profile system would tend to increase the allocation made to high price times, reduce it at low price time, and so increase the departure from predicted consumption. This, in turn, exposes the supplier to risks of imbalance prices.
- There is no mechanism for smaller generators, which will form an increasing proportion of the generation, to participate effectively in the market.

  Aggregation is one suggested way in which smaller players can participate. NGC normally articulates its requirements using the concept of a “virtual power station”. This may not match the natural behaviour of the underlying plant, and puts at risk the benefits of the distributed activity, whether generation or consumption.

Adverse impacts are further increased with the involvement of domestic-scale microgeneration.

- Those suppliers involved with a consumer operating microgeneration face increased variation and reduced predictability of the aggregated demand that they can contract for. This increases their exposure to the Balancing Mechanism, and so reduces what they can afford to pay for the microgeneration.
- Suppliers have no influence on the timing of domestic scale generation. This they may well be paying for generation made during periods of low wholesale price, and be providing electricity at times of high wholesale price. This increases their exposure to the imbalance price and their risks. This creates disincentives to entering this market.
- DNOs also have no means of influencing the timing of domestic generation, and so will ultimately have to build more powerful technologies to manage the local voltage. They will inevitably wish to minimise its penetration to manage these risks.

In summary, various aspects of the current regime mitigate against the successful adoption and penetration of domestic-scale microgeneration, and the ensuing prize of substantial environmental and infrastructure benefits.

5 Participatory Electricity Markets

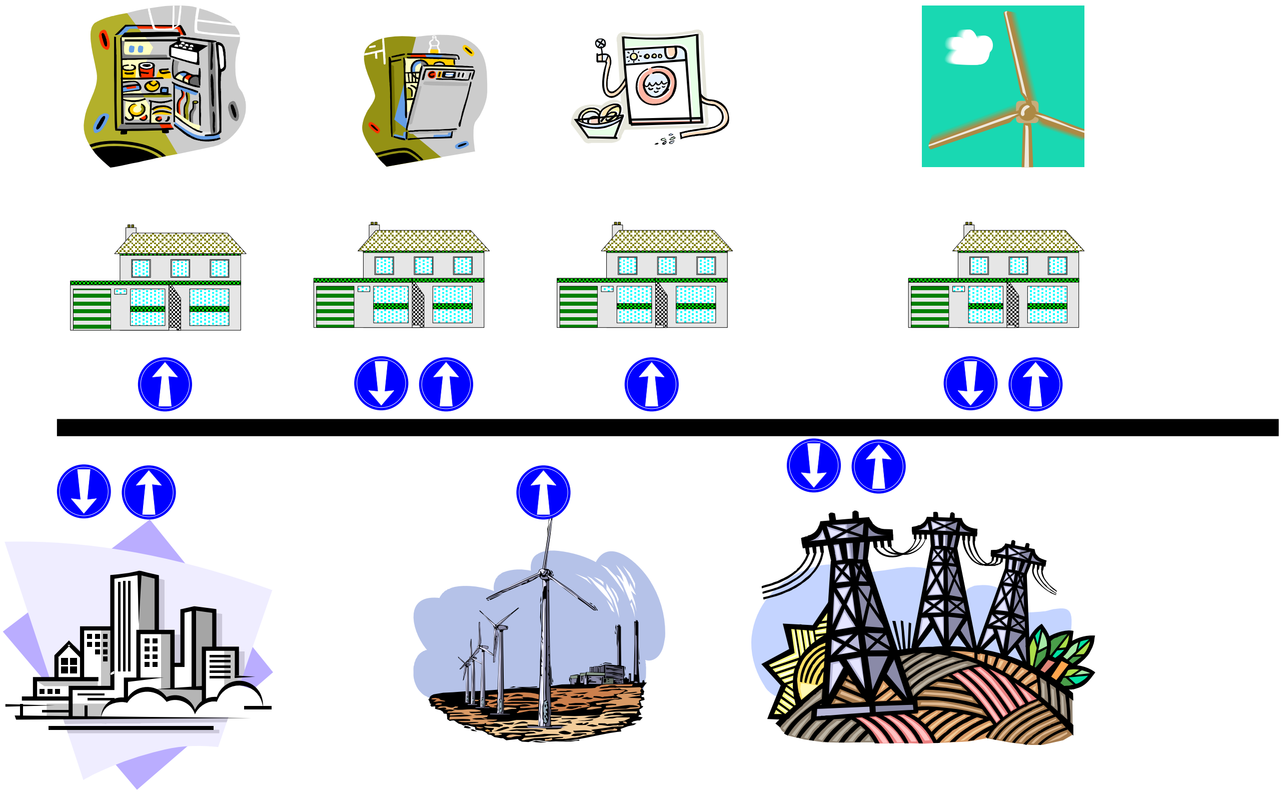
ResponsiveLoad Limited believes better markets, with active participation by consumers as well as generators and infrastructure providers, will lead to an Electricity Supply Industry that both meets the needs of its customers, and does so without jeopardising the future of the planet.

This section begins with an overview of the vision sought, and then discusses the metering implications. It then considers possible evolutionary routes towards this vision, and finally presents recommendations as to a regulatory strategy that contributes towards it.

5.1 Neighbourhood electricity grids

Professor Fred Schweppe and colleagues published their seminal book "Spot Pricing of Electricity" [2] in 1988, shortly after Professor Schweppe died. Much of the thinking was published in earlier papers, such as "Homeostatic Utility Control" [3] published in 1980. The concepts here are direct descendents of the ideas proposed at that time, but are transposed onto a more local infrastructure.

Consider the diagram showing aspects of a neighbourhood grid:



A number of houses or domestic premises are connected to a local A/C mains electrical system – the neighbourhood grid. All use a variety of consuming appliances (fridges, washing machines, dishwashers etc) and some may have some form of domestic scale generation (wind turbines, solar panels, Domestic Combined Heat & Power etc.) We do not yet know the optimum size of such a grid, so it may include a city-wide network. It is likely to include some form of ambient renewable generation, such as a local wind farm, and will be connected to a regional or national grid via a substation capable of exporting power from or importing power to the neighbourhood grid.

In such a grid, the objective is to keep supply and demand in balance, and there are several controls available to achieve this balance:

- Fridges, when fitted with ResponsiveLoad, provide a buffering capacity, smoothing out short term imbalances. By subtle changes in the timing of their motors, they act in much the same way as a capacitance smoothes voltage fluctuations. This leaves unaffected the primary fridge function of keeping things cool.

- DCHP runs as suits the householder, usually driven by the need for heat. But there is some flexibility, in that there is discretion of a few minutes as to when the unit runs.
- Appliances, such as dishwashers, have discretion as to when they run. While there are times when the need for the service is urgent, more commonly a delay of several hours is unimportant.
- Unlike today's substations, the substations include modern power electronics that allow it to control the electricity flow. So it has discretion as to the volume of imports or exports.
- Distributed generation. A city-wide grid is likely to include one or more "despatchable" generators, which have nearly absolute control over their generation, whether from a renewable biomass source, or from fossil fuels, such as gas, oil, or coal.

A key question arising from this is: How best should the participants in such a grid achieve their objective of balance?

The idealised economists answer is to have a market, with a "spot" price that influences the behaviour of all the participants, and that varies according to how long or short the market is.

In such a market, ambient sources would tend to be the price setters, so when ambient sources are plentiful, the price will tend to be low. Discretionary loads, such as domestic laundry machines, water heaters, and dishwashers can lower their costs by running during such periods. Equivalently, when ambient sources are scarce, prices will be higher, and such loads are best postponed. Individuals can make their own judgements about how urgent their dishwashing might be, and choose to accept a high price to avoid a wait. Industry has many similar choices.

Generators who have control over their conversion, whether biomass or fossil fuelled, will clearly aim to maximise their output at high price times, and minimise it at low price time. They too have choice.

Domestic generators also have some choice. When prices are low, they can choose to consume electricity, or to postpone generation. When prices are high, they can bring forward their generation. As technology develops, their choices will widen.

In such a market, there is no clear limit to the penetration of ambient sources onto the grid. With reasonable diversity it could reach or exceed 100%. The market would tend to have consumption constantly adjusting to match the available generation. This is an inverse of the traditional mindset of meeting all demanded consumption by generation and so holding reserves to cope with temporary peaks.

In such a market, there is also likely to be unlimited potential demand for electrolysis (to make hydrogen), or its equivalent (to make methanol) to fuel the transport fleet. So if fuel filling stations were on the grid, they would stock up when prices are low (perhaps during sunny afternoons as well as windy nights.) The distributed fuel storage capability could well buffer a shortage of wind lasting several days.

And in such a market, the irretrievable conversion of fossil fuels to electricity would be profitable only at the times of highest prices. It would become profitable to husband stores of fossil fuels, not treat them as the cheapest available resource.

All we need is a real time price!

Happily, on such a grid, the system frequency intrinsically reflects whether the market is long or short. If the market is short, the frequency is low, and if it is long, the frequency goes up. The innate variability is damped by the "capacitance" of the ResponsiveLoad fridges and other devices.

This innate signal can be converted to a price by one (or more) "market makers". This may be a signal broadcast by the market-maker(s) in real time, although this does impose communications costs and issues.

Another possibility is to publish "contingency" prices that come into effect according to a function of the system frequency (including its immediate past behaviour). The contingency prices can be broadcast in advance, perhaps even seasonally, so there is no requirement for real time communications.

5.2 Metering

Whatever the method chosen to distribute the real time price, continuing to meter only in kwh will not record the costs incurred or prices earned by the activities of participants. Rather metering will need to integrate the flows of costs to and from the participants, taking into account both the electricity flows and the real time price (or rather prices, as a margin between inputs and outputs is appropriate.)[5]

Such sophistication of metering is well within the capability of modern microelectronic devices, and it may be attractive to integrate the metering into other household services (such as an internet or TV gateway). The main (and readily addressed) challenge is to keep the integrated reading secure.

Sophisticated metering, while it may be driven by the need for micro-generation, also raises other attractive possibilities. For example, a regulator could require the costs of "standby" consumption in TVs or PCs etc. to be incorporated into the initial purchase price. A sophisticated meter, upon perceiving the device on the domestic network, can then discount this consumption. This would make clear to consumers the costs they face when buying devices with inefficient standby features, and so provide manufacturers with incentives to minimise such waste.

Indeed, a variety of products could have an element of electricity pre-purchase – much as do mobile phone tariffs today.

5.3 Migration

The vision of the neighbourhood grids readily transposes to multiple grids of different scales, interconnected by appropriate substations. It is not yet clear what might be the preferred size of grids. However, each grid has a degree of autonomy, with local generation, and local pricing. So at least some of the benefits of local facilities, such as wind farms, are shared by the locality. Each grid can have multiple (and partially redundant) interconnections to other grids and so manage the risk of the sort of cascading failures that cause the huge blackouts of recent years.

This flexibility also permits gradual migration. Individual neighbourhoods, towns or regions can implement the new grids, reusing much of the current infrastructure – only some substations need to be replaced[6]. When grids first change existing domestic infrastructures can continue unchanged, and the benefits arise as new appliances are replaced.

Over the years of migration there are opportunities for innovation in appliances and domestic energy using technologies. With care and direction, we can expect to see far more efficient and satisfactory lighting, such as LED lighting. We can expect to see lower consuming entertainment and information devices, and we can begin to tackle the many sources of parasitic loads from electricity conversion taking place in TV, Hi-Fi, PCs, mobile phone and laptop chargers and games consoles.

This cannot be done overnight, but it must started soon and done quickly, as the window of opportunity to start to reduce emissions is short. In 5, or possible 10 years we will need to have an infrastructure capable of supporting civilised living with great penetration of renewables, and incentives for high efficiencies.

5.4 Recommendations for Regulation

We believe the environmental and societal outcomes sought and outlined are achievable by steady evolution of the existing ESI and current regulation towards this vision of distributed electricity markets, making full use of domestic scale microgeneration and the intelligent use of intelligence embedded with appliances.

We do understand that this vision demands change from the (often unconscious) mindset underlying current regulation and industry structures. So much has to be done both to establish the scale of the benefit arising, the nature of the future infrastructure, and how best to move towards it. **Our first recommendation is that**

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[5] A similar effect can be achieved by shortening the period associated with each kwh measurement. However, a measurement needs to be recorded for each period, and, as periods are shortened, so do the data volumes grow. There is no obvious limit to how small the period should be (as is shown by the different choices in different wholesale markets). As volumes grow, so also does the value of each data item fall.

[6] Much of the substation infrastructure is reaching the end of its long useful life. Well planned replacement of life expired equipment can deliver the benefits of this vision with minimal "stranding" of past investments.

the benefits, risks and opportunities of this vision are properly and fully studied, with public funding, and the strategic policy and regulatory impacts more fully assessed.

We recognise also that this can be considered a radical vision, with broad and deep policy implications, most specifically on the metrics used throughout the industry. **Our second recommendation is that Ofgem takes a radical and deep look at the broad philosophy of metering in the context of the prospective shift from large scale generation.**

Appendix A References

[1] **The regulatory implications of domestic-scale microgeneration**. A consultation document. Ofgem.123/05 April 2005. Available from www.Ofgem.gov.uk

[2] **Spot Pricing of Electricity**. Fred C Schweppe, Michael C Caramanis, Richard D Tabors, Roger E Bohn. Kluwer Academic Publishers. 1988.

[3] **Homeostatic Utility Control**. Fred C Schweppe, Richard D Tabors, James L Kirtley, Jr, High R Outhred, Frederick H Pickel, Alan J Cox. IEE Transactions on Power Apparatus & Systems. Vol PAS-99, No 3 May/June 1980.