School of Architecture, Planning & Landscape
Global Urban Research Unit
University of Newcastle upon Tyne

Electronic Working Paper No 23

Pathways to 'Smarter' Utility Meters: the Socio-Technical Shaping of New Metering Technologies.

Previously published in November 1995 as Working Paper No. 56
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ISBN 0 905770 47 1

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Summary

Radical changes in the development and implementation of metering technologies for the provision of essential resources to domestic, commercial and industrial sectors are currently transforming the relationship between utilities and their customers. Focusing on the use of water, electricity and gas meters in the domestic sector this working paper provides a preliminary discussion of the current metering debate and a guide to new research issues for the social sciences.

We will highlight the technical disputes, scientific uncertainties and commercial priorities governing the development, implementation and use of new metering technologies in the power and water sectors. In doing so we ask some important questions about the profound social, economic, political and geographical disparities that are emerging through the use of new metering technologies by British utilities. More generally we will point out the limitations of a purely technical/economic approach to understanding the metering debate, so demonstrating the urgent need for a more sociological perspective on technical innovation in the utilities sector. Specifically we will suggest that we must deepen our understanding of the social shaping of the development, implementation and use of new metering technologies if we are to successfully identify the technological and institutional approaches best placed to minimise social dis-benefits of prepayment metering while maximising the environmental potential of smart metering.

1. Introduction

The Metering Revolution

Utility meters represent what Bruno Latour and other sociologists of science and technology term an 'obligatory passage point' (Latour, 1992, p.234). That is, domestic gas, electricity and water meters are the 'gateway' technology around which the most significant transactions between utilities and their customers are based. Energy and water resources pass through the meter which records consumption providing the information for the billing of utility services. Moreover, the meter acts as the referee of legitimate access to the infrastructure network, potentially signalling the application of the ultimate sanction for non-payment and indebtedness - disconnection from the network. As Madeleine Akrich suggests;

> The way in which the individual/consumer relates to the network, and via the network to the electricity company, is codified and quantified by means of a basic technical tool, the electricity meter. This formulates the initial contact between the producer and consumer. If one or the other fails to meet its obligations, the meter becomes invalid or inactive. Meters have a symmetrical effect on the producer/consumer relationship. The agreement of both is required if the are to tick over. Accordingly, the *set* of meters is a powerful instrument of social control (Akrich, 1992).

Radical changes in the development and implementation of metering technologies for the provision of essential resources to domestic, commercial and industrial sectors are currently transforming the relationship between utilities and customers (Marvin & Graham, 1994). Driven by the commercial priorities of a liberalised marketplace, utility companies are dramatically re-configuring the varying contexts of utility consumption by commodifying essential resources through the introduction of new tariffs, products and styles of service which vary across space, time and customer classification (Guy & Marvin, 1995). A revolution in the role of the utility meter is central to this process. So called 'Smart' metering technologies are creating new opportunities for efficient use of resources which have profound implications for our understanding of the role of information, inter-active control and resource use in shaping the social, economic and environmental profile of contemporary cities (Dauncey, 1990). At the same time the introduction of prepayment metering has raised the spectre of widespread self-disconnection of the "utility poor", so threatening the universal service ethic which has shaped the development of British infrastructure networks (Marvin, 1994a).

The changing design of meters is being powerfully shaped by a wide range of socio-technical factors. In particular, the emergence of new metering technologies is taking place against a background of commercial restructuring of the utilities marketplace, rapid technological innovation in the fields of metering and communications and competing institutional structures of technical codes and standards (Sioshansi et al., 1990). Furthermore fast changing regulatory frameworks, complex choices over levels of commercial functionality and the ebb and flow of social and political pressure, all have powerful implications for meter design, and by extension, the restructuring of customer and utility social relations. As we will demonstrate, the radical restructuring and reorientation of British utilities over the past decade is clearly reflected in the changing design and use of metering systems. The meter therefore, provides a critical window through which we can begin to unpack the social, economic and environmental implications of the privatisation and liberalisation of the British utilities sector.

Technical Development Pathways

The recent explosion of interest in the commercial strategies of the utility business goes a long way to explaining the emergence of the, hitherto unseen, utility meter 'out from the cupboard under the stairs' into the glare of public attention. Driven by new commercial priorities, styles of managing infrastructure networks are changing fast. Innovative metering technologies are a central component of these developing strategies. Not that the implementation of innovative metering technologies is in any way smooth or linear in practice. The emergence of new metering technologies is taking place within a conflictual framework fashioned by competing commercial utility companies, public regulatory bodies, meter manufacturers, telecommunication providers, voluntary and consumer groups (Dooley, 1992). Each of these groups are pursuing their own technical agenda, driven by specific aims and priorities. The social, economic and environmental benefits of new metering technologies is being shaped by competing, and often conflicting, factors; technological choices, economic costs, social acceptability, health concerns and access to information. There are a range of issues which will fundamentally shape the potential benefits and costs of smart metering technology:

- How will utilities respond to pressures from regulators to fit a new metering infrastructure?
- Which type of communications media will be utilised in the control of smart meters?
- What range of meter functionality will be exploited?
- How will utilities negotiate social and political opposition to new metering technologies?
- Who will be given smart meters?
- Will the users welcome and utilise enhanced control over utility services?

The uncertainties surrounding this powerful technology are many and varied. However, despite such major changes in metering technology, the fundamental restructuring of the utilities sector and the regulators determination to use meters to open up utility networks to competition, there has been very little academic interest in the changing role of the domestic meter. This is surprising. The government, utility regulators and privatised utilities are all making questionable assumptions about how households will respond to the 'metering revolution'. What little academic interest exists has a strong technical or engineering base with little evidence of any wider critical appraisal of the social, political, economic or spatial issues raised by recent changes in domestic metering[1]. This is an unfortunate situation - fundamental changes are now taking place in the ways in which millions of households will receive their energy and water services. Decisions as to the role of metering technologies in this process are being taken with little critical assessment of the potential social and environmental issues raised.

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[1] See for instance the IEE (1987, 1990) for reviews of technological and engineering based innovations in metering technology with very little discusssion of the wider socio-economic issues raised by such developments.

In this working paper we wish to ask some important questions about the profound social, economic, political and geographical disparities that are emerging through the use of new metering technologies by British utilities. At the same time we will point out some of the environmental and commercial benefits of smart utility network control. The paper acts both as a preliminary discussion of these issues, focusing on the use of electricity, gas and water meters in the domestic sector[2], and as a guide to a new social science research topic[3]. We will highlight the technical disputes, scientific uncertainties and commercial priorities governing the development, implementation and use of new metering technologies in the power and water sectors. In particular we will point out the limitations of a purely technical/economic approach to understanding the metering debate. In doing so the paper will demonstrate the urgent need for a more sociological perspective on technical innovation in the utilities sector. Specifically we will suggest that we must deepen our understanding of the social shaping of the development, implementation and use of new metering technologies if we are to successfully identify the technological and institutional approaches best placed to minimise the social costs of prepayment metering while maximising the environmental potential of smart metering.

Structure of Paper

The rest of the paper is structured around 5 sections:

- Section 2 - The Socio-Technical Development of Meters - reviews the main shifts in the development and implementation of metering technology over 3 generations of technological innovation.
- Section 3 - Re-Configuring the Meter - reviews the key actors involved in contemporary metering debate. We focus on the aims and practices of utility regulators, companies, customers, meter manufacturers, telecoms providers, consumer and voluntary groups, unpacking both their relative enthusiasm for and concerns about new metering technologies.
- Section 4 - New Logic's of Smart Metering - inserts the metering debate into the context of the privatisation and liberalisation of utility markets. It argues that there has been an important shift away from the universal service ethic of the nationalised era towards new logic's of utility provision. We go on to explore the ways in which the application of new metering technologies is accelerating the emergence of new logic's of cherry picking, social dumping and demand side management.
- Section 5 - Conclusion - sets out some new ways of thinking about the smart metering revolution drawing upon established ideas from the sociology of science and technology. We conclude by identifying future research topics.

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2 All energy customers have a meter but this is not the case in the water sector where only large users and 7% of domestic users have a metered supply. Consequently the debate in the water sector is about the introduction of metering technologies rather than the restructuring of existing systems

3 There are, however, also important debates about the use of meters in commercial and industrial sectors together with growing interest in the 'metering' of road use through electronic road pricing systems, but both these issues are outside of the remit of this paper.

2. The Socio-Technical Development of Meters

An understanding of the contemporary debate about the development and implementation of metering technology needs to be based on a general review of the evolution of the domestic meter. Figure 1 provides a summary of the main features of domestic metering during three critical periods of development. These periods are based on the specific technology utilised, the level of meter functionality and system of communication employed in each era.

Figure 1 The Development of the Domestic Meter

	Technology	Functionality	Communication
"Dumb" Meters 1880s -	Mechanical Electro - mechanical	Measures consumption in kWh, therms & gallons. Coin prepayment.	Manual by utility and customer.
New Functions Mid-1970s -	Solid State Electronics	Load Management. Tariffs.	Economy 7. Prepayment Tokens.
"Smart" Meters Mid-1980s -	Modular Microprocessor	Multi-functional	Two - way remote communication using telemetry, telephone, radio, mainsbourne & smart cards.

"Dumb" Meters

The development of cheap, reliable and effective metering systems able to accurately measure domestic use was a major problem for early utility companies. Energy services were frequently sold by the 'hour' based on the 'number' of gas jets or bulbs used or on a flat rate pricing system that provided basic access to energy services. Although energy utilities attempted to monitor customers to ensure they kept to their contracted levels of usage there was clear potential for fraud. Moreover, flat rate contracts hampered accurate demand forecasting and load control. The imposition of energy meters was therefore vital to the development of a cohesive, controllable electricity network. As Madeleine Akrich puts it, in the development of an electricity network, "the set of meters measures the cohesion of the socio-technical edifice materialised by the network" (Akrich, 1992).

Initially, different types of metering technologies, based on a range of mechanical and electromechanical systems, proliferated but by the end of the nineteenth century metering technologies were beginning to stabilise (DTI 1974). The Ferraris disc electricity meter, first developed in 1884, became the standard meter within the electricity industry, while gas meters were based on simple mechanical devices. The development of relatively cheap, reliable meters enabled the highly fragmented and localised gas and electricity utilities to extend their networks into the domestic market from their established customer base in the commercial and industrial sectors. By contrast, early water supplies were explicitly targeted at domestic customers, in preference to the commercial and industrial sector, in the interests of promoting improvements in public health. Driven by a strong supply orientation, aimed at ensuring universal access to clean water supplies, domestic premises were simply piped-into the water network, bypassing the complications of metering. The early 'dumb meters' had relatively limited functionality - they simply measured resource consumption in standard units - therms, gallons, kWh - at one standard tariff. Communication with the meter required a physical visit by a meter reader to manually record energy consumption and relay the information back to the utility for processing in labour intensive administrative and accounting systems. Those households who operated on credit terms were subsequently issued with a bill for payment, while households who the utilities preferred not to supply on credit terms were supplied with prepayment coin meters to avoid debt.

These metering systems underpinned the extension of utility services towards universal or near-universal services, dramatically transforming the highly fragmented gas and electricity sector inherited by the new public corporations upon nationalisation in the late 1940s. Aided by such technical innovation, the utility industry could prioritise the development of economies of scale in the provision of energy services. The nationalised period of utility control was characterised by an implicit assumption that wide geographical and social disparities in charges and access to services would be slowly ironed out. A commitment to universal service obligations, the public service ethic and cross subsidisation from large users, pushed the networks into poorly served rural areas and provided enhanced services for small domestic customers. From the 1930s utilities actively promoted the electrification of the domestic household to develop loads that would make the most effective use of generating capacity (Chant 1989 p. 95-108). Universal tariff systems were developed, despite wide variations in the actual costs of serving customers, to support the modernisation of post-war British society. This strategy reflected a more general public service ethic and the conception that utility services were quasi-public goods that had no place in a free market. In this way, social relations between the production interest of the utility and the consumption interests of the customer were prescribed through the meter. Utility users were configured as more or less 'equal' citizens, each with the right to connection to essential services (along with rights to education, health and housing). This level social geography correspondingly configured the country as an homogenous economic space. The priority diving the development of utility networks was to further even out the social and physical dimensions of this space. Of course there were obligations that went along with public citizenship, including prompt payment of individually apportioned costs. In creating a flat utility landscape the utility managers had to make a judgement about a customers credit worthiness. The type of meter installed acted as a physical surrogate of this judgement - should the customer be allocated a normal credit meter or a coin pre-payment meter? Installation of a pre-payment meter meant that the utility could avoid the problem of customer indebtedness with the customer being forced to coin feed the meter before obtaining a supply.

Consequently, complex sets of social relationships were drawn around and defined by the meter which acted as a source of social control. As Madeleine Akrich argues:

> Each individual meter intervened as referee and manager of the relationship between supplier and consumer. Taken together, the set of meters operated as police in a collective organisation, uncovering irregularities. Such irregularities appeared first as deviations in consumption curves that were neither localised nor sanctioned (Akrich, 1992, p.218).

To enjoy the benefits of this socio-technical system passive acknowledgement of the utility industry's rules and regulations was mandatory. Ownership of the system underlined this socio-legal position. For although the meter is usually located within the customers own premises it remains the property of the utility who have statutory rights to gain access to their meter. Of course, both the customer and utility have an interest in recording resource consumption accurately. Dispute resolution procedures have been enshrined in law to allow customers to challenge the accuracy of their meter. However, the complainant has to pay the cost of meter testing and adjudication if the meters accuracy falls within predetermined limits.

In sum, the mundane world of post-war infrastructure provision pre-scribed a wide range of social, legal and environmental relations for the whole country. Decisions as to the development and management of these networks remained, for the most part, beyond the control of the public at large who sacrificed choice of utility services for the greater good of relatively cheap, reliable power and water supplies. 'Deviant' users of utility services were swallowed up as the network grew, stabilised and naturalised itself as the technically 'rational' approach to infrastructure provision. This socio-technical system provided the basis for volume metering of utility services for many years - the majority of domestic meters in the 1990s remain based on technologies that were well understood and widely used in the 1890s.

Developing New Functions

Although metering systems remained remarkably stable there were a number of important changes in domestic metering from the early 1970s. These shifts developed in response to a series of wider problems in the utilities sector particularly with the economic performance of the electricity supply industry (ESI). The ESI came under increasing criticism for its increased costs, inefficient economic performance and the difficulties of accurately forecasting future demand. During this period the established supply-led trajectory of electricity network management based on increasing economies of scale came under increased pressure as the linkage between economic growth and increased electricity use weakened creating huge levels of over-capacity. Although a number of proposals for wide ranging reform were considered none where implemented and the main changes focused on new methods of financial control and management. This new context helped shift the industry's attention towards its relations with domestic users. In particular the development of new techniques that would help reduce the industry's costs and improve the economic performance of the sector. The availability of cheaper electro-mechanical metering devices helped focus attention on the meter as an agent through which relationships between the utility and different types of customers could be re-shaped. These shifts focused on two key issues.

Alternatives to Coin Prepayment.

During the late 1960s and early 1970s both the gas and electricity industry was facing increased difficulties with coin operated prepayment metering (see Attree and Green 1990, O'Brien et al 1990 and Stimpson 1990). With increasing energy prices the meters had become a valuable target for theft and fraud, it was difficult to protect coin collectors and meters jammed or became full before regular collection was due. The rising cost of servicing these meters together with high levels of lost income became a serious issue for the energy sectors. The fuel industries responded to these high transaction costs by phasing out coin operated pre-payment meters. However, during the mid 1970s the industry came under increasing pressure, from the Select Committee on Nationalised Industries and the National Consumer Council, to develop a prepayment meter designed to overcome some of the socio-administrative difficulties facing coin based prepayment provision.

The public utilities and meter manufactures began to evaluate the potential of using solid state electronics and new ways of communicating with the meter. Early investigations highlighted the significant technical potential of electronic meters. From the mid 1970s the industry experimented with the use of tokens, keys and cards to substitute for cash transactions in prepayment meters. From the early 1980s electricity boards invested in new forms of prepayment meters based on these technologies. Customers bought cards, tokens or keys from electricity showrooms and local outlets which were then used to recharge the prepayment meter. Although the utility had to set up a new distribution network for the tokens they avoided many of the costs - particularly theft, regular emptying of the meter etc - associated with coin based transactions. While utilities still had to visit the users home to alter tariffs, the level of debt repayment and to monitor fraud they were able to increasingly "disengage" from marginal users thereby avoiding the huge transaction costs associated with coin operated meters. These new metering techniques allowed utilities to more closely control the costs and depth of their linkages with the most marginal users by mediating social relations through the card or token. Card, key and token meters quickly replaced coin operated devices in the electricity sector. By 1990, 8% of electricity customers paid by coin or token prepayment (Woodside and Jones 1990).

Managing Electrical Loads

Metering technologies also developed in response to increasing difficulties managing a large electricity production system based on larger coal and nuclear power stations. Since nationalisation the industry had operated on powerful assumptions that electricity consumption would continue to increase in line with higher levels of economic growth. In response the industry had to ensure that sufficient supply capacity was brought on stream in anticipation of increased demand. However, in the early 1970s severe financial restrictions prevented the industry investing in new power stations while electrical demand itself became increasingly unpredictable and heterogeneous. The linkage between economic growth and electricity demand became increasingly de-coupled as firms paid more attention to energy efficiency in response to increased fuel prices. These shifts raised serious challenges for the industry based on huge power stations which could not be simply switched on and off in order to meet diverse patterns of demand. The ESI was forced to consider new ways of managing demand in order to maintain the technical and economic efficiency of this supply-led logic of network management. New Economy 7 meters, based on electro-mechanical switches which provided two electricity tariffs - the normal day-time tariff and a less costly off-peak tariff provided electricity for water and space heating at night - helped provide a crude form of load management. It enabled utilities to fill the night time trough when demand was much reduced with demands for hot water and domestic heating.

Re-shaping Social Relations

Overall, the increasing social and technical complexities surrounding the supply and distribution of utility services signalled a crisis in the conventional logic of infrastructure provision. This crisis was instrumental in sparking a metering revolution. The use of these new metering technologies has had important implications for the social relations between customers and utilities. In the case of Economy 7 the electricity sector started to take a much closer interest in what went on beyond the meter in the customers own home. The electricity industry began to market domestic space and hot water heating packages, partly in competition with gas, but principally to build up a base of demand which could then be controlled by the meter. Employed in this way these new meters started to shift the balance between consumption and production interests. While the customer benefited from lower tariffs it was the utility that decided when power should be provided for home heating. In this sense the power of utilities over the use of infrastructure services was increasing. Decisions about household consumption were transferred, via the meter, to the utility. By way of contrast, the development of token or card operated prepayment metering signals a withdrawal by the utility, signalling important shifts in the relations between the utility and its prepayment customers.

Towards Integrated Smart Meters

This complex shift of balance in the relationship between consumption and production interest signalled both a form of re-engagement between customers and utilities and a complex form of withdrawal. With the arrival of yet another generation of meters this logic is being extended. Since the early 1980s there have been major improvements in metering technology based on integrating relatively low cost micro-electronics. A series of experiments with new forms of energy management systems have explored the extended functionality of these innovative forms of metering technology. These experiments demonstrated the technical feasibility of multi-functional meters with the potential for complex two way communications between the utility and customer. The further potential for using telecommunications to integrate meters into gigantic 'control systems' began to be discussed as the basis of a radical new way of managing utility networks. Here we see the implications of smart metering applications for smart network control:

> A computer screen shows the map of a residential area north of Bristol. At the touch of a button, the screen prints up real-time details of electricity consumption in any of 30 houses in the area - not just voltage, but wattage and whether the electricity being used is inductive or reactive. More than that, the computer record for several days in 11-minute blocks, providing a detailed history of each household's life patterns (Lascelles, 1994).

Smart electronic meters can be produced at a similar cost to established technologies but with dramatically extended operational features. These integrated or intelligent meters are more secure, able to offer remotely programmed multiple tariffs with the ability to make real-time information about supply and use available. The growth in sophistication of these smart meters over the traditional mechanical units is profound. Conventional meters simply recorded fuel consumption. With smart electronic meters it is possible to add extra functions, as necessary, relatively easily and cost effectively via additional modules through the use of surface mount technology (Gore 1990, p.73). The enhanced functionality of the smart meter could include a wide range of potential applications:

- Encouraging customers to use water or energy at different times through differential tariffing which may prompt customers to spread their load. It has been suggested that meters could "utilise sound or a colour coded display systems to inform consumers they were over-consuming during the high-cost period" (Dauncey 1990 p.59).
- To assist the elderly by adding a temperature sensing device to the display unit as a hypothermia warning. This flashes a message to the customer automatically when a pre-set low temperature is reached. In a similar vein demonstrations have been made of a speaking display unit for blind customers and display messages have been repeated on a television screen. There are "a wide range of display facilities could be made available to customers, some basic and provided free by the Company, others of a more sophisticated nature and optional" (O'Brien et al.1990, p. 187).
- Consumers could choose energy reduction targets and programme their meters to inform them (on a daily, weekly or monthly basis) whether they were exceeding or meeting these targets (Dauncey 1990, p.59).
- A more sympathetic approach to collection of debt by agreeing a weekly payment which is monitored by the meter. Any weekly shortfall can then be collected in smaller additional amounts over next few weeks (Stoddart 1994).

The new functionality of the smart meter relies on new methods of two-way communication with the meter. A wide range of communication systems - including the Power Line Carrier (PLC), telephone, radio and use of smart cards or tokens - are developing rapidly. Hitherto communication between utilities and users was merely one-way - via meter readers - limiting the ability of more sophisticated load control techniques, for instance through the use of multiple, real-time tariff pricing. Recent developments have focused on the development of two way communication via the customers meter to facilitate a more dynamic relationship between utility producers and consumers. There is great potential for utilising the powerful communications features of smart meters. For instance Dauncey has examined the potential role of meters in environmental policy - particularly through the energy management potential of metering devices arguing that it is "time for the household meter to come out of the closet, and appear as a piece of attractive household eco-furniture" (Dauncey 1990, p.59). The smart meter could send instructions to specific appliances (air conditioners, water heaters, washing machines) at peak times instructing them to switch off or slow down before commencing when capacity is available. Alternatively price-signals could be sent to the home through the meter and directed to pre-programmed appliances instructing them to operate at specific times in response to costs.

These innovations have been widely tested by gas and electricity utilities during the 1980s, while the industry was still in the public sector, through a number of large scale experiments involving the utilities, meter manufacturers and telecom companies. These tests were aimed at evaluating the technical and commercial feasibility of smart meters. In particular, several trials of advanced metering in the domestic sector were carried out under the auspices of the Electricity Council (now the Electricity Association), London Electricity, British Gas and Thames Water, all working with Thorn to test a mains signalling system for Automatic Meter Reading (AMR) and load switching in 60 homes (Dooley 1991a p.14). While the most innovative work has been carried out in the electricity sector, water companies, such as Wessex water, are now working with the privatised Regional Electricity Companies (RECs) in demonstrations/evaluations of smart meters (Dawn 1994). There are, however, major physical, technical and institutional problems for water companies who wish to employ smart metering technologies, including a large proportion of dispersed rural customers and the disproportionate expense of employing PLC on a third party basis. It has also proved very difficult for utilities to co-operate and share costs of metering and communication technology, despite the low costs and attractive operational benefits. Particular problems have included competition between gas and electricity companies and issues of safety and access. But the added communications value of the ability to implement variable rate tariffs and to shed load in periods of water stress such as drought may well shift the economic equation in favour of metering (Dawn 1994). Water companies have already developed budget prepayment meters similar to electricity and gas prepayment systems. These meters provide both an audible and visual warning when credit is exhausted but allows emergency credit for a week. Similarly, the advent of joint utility companies selling electricity, gas, telecoms services (and in the future maybe even water) may further facilitate integrated metering systems. Although these options have continued to be explored following privatisation, the pressure and direction of change has shifted rapidly. Both the "Integrated meter" (Gore 1990) and the "Intelligent" electronic meter (Dauncey 1991) are now being produced, tested demonstrated and applied in earnest.

Recent smart metering developments have built upon the dual logic of development created during the end of the nationalised period of utility control. The CEGB developed more sophisticated methods of load management by remotely controlling the times when the meters took a supply for water and space heating over the long wave radio 4 network, thereby making the most efficient use of capacity on the system. Over one million of these meters are now in use providing variable tariffs and controlling the domestic water and heat load independently from the lighting and appliance load, providing an example of the efficacy of 'smart' utility control (Clarke and Seddon 1990). Privatised RECs have continued these experiments through the development of meters that can have up 7 different tariffs for different combinations of heating, hot water and general electricity supply. These could enable RECs to offer particular packages of services to different types of customers with the utility making the most effective and profitable use of electricity supply. REC's have now demonstrated metering systems with two-way communications through which they alter tariffs and monitor their customers response. As we shall see in the next section it is proposed that these smart meters have a central role in opening up the domestic electricity market to competition.

At the other end of the market there has continued to be significant innovation with smart card technologies. Although the token, card and key systems did resolve many of the problems associated with coin prepayment new issues emerged. The tokens themselves were extremely valuable and subject to theft and fraud while the utility had to visit customers premises to alter tariffs and the level of debt re-payment. Consequently both the gas and electricity sectors developed new smart card prepayment systems which provided much more secure form of two-way communications between the utility and meter. Each card is configured for a particular meter reducing the potential for theft and fraud. The card itself carries a whole range of information from the utility back to the meter - this relies on the card being physically carried by the customer between the charging point and the home. This information includes changes in tariffs, levels of credit and debt repayment, household energy use and monitors the safety and performance of the meter (O'Brien et al 1990).

Smart card operated prepayment metering signals a withdrawal by the utility, fundamentally altering the balance between the utility and its customers. The utility only needs to enter the customers premises once every two years to perform physical checks on the meter. Critically, the system was less open to fraud and avoided the need for physical disconnection on the part of the utility for non-payment. All these shifts in utility practice have had a corresponding impact on utility customers who are now forced to travel to recharge their cards while also suffering a loss of control over the timing of payment and less means to resist disconnection effectively self-disconnecting themselves from the network when they can no longer afford to charge the meter. Alternatively at the least the customer has more control over self-disconnection than when the utility decided to disconnect customers.

The development and implementation of these smart meters is fraught with commercial risk, technical difficulties and operational uncertainties. Currently, it is only possible to sketch a map of the varying technical development pathway's presently being explored. To summarise, there are a whole range of relevant, if disjointed, themes in the development of the meter that are worth noting:

- most meters are still based on traditionally dumb technology while new metering technologies take approximately 10 years from development to application stage.
- meters have become more complex in terms of the functions and communications capabilities.
- the electricity sector tends to lead new metering developments, followed by the gas sector and more recently joined by the water sector in the 1990s.
- the feasibility of meters tends to be tested through joint utility, meter manufacturers' and communications providers' evaluations.
- ·there is an emerging dichotomy between the development of prepayment metering technologies and smart meters for load control.

Clearly there are been major increases in both the functionality and ability to remotely communicate with domestic meters. Moreover, the new integrated meters have a wide range of potential functions that will have important implications for the relationship between customers and utilities through closer engagement and/or gradual withdrawal. The socio-environmental outcome of such technological innovation depends much upon the particular technical development pathway(s) - the level of functionality and scope of communications link - chosen by the utility industry. But which technical development pathways will be chosen, by whom and why? To start to answer these questions we must begin to unpack the institutional interests that are shaping the development of meters?

3. Re-Configuring the Meter

The implementation and use of new metering technologies does not simply reflect new technological capabilities. New applications are driven by broader social and political changes in the utilities sector. In particular there are a variety of professional actors with a central role in shaping the development of metering technologies. In order to develop an understanding of how the conventional meter is being re configured it is therefore important to unpack the diverse - sometimes conflicting, sometimes overlapping - interests of these groups. We will examine interests of 6 significant actors in the construction of metering technology; utility regulators, companies, consumers, meter manufacturers, telecoms providers, voluntary, consumer and community groups.

Utility Regulators

Utility regulators are playing a central role in the metering debate in each both power and water sectors. For the electricity regulator OFFER, the introduction of smart metering are central to the opening up of the electricity network to competition in all sectors. The use of smart meters will be vital to promoting competition in the domestic sector where, in 1998, it is hoped that all 24 million domestic customers will be able to select their electricity from any REC. In order to "make competition in supply a reality for all customers" a major change in metering and communications technology will be required. A new smart metering infrastructure with two-way communications between customers and suppliers should be enable domestic users to select their supplier with all the transactions being handled electronically. The superimposition of a new electronic communications and metering infrastructure over the fixed electricity network could create a new virtual market in electricity supply. A consultation paper on domestic metering was published by OFFER in 1992 setting out a timetable for the introduction of integrated metering technologies. This report suggests that RECs should take the lead in deciding which metering system they want to adopt. It is envisaged that while it is likely that the REC will want to select one system (though there may be variations in the treatment of urban and rural areas), metering and communication services could be subcontracted, creating a competitive market in meter manufacturing, and that utilities will carry out further trials and evaluations of different systems. OFFER argues that the new system will produce major benefits for utilities and their customers. There are, however, major technical and institutional uncertainties about whether the new monitoring and billing systems will be in place by 1998. The utilities charged with preparing the new system "are expressing mounting concern about the problem of running a market that would need more than 1 billion transactions to reordered each day"[4]. It is now increasingly likely that only the largest homes will have smart meters while the rest of the market will be split up into a 4 profiles based on simple charging bands.

Water is somewhat different from the electricity sector. Whereas it is normal for commercial and industrial users to pay for their water use by volume only a small minority of domestic users are metered[5]. But as the concern with water stress has grown interest in water metering has surfaced. The current Conservative government are very much in favour of extending metering to the

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[4] Tieman, R. (1995) Offer sidelines new electricity meters, The Times 18th April 1995.

[5] Only 4% of domestic customers where charged by volume in 1993 (OFWAT, 1993a).

domestic sector, as are the regulators OFWAT and the NRA. The regulator, DOE, and representatives of all the water companies worked together in the national water metering trials which began in 1989. The trials were not designed to assess the relative merits of a range of competing charging options, instead focusing on the socio-economic feasibility of metering. The feasibility study covered 60,000 households in 12 areas which reflected a variety of house types and socio-economic composition, although it didn't form a representative sample of the country as a whole. However, a number of wider social and financial issues were also raised by the study which has locked the water industry into a long and controversial debate on the relative merits of metering. Although the regulators are still pushing for selective metering the water companies have all indicated that they want to consider alternative payment options.

Utility Companies

The domestic meter is of central importance to utility companies. As we have suggested it provides the 'gateway' through which all the most significant social relations with their customers are structured. Changes in the functionality of meters therefore have important consequences both for the utility and their customers. Critically, utilities must consider the costs and benefits of adopting new metering technologies. Consequently there is great debate in the utilities sector about the need to adopt new forms of metering technology, what functions should be added to meters and how what forms of communications to employ. The utility regulators have a central role in structuring the terms of this debate, responding to the concerns of utilities over the socio-economic complexities of widespread installation of smart meters - particularly the problems with communications. However, there are clear interests for the utilities in installing new integrated metering technologies.

New metering technologies can be used to transform utility services they offer opportunities for cost savings, efficiency gains and service improvements (See Sioshansi and Davis 1989). Pre-privatisation, nationalised utilities provided uniform services based upon average cost pricing and a universal quality of service. However, with privatisation Utilities are now facing open up to increasing competition and are under severe pressure to differentiate services by price, quality, and time of use to different types of customer in order to raise profits through heightened operational efficiency. This means replacing cross-subsidies from large to small customers with a new emphasis on real-time, cost based pricing. We are likely to see a range of new utility strategies in this increasingly competitive environment. In particular, a turn towards services tuned to meeting the needs of particular types of customers through a combination of the lowering overall cost, improved quality of service and new service options, with costs strategically allocated amongst customers rather than evenly spread. A key to implementing these new strategies is exploiting the information and communication features of smart meters. Cost-based pricing requires "better monitoring of what customers are using and when they are using it" (Sioshansi and Davis 1989 p.602). An electronic meter and communication with a utilities load centre facilitates real time pricing. Moreover, when operational the metering system can provide other functions in addition to time-related pricing:

> The utility should be able to connect and disconnect customers remotely at the touch of a button, respond to telephone inquires with the current meter reading its disposal, and diagnose faults and outages more quickly and automatically than is presently possible.

> Customers should be able to get fuller details of their usage on their bills. To help them manage their electricity consumption better, they should be able to get up-to-date readings of their account and they should not be bothered with the inconvenience of meter readings... (Sioshansi and Davis 1989 p.603)

Low cost high speed communications open up potential for better load control, energy management and automation of distribution system, for example, automation of distribution systems in areas where utilities have little information and monitoring capacity, pre-programming domestic appliances for use during low cost off-peak periods or even allowing utility's to remotely control appliances. There is also the potential to tie together data on customers which can be utilised by different departments to link together commercial and technical information for marketing purposes (Dooley 1991b).

These technical innovations have the potential to transform electricity, water gas resources from a single dimension product measured by KWh, therms and litre's to the status of a commodity whose price varies by the hour. The benefits to utilities do not end here. Automatic Meter Reading (AMR) can generate major savings for the utility (Ward 1989). Reduction of the direct metering costs represent only a proportion of the cost savings - additional benefits include reduction in theft, aiding leak detection (in the water sector), increasing cash flow, trimming bad debt and 6 monthly reading in gas and electricity which can be set to contain costs (Reynolds and Edwards 1992 p.2). Increased accuracy of readings will be a major boon. For example, in 1990-1991 British Gas took 28 million readings at cost of £20m. Many of these readings incorporate an underestimate meaning that the utility has to estimate current and future demand based upon assumptions about how customers behave. We have referred above to the problems associated with manual meter reading. Only 70% of visits obtain a reading first time, 30% fail. There are huge problems with inquires about estimated bills, a fast change-over of occupancy (10% in one year) and widespread theft (particularly of gas). In order to minimise these problems British Gas aim to AMR all domestic customers by the end of 1997 (Reynolds and Edwards 1992 p.14). The development of a low-cost two-way communication device with the meter between utility and customer also offers potential for non-utility services. Examples include information retrieval, electronic mail, home security and energy management. The meter as communication device becomes an important access point for these utility services. There are also close linkages developing between metering and the future of smart homes, appliances and the metering debate (see Rosenfield et al.1986).

Those water companies that opt for meters are faced with the choice of dumb or smart metering systems. These are three main options once the industry has to adopt alternatives to charges based on rateable values after 2000 - a flat rate, a banded system similar to council tax, or metering. The water companies have still not confirmed what system they will use. While most water companies are now fitting meters to new developments, only Anglia water has committed itself to universal metering leading them to experiment with radio based AMR which exploits Anglia's extensive telemetry network. Whereas a few water companies have announced a decision to extend water metering in their areas, the majority have yet to decide and some are even opposed to water metering due to the small cost of supplying additional water (unlike gas and electricity) in comparison to installing meters (Pither 1993). Around the time of the metering trials there was a real momentum in the industry towards retrospective metering. Now there is much more caution and some of the previously pro-metering companies are now opposing metering. Anglian water, who were originally in favour of universal metering, are currently reviewing its policy as are Yorkshire Water[6]. In particular implementation costs have dampened the enthusiasm of many companies, although this is less onerous in new properties and many companies are fitting all new properties with meters. Further, there is the question of whether the 10% saving found on the Isle of Wight is sustainable? FoE have found in Canada that relative savings declined as customer became used to paying for water on a volume basis. In fact consumption returned to follow the pre-metering trend only 3 years after meters were installed (FoE, 1992, p.9). Clearly, universal metering is not a short term solution and while leakage levels remain high there is likely to be stern opposition to mandatory metering. Nevertheless, set against the background of the end of rateable valuation/charging by the end of the year 2000, a looming crisis in the water charging mechanism with 18 million properties needing to be billed, selective metering is likely to proceed particularly in areas of water shortage.

A final positive spin-off for the utilities seems likely to be the use of new smart meters to build up sophisticated consumer profiles at the household level. As the interest of the utility pushes beyond the meter into the customers home, they will be able to assemble much more detailed and precise information about how individual electrical appliances are used in the household. Each appliance has its own particular signature when switched on or off allowing utilities to build up profiles of their customers. These will be extremely valuable to both utilities and other companies who buy this information.

Utility Customers

The principal issue affecting utility customers concerns access to the meter. This issue revolves around two dimensions - the degree of choice involved and the cost of the meter. In the electricity sector it is not clear on what basis integrated meters will be made available to domestic customers or how capital and installation costs will be allocated. OFFER envisage a situation in which customers would be able to choose meters which provide the particular set of features in which they are interested from electrical appliance stores. But as we have demonstrated, there are critical differences between the consumer benefits of smart and prepayment meters. The main motivation for a customer buying a new electricity meter is the choice that this gives them in selecting an electricity supplier. This is only possible with a relatively expensive smart meter and it is not clear if consumers, especially domestic customers, will be willing to spend £70 to achieve what might be at most be a 5% saving on a £300 electricity bill. The industry have estimated that less than 10% of customers are likely to be really interested in energy and cost savings (Lascelles 1994). It is possible that some customers may be willing to invest in integrated meters because of the additional services they offer. For instance an electricity council survey in 1986 found that 81% of electricity consumers wanted their meters to show how much they owed the utility (Electricity Consumers Council 1986).

Such services are, however, more likely to be selected by larger, wealthy consumers who can afford entry, and additional service costs. The meter could be sophisticated enough to store

[6] See: NRA, Demand Management Bulletin; No. 8, December 1994, p5 and No. 10, April 1995, p4.

information about a customers account allowing the utility to inform the customer, through the meter, how much credit the meter has and the meter could warn or disconnect the customer when they overran a prearranged budget. Of course, "this type of scheme would require a major change in people's attitudes to electricity billing.." (Sioshansi and Davis 1989 p.602). Herein lies a further issue relating to utility customers and the metering revolution, will consumers use smart utility systems creatively and intelligently? Can customers cope with variable tariffs? Such a system has been successfully utilised in the operation of the telephone network through a distinction between local and long distance calls and between cheap, standard and peak tariffs. Experiments with variable tariffs have shown that customers have responded to such load management techniques resulting in a shift in peak consumption (with typical reductions of 10% - 20% of the peak). Such smart network control could result in major energy savings (see Rosenfield et al.1986). According to studies in the US customers shifted kWh sales between pricing periods saved customers saved up to 24% (Electrical World 1991).

At the other end of the scale low income and marginal customers are being offered a different type of choice. Access to prepayment meters largely depends upon the policy of individual utility companies but they are usually utilised to reconnect any customer previously disconnected for non-payment or as a preventative alternative to disconnection. Prepayment metering technologies have a variety of costs and benefits for utility customers. At least the system puts the customer in control of their own energy supply when the customer, rather than the utility, disconnects from supply and it also prevents the customer becoming indebted to the utility. The increased control it gives customers have even led to new demands for opening up access to prepayment meters for those low income and marginal customers who decide they want the system (Law et al.1990). There are, however, major areas of concern. Customers on prepayment systems have to pay a higher tariff and standing charge in order to meet the utilities "higher costs" of establishing and maintaining the systems. The accessibility of charging points for customers can be a problem for some customers while levels of self disconnection are effectively hidden and not subject to any wider public debate.

So, the degree of choice available to utility customers over types of meter varies greatly. For example, some water customers are being forced to accept compulsory water metering of new properties, British Gas are offering a prepayment meter to most customers while the attitude of RECs to prepayment vary. Water customers have so far proved very uncertain about the merits of metering. Widespread resistance to the imposition of metering has received high profile media attention and has resulted in many companies withdrawing plans for retrospective metering initiatives. Again this is a controversial area. An OFWAT survey found that 71% of households found metering acceptable. The majority of customers had lower bills while less than a quarter paid 20% more than their rateable value bills. However the survey also found that 4% of customers, mainly families with health problems requiring additional use of toilets and laundry, suffered health and financial hardship as a result of metering. But the sample is not representative of those on benefits so a much higher percentage of households may find difficulties paying bills when water is metered.

Meter Manufacturers

The meter manufacturing industry are quickly responding to the new market opportunities developing in the UK. If new metering technologies are adopted in both the electricity and water sectors the potential sales will be measured in billions of pounds. However, there is considerable uncertainty about how this market will develop. The cost of an electricity meter if installed in all homes would be in excess of £2.5 billion excluding labour costs (Boardman and Houghton 1991, p. 72). If all households were installed with a water meter the cost is likely to be between £5 - £7.5 billion. Venturing into this market is risky. However, the manufacturers have made efforts to persuade the regulators that effective integrated metering products can be introduced at realistic prices. For instance, the industry estimates that 2 way main signalling electricity meters can be made available at under £60 with a cost of between £2 - £12 for the PLC communication (Lascelles 1994, Tunbridge 1994, p.30). This compares with the present metering costs of £25 for the basic meter, £45 for an Economy 7 meter, £110 for cashless prepayment and £110 - £130 for a multi--rate meter with teleswitch (OFFER 1992). In 1992/3 costs of installation for 95% of households were £165 for internal meters and £200 for external meters. Annual running costs above present rateable values were nearly £20 per property. Of this nearly £14 was for billing, enquires and customer services.

The capital costs of installing water meters are high - around £200 for externally sited meters, slightly less if the meter is sited within the home (FoE, 1992, p9). The cost of reading of meters, around £20/year including reading, billing testing, maintaining, is also a problem. The Labour Party estimate it would cost £5 billion to install water meters universally and £1/2 million to operate (Dobson 1995a, p1). Some experimentation on remote meter reading[7] and joint metering reading with other utilities using real time infomatic systems is occurring but no satisfactory solutions have currently been found (Dawn 1994). In order to cover these costs over a 10 year period customers would have to pay an extra £40/year (£20 reading/£20 capital cost). On an average bill of £100 this is clearly a significant outlay. As recent media debates have highlighted, leakage control and pipe replacement may prove a more cost effective use for this investment (Dobson 1995b). There is also some evidence that measured water charges have grown quicker than unmeasured, further stoking public fears of an escalation of water charges after metering (OFWAT, 1991, p7)[8].

A more central issue for manufacturers, seeking to minimise exposure to commercial risk, is the choice of metering technology - should systems be standardised, or will utilities adopt their own particular systems, which may not be compatible with systems adopted by other utilities. In addition, the manufacturers need more information about the structure of the market, functionality (1/2 or 4 hour pricing), and the technical facilities needed to support meter systems. The regulators have so far left many of the key decisions about the choice of meter and communications to the individual utilities with little guidance about costs or technical standards. Consequently, it is unlikely that a national standard for metering systems will develop in either

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[7] See: 'Remote Metering Moves Closer', Water supplment in Electrical Review, Vol. 226, No. 9, p42.

[8] See: Public Utilities Access Forum (1994) Minutes: Water Issues Sub-group, 15th March.

the water or electricity sector. The industry has responded to this uncertainty in a number of different ways. The Beama Metering Association (BMA) was formed to co-ordinate the response of metering manufacturers to the metering code of practice that will be drawn up for the domestic electricity market in 1998. The Association support the concept of developing modular meters which can be added to the basic electronic meter to increase its functionality and maintain compatible with Power Line Carrier, telephone or radio based communications systems (Tunbridge 1994, p.31). Although some companies have already adopted the modular concept it is still not clear if these designs are compatible with other companies systems.

Alongside these attempts to develop some form of standardised approach to metering standards, most of the major manufacturers are working with the utilities to develop and evaluate the feasibility of their particular systems. There are currently a wide range of different systems under development, each claiming the mantle of an industry 'standard' (Tunbridge 1994, p. 32). However, the OFFER metering consultation paper argued that the manufacturers should be prepared to license metering designs to create a competitive market in metering construction. To date, the meter manufacturing industry has kept its options open in response to the uncertainties about the future of the utility marketplace. Until the nature of the market is clarified the industry will continue to work with utilities to establish the feasibility, reliability and efficiency of their products. In sum, while there are still major technical problems, particularly around types of communication systems, and institutional issues to be resolved, meter manufacturers are making significant efforts to construct a new market for integrated metering products. Gradually these companies are demonstrating the feasibility and cost effectiveness of new metering technologies, nudging open a potentially huge and lucrative market.

Telecommunications Providers

The development of integrated metering technologies raises a whole set of key issues for telecommunications providers. As with the meter manufacturers, there is considerable uncertainty about which communications link will be selected for communicating with the integrated meter. As we have seen, there are several competing systems currently being assessed. The electricity industry has shown considerable interest in the Power Line Carrier as the industry would then own the communications link and could sell third party access to other utilities. However, utilities have shown considerable reluctance to give up ownership of the communications link to their meters, and so to potential competitors or other third party suppliers. The main issue here is the potential loss of confidentiality and security plus the uncertainty about future costs of accessing the meter.

Despite these problems a number of third party suppliers have shown considerable interest in providing links to integrated meters. There has been significant development work on the PLC concept which has helped improve its reliability. In addition a number of other telecommunications providers have shown interest in developing products for the utility market. During the mid-1980s, BT co-operated with the Electricity Council and utilities in demonstrating the feasibility of using telephony links. However, in 1987 BT withdrew from these studies because they felt that the low level of demand from utilities, and the then low level of competition, did not warrant major expenditure. All this has changed. There are now a range of competing communications devices for integrated meters. Consequently, BT now plan to launch a 'no dial' AMR service for gas, electricity and water meters in early 1995. Trials are underway with utilities and meter manufacturers to fit the meter with a device costing £10 that enables it to be read in response to a customer inquiry, used for tariff downloading and for remote disconnection, with connection available from anywhere in the UK (Turnbridge, 1994 p.32). One meter manufacturer, Schlumberger, has launched a joint venture with cellular telephone company, Motorola, to develop AMR for water, gas and electricity industry (Electrical Review vol 226, No9, p.42). Cable companies have also expressed interest in providing communications links to meters and the growing involvement of electricity and water utilities in cable companies may help facilitate co-operation between the two sectors.

Competition is hotting up. A growing number of telecommunications suppliers are currently developing communications products and services, particularly for gas and water utilities who do not have the potential of using PLC systems. The established telecommunication providers, particularly BT, are extremely concerned at the prospect of utilities developing their own proprietary communication systems and then offering telephony and value added services. Of course, there are still considerable uncertainties about the cost of these services and the level of security available to the utility. In the UK market, utilities have so far shown considerable reluctance to pass control of the communications device over to third parties, as is common in France and Germany. In the first instance utilities have sought to exploit there own potential links in the form of PLC and their own extensive communications networks. However, the liberalisation of the telecommunications market and utilities own diversification into telecommunication services may create new opportunities for developing new links with integrated meter systems.

Consumer, Voluntary and Community Groups

There are a range of non-professional groups who have taken a interest in the relationship between metering technology and the implications for utility customers. These include consumer groups such as the National Consumers Council (NCC) and the National Association of Citizens Advice Bureaux (NACAB), together with voluntary groups, charities and community groups. Their main areas of concern are the social issues raised by new metering technologies for low income and marginal households. These groups have attempted to question the wider economic consequences of changes in metering technologies and have have often been very critical of the lack of attention paid to impact of the metering revolution on the "utility poor". There are two main areas of concern. The first focuses on the social policy issues raised by the introduction of prepayment metering systems. These systems have primarily been responsible for the apparent decline in disconnection's from gas and electricity networks (Ernst, 1994 p. 139 - 141). Although these system provide major benefits for utilities - a continuous revenue stream in advance of consumption and the retrieval of debt at minimum cost - they do raise new problem for domestic customers. The main problems are:

- ·'Self disconnection' from the network when a customer is unable to use the service because of lack of money or self-rationing of use,
- ·The level of debt repayment set automatically through the meter.

- ·Levels of standing charges for prepayment meters which are higher than conventional credit meters.
- ·Limited access to card or token dispenser and charging points.

A number of campaigns have placed pressure on utilities and the regulators to ensure that the balance between utilities and low income customers does not shift too far in the utilities favour. But still, these are highly contentious issues. Utilities argue that additional costs of operating prepayment systems require additional charges whereas consumer groups argue that these systems bring significant benefits to the utility.

The second area of concern is around the problem of water poverty. Consumer groups have been very critical of the substantial rise in water disconnection's in the in the run up to, and immediately following water privatisation (Marvin 1994). Consumer groups are also extremely concerned about the potential problems of water metering for low income households (which tend to rely on substantial water supplies). With over 1 million households housing an incontinent adult, the NCC want a fixed fee, whereas at present, 4 million households receive social security payments of £2.25/week to subsidise average water bills of £3.25. There have been examples of successful campaigns shifting the stance of utilities and forcing them to provide alternative charging methods to metering in new development (Pithers 1993). Here, protesters have called for bans on water disconnection, supported attempts to ban the introduction of prepayment water metering and argued for the development of alternative charging mechanisms to water metering. Such campaigns claim wide public support with the National Campaign for Water Justice arguing that OFWAT data on public acceptance of water metering "misrepresented public opinion" (Pithers 1993).

While the savings identified in the Isle of Wight study were not income related, some hardship was identified, particularly for those in the lowest rateable value housing (who therefore paid least for their water and also coincidentally represented the highest family size and highest incidence of illness)[9]. This group experienced the highest increase in charges while the richest saw the biggest decreases. These social costs of metering make water companies uneasy, providing an immediate disincentive to further implementation of domestic metering (OFWAT 1992a). Opposition to metering on social and health grounds has been led by the NCC. The NCC argue that the Isle of Wight study was socially unrepresentative, with only 6% of households receiving income support, one-third of the national figure (NCC 1992, p7). This suggests that if universal metering was introduced, levels of hardship due to water poverty could rise dramatically over the whole country. This has prompted a growing coalition of interests opposed to mandatory metering including consumer groups, the Labour Party and local authorities (Halsall, 1995).

Consumer groups representing the views of marginalised and low income customers are significantly shaping the emergence of new metering technologies. They have demonstrated the differential effects, even dis-benefits of the introduction of smart meters for low income, disabled

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[9] 3.8% of a sample of 6,429 hpouseholds on the Isle of Wight were identified as having experienced social or financial 'hardship. A further 8% claimed difficuly in affording their water bills since being metered (OFWAT, 1992a, pp i-ii).

and elderly customers . Their aim is to influence the development pathway of meters by ensuring that regulators and utilities are sensitive to the needs and particular circumstances of marginalised groups.

Shaping the Meter

There are clearly major areas of disagreement between the utilities, regulators and community groups about the direction in which utility metering is developing. Each set of actors are attempting to shape new metering technologies. Clearly the regulators have a central role in framing the terms of the debate. But there are important differences across the three regulators. While OFGAS has yet to make any pronouncement about how the domestic market in gas will be opened up in 1998, OFFER has made it clear that the RECs will have to develop new integrated metering infrastructure (although the RECs will have considerable discretion in how they fulfil this requirement). Similarly, while water metering is the preferred option for OFWAT this option is not being forced on water companies. Overall there is considerable uncertainty about the future of water metering. Meter manufacturers and telecommunication providers are working with utilities in a complex consortia to test the commercial feasibility and evaluate the technical virtues of different metering systems. At the same time, opposition to new types of metering has come from consumer, voluntary groups and charities who have adopted a critical stance to the uneven opportunities and dis-benefits created by smart metering. In order to untangle some of these confusion's we must look a little more closely at the social, economic and environmental effects of the implementation of smart meters.

4. The Logic's of Smart Metering

Privatisation of the utilities sector has stimulated radical changes in the provision of energy and water services, notably in the electricity sector. Lightly regulated companies now operate in highly competitive markets. No longer based on the public service ethic of the nationalised period of utility control, essential resources are being transformed from quasi-public goods into private commodities. Utility services are now sold on the basis of localised, cost-based pricing in a marketplace driven by the search for maximum profitability. Such competitive systems of energy supply are generating significant spatial and social disparities in levels of access to energy services. No longer encumbered by the need to use large customers to subsidise small domestic customers, tariff re-balancing and competition have resulted in a general reduction in prices for large energy users. Moreover, smart metering technology is actively facilitating these changes, emphasising the degree of social control embodied in this essential 'passage point' to basic utility services. The flexibility of these meters, which now incorporate powerful microprocessors and versatile telecommunications facilities, is offering new levels of control to utilities who are increasingly able to dictate who can consume utility services, where, and at what costs. As cross-subsidisation evaporates, the costs and benefits of privatisation are being unevenly distributed. Aggregated markets dominated by universal tariffs are giving way to extremely complex 'utility landscapes' where access is restricted by the functionality of the specific meter installed. Consequently, changing styles of utility service are resulting in very different experiences for consumers, depending on their social, spatial and commercial profile. We argue that these shifts have led to the emergence of three related social, economic and environmental logics which increasingly guide the management of utility services which we term social dumping, cherry picking and demand side management. New metering technologies are now playing a central role in the emergence of these new logics of network management.

Whilst large users of utility services - those who are most profitable to serve - are emerging as foci of cut-throat competition, many marginal domestic consumers of utilities are being forced to the sidelines of utility networks by the imposition of powerful metering technologies. Tariff re-balancing means that larger users face absolute declines in costs while marginal groups face stiff increases in connection and service charges, on top of the recent imposition of VAT. These two processes - which we term 'cherry picking' and 'social dumping' - are inextricably wedded to each other. The 'dualisation' of utilities introduced by cherry picking and social dumping is creating a range of metering applications, each aimed at achieving different goals and each having profound social and geographical implications for domestic households in the UK. While this form of dualisation is only gradually developing, the logic of privatisation seems certain to promote increasing social and spatial polarisation. We can illustrate this argument by looking at the development of metering technology at the bottom and top end of the domestic market, the respective locations of the social dumping and cherry picking processes.

Social Dumping

The first example looks at the most developed application of new smart metering technologies - the prepayment meter. As we have already seen, serving marginal, low income and poor households has always raised serious problems for utilities. These households tend to consume relatively small amounts of energy and are associated with non-payment of bills, debt and disconnection, all of which raise significant costs for utilities. The early solution to these issues was the development of the coin-operated prepayment meter, but associated problems of theft, fraud and collection created additional costs for the utility. Since privatisation, it has also created a serious public relations problem - at a time when the newly-privatised utilities have been desperate to improve their public image. A new urgency to cut costs and improve the reliability of cash flow, together with pressure from the regulators to reduce disconnections, has led to the development of prepayment metering amongst RECs, British Gas and even some water companies.

By the end of the 1990s, several million households are likely to have gas and electricity prepayment systems. Prepayment telephone and water metering systems are also emerging - (it is not inconceivable that one household may eventually have access to two, three or more systems of prepayment). These systems of metering have a profound impact on the relationship between customers and the utility. The smart card becomes the medium through which information is physically carried between the utility and the customers' meter. Once the system is installed the utility can avoid the huge transaction costs associated with non-payment, debt and disconnection. Of course the customer no longer has to worry about the utility deciding when they should be disconnected - instead they can 'choose' when to self-disconnect themselves when they can no longer afford to charge the card. Prepayment meters may bring benefits for both the utility but low-income households seem to be being presented with an odd sort of 'freedom of choice'. The critical problem is the way that prepayment systems effectively *hide or disguise* the issue of poor access to energy services. On the surface it may seem that levels of disconnection have fallen dramatically in recent years. Yet millions of households still cannot afford the fuel services they need to adequately heat their homes. Prepayment effectively re-configures the problem of disconnection, which is easily measurable by the regulators, and shifts it 'indoors' (where marginal households effectively self-disconnect themselves from the networks), rendering it invisible. There is consequently little information about the numbers of households self-disconnecting, the duration of disconnection or any means of monitoring the impact on family health and the fabric of the home.

Cherry Picking

Concurrently, there is a very different debate between utility companies about how smart metering technologies might be used to maximise commercial advantage in more lucrative markets. Smart or intelligent metering technologies are playing a central role in opening up what have previously been considered as naturally monopolistic markets to competition. While many of the significant issues have still to be resolved by the regulators and the industry, each party recognises that if the domestic market is to be opened up to full competitive pressures, new metering technologies will need to be able to control flows of utility services with an unprecedented degree of sophistication down to the level of the individual household.

Those households who can afford the initial outlay for smart metering technology, or are a lucrative enough customers for utilities to install a meter, will be able to choose from a range of different energy service packages. Even though much of the physical plant underpinning the services will be the same as the old network, open access regulations and new metering technologies will make competition possible without the huge costs and disruption of duplicating all local networks. As with the existing telecommunications market, it will be possible to choose from a range of competitor's - like British Telecom and Mercury - picking the one which offers a preferential tariff or better services.

New technical means of linking up meters - and, increasingly, other domestic technologies - to the providers of services via telecommunications are crucial here. It is this 'convergence' between telecommunications, meters, and domestic appliances of all types that is at the centre of current speculation about the 'smart home'. For example, Electronic Data Interchange (EDI) with the meter via radio, power cable, telephone or cable will create further markets in domestic energy supply. Through such 'real time' information flows, it becomes possible for competitive utility companies to monitor existing and potential customers very precisely. Data on a customers energy consumption, usual method of payments, tariff preferences and credit rating can be collected and retrieved to better inform commercial practice and to optimise the performance of the infrastructure network. Those customers who are the focus of this cherry picking process seem likely to receive new levels of service innovation, lower utility costs and enhanced responsiveness. For utilities, new metering technology will bring crucial strategic weapons in the increasingly competitive race for the most lucrative customers and enhanced profitability.

Clearly, this cherry picking process, by definition selective and precisely targeted in both social and geographical terms, will contribute to social and spatial polarisation in complimentary ways to the social dumping logic of prepayment metering. Only those utility customers who can afford the technology and/or have sufficient demand to be attractive to suppliers are likely to benefit. Of course the actual changes to day to day practices initiated by these metering systems are uncertain. Both the customer and utility will have to define for themselves how competitive markets for domestic supply might operate. Once the communications link to the household meter is in place, the utility may use it as the basis for a variety of diversified value-added services - perhaps home entertainment, a telephone or even energy management applications. Thus, smart metering technologies and the corresponding logic of cherry picking seem likely to generate increasing cross-diversification, mergers and strategic-alliances between utility companies, like those already developing in the cable TV sector. Moreover, having access to such key consumers will provide potential for further diversification into the exploding markets of cable TV, telecommunications and value added information and media services. In the long run, many lucrative spin-off services are likely to develop as energy and water utilities develop closer links with computing and telecommunications companies such as telesurveillance and security, 'smart' services such as distant control over household appliances and utilities, and teleshopping and home entertainment services.

However, social and economic polarisation is not the full story. Focusing exclusively on the socio-economic implications of the splintering process can result in an overly negative view of the impact of privatisation and liberalisation of utility networks. These concerns can mask more positive and environmentally-beneficial effects of a more competitive approach to infrastructure provision through the emergence of demand oriented management strategies.

Demand Side Management

Essential resources such as water and energy have hitherto been treated as public goods, cheaply and universally available to meet national social and economic priorities. The environmental impact of this approach to urban infrastructure provision has been profound. By prioritising network supply capacity the environmental and economic 'costs' of such expansion have been ignored and the dynamics of demand neglected. Minimising the environmental impact of energy and water supply depends upon counting the economic costs of infrastructure provision (Winpenny 1994). In turn, the management of water and electricity as economic resources relies upon technological innovation that:

- enables the introduction of tariff structures that highlight the 'costs' of resource use,
- provides detailed information to consumers on electricity and water consumption which may direct cost conscious resource use, and
- allows utilities to closely monitor network performance and changing demand characteristics in order that they may maximise operational efficiency of infrastructure systems

The technical development and implementation of sophisticated metering technologies is central to these environmental aims. Until recently, meters have played a relatively limited role in the utilities' environmental strategies. We have already seen that in the water sector domestic resource consumption is rarely metered leaving customers to pay a charge based on rateable values while in the electricity sector 'dumb' meters have simply acted as a neutral arbiter of resource consumption in terms of KWh. Costs have tended to be based on a single tariff level with metered consumption read manually. Smart metering has changed all this. Metering of individual consumption highlights the impact of resource use to consumers and provides indicators of demand to the utility. On the basis of such information consumers and utilities alike can make informed choices about resource use and provision, thereby maximising the economic efficiency of resource provision and use while minimising the environmental impact of infrastructure systems. New 'smart' meters provide more detailed/focused information on user-demand than hitherto available. For instance, in the electricity sector 'smart' metering makes it possible to map in detail the load profiles of electricity consumers against a utilities overall distribution network, allowing location of the energy impact of domestic, commercial or industrial demand in different areas, at varying times of day/night. Such a process also promotes a much deeper, 'beyond the meter', relationship with the customer, encouraging users to take a greater interest in their own energy usage by offering the possibility of switching between different tariff regimes. Similarly in the water sector metering allows utilities to more accurately assess current and future demand profiles thereby stimulating greater flexibility in the planning of water infrastructure while stimulating heightened conservation on the part of water consumers. The environmental potentials of the new metering technologies are profound, providing new environmental strategies by managing the flow of resources from utility to customer:

- Water metering trials in the UK recorded demand reductions of up to 20% per household, while US studies of the impact of variable tariffs and load control found major falls in both peak and total household energy consumption. Such initiatives can generate significant economic and environmental savings by displacing or postponing the need for new water and energy infrastructure supplies (see Rosenfield et al.1986, The National Water Metering Trials 1993).
- Customers develop new knowledge about the economic and environmental cost of resource consumption while the meter can provide feedback about the effective of household conservation and efficiency measures (see Electricity Consumers Council 1986).
- Utilities can build up detailed information about a households consumption patterns even to the degree of identifying when a particular appliance is utilised. Non-essential appliances can then be shed in real-time through remote signalling, thereby avoiding environmentally and economically expensive peaks in demand (see Adamiak et al 1990).

Appreciation of the critical role of new metering technologies in the environmental monitoring of cities has hitherto been absent from technical debate on Sustainable Cities. While many utility's commentators have noted the environmental opportunities arising from the development of 'smart' metering few have identified the environmental risks of simply abandoning control of the technical parameters governing the implementation and use of metering to commercial competition (Marvin 1994b).

5. Conclusions

Examining recent changes in the application of meters provides an important window onto the broader processes of utility restructuring in the late 1990s. It allows us to begin understanding the complex social and geographical implications of this restructuring. In this working paper we have briefly outlined the issues and debates currently shaping the development, implementation and use of smart metering technologies. As we have illustrated, it is a messy business. Such technological innovation cannot be viewed as in any way seamless. Following the threads of the metering revolution does not correspond to unravelling a pure techno-economic logic. Instead, a highly variable social and economic utility landscape, a volatile marketplace and rival technological systems, together with competing meter manufacturers and telecom providers, regulators, utility companies and user groups with differing aims and objectives - makes up the changing map of metering innovation. Social, technical and physical factors alike are mutually shaping the emergence of new utility metering technologies. Such complexity cannot be usefully captured through conventional technical and economic understandings of technological innovation in general or the utility business in particular. A more synthetic approach is necessary.

Thinking about Smart Meters

> Technology does not spring, ab initio, from some disinterested fount of innovation. Rather it is born of the social, the economic, and the technical relations that are already in place. A product of the existing structure of opportunities and constraints, it extends, shaped, reworks, or reproduces that structure in ways that are more or less unpredictable. And, in doing so, it distributes, or redistributes, opportunities and constraints equally or unequally, fairly or unfairly (Bijker & Law 1992, p11).

The metering revolution is being driven by a complex mix of technical, regulatory and commercial innovations. Privatisation and liberalisation of utility markets, regulated pricing structures, aggressive marketing strategies, more demand oriented network management initiatives and wider consumer choice all provide the context for the development and application of new metering technologies, which in turn facilitate further regulatory and commercial innovation. Mapping and analysing the likely implications of such a process therefore demands an analytical approach which recognises the ways in which technological artefacts and social processes mutually shape each other. Such studies of socio-technical change are now finding a collective home as the sociology of science and technology (see Bijker, Hughes & Pinch 1987, Bijker & Law 1992). Common features of socio-technical studies include avoidance of individualist explanations of technological innovation (the genius inventor), moving away from any form of technological determinism (the loom as handmaiden to the industrial revolution), and critically, a refusal to distinguish between technical, social, economic and political aspects of technological development. As Thomas Hughes has graphically illustrated, in understanding the development of technological systems "sociological, techno-scientific and economic analyses are permanently woven together in seamless web" (Hughes, 1983). In this world without seams, both social institutions and technical artefacts can be understood as 'actors' who actively fashion their world, constantly re-shaping contexts of socio-technical interaction. For example, in following the development of a prototype electric (VEL) car in France Michel Callon (Callon 1987) does not distinguish the "animate from the inanimate, individuals from organisations".

> Callon's actors include electrons, catalysts, accumulators, users, researchers, manufacturers, and ministerial departments defining and enforcing regulations affecting technology. These and many other actors interact through networks to create a coherent actor world (Bijker, Hughes & Pinch, 1987, p.3).

In his study Callon neatly demonstrates how a 'network' is dynamically created between these heterogeneous 'actors' in order to produce a vision of a technically and commercially feasible electric car. The development of powerful electrochemical batteries, a growing markets of users tired of the polluting effects of petrochemical motors, a consortium of potential manufacturers keen to tap a lucrative future market and government departments keen to reduce noise pollution are all inextricable linked by the engineers of the French electricity company EDF in their effort to create a new market. As Callon puts it:

> None of these ingredients can be placed in a hierarchy or distinguished according to its nature. The activist in favour of public transport is just as important as a lead accumulator which can be recharged several hundred times (Callon, 1987, p.86).

In this way he presents an analysis of technical innovation based less upon technical description and more on a specific mode of social organisation in which technical artefacts are shaped by social and regulatory processes, <u>but</u> which in turn reshape the social contexts in which they are developed. However, as Law and Callon point out, "it is too simple to say that context influences, and is simultaneously influenced by, content" (Law & Callon, 1992, p.21). Rather, we must seek to explain the coevolution of technological artefacts and social institutions as socio-technical processes with no 'inside' (consistent, immutable technical properties) and no 'outside' (purely contingent social influences). Law and Callon proceed by making a distinction between local and global networks. The "local network" comprised of the heterogeneous "bits and pieces" necessary to the production of a technical artefact, while the "global network" is a dynamic social, regulatory and commercial network "that generates a space, a period of time, and a set of resources in which innovation may take place (Law & Callon, 1992, p.21). In this way:

> The notions of context and content that are used as common analytical devices in the sociology of science and technology may be transcended if projects are treated as balancing acts in which heterogeneous elements from both 'inside' and 'outside' the project are juxtaposed (Law & Callon, 1992, p.22).

Transactions between local and global networks are mediated through some form of "obligatory passage point" which may be an individual such as a deal making entrepreneur, an organisation which controls the operation of a whole industry, or even a technical artefact such as a hydraulic door - which extracts energy from each passer-by in order to restrain the process of closure (Latour 1992, p.234).

As we suggested in our introduction, we believe that the utility meter can be understood as just such an obligatory passage point. On one side of the meter we have the global network, the infrastructure network made up of competing utility companies, regulators, relevant government departments, social and consumer groups. Each of these actors is shaping the new world of privatised utility provision which makes up the context in which local networks of meter manufacturers, telecoms providers and different user groups fashion the development, implementation and use of new metering technologies. But to reiterate, this is a two-way process.

At the same time as new modes of infrastructure management (the global network) creates the space for the production of smart meters, new forms of metering (the local network) facilitate the emergence of new logic's of utility provision (so reshaping the global network). Not that the balancing of these two networks is any way inevitable. This is a dynamic and inherently unstable process. As we have pointed out above, each of the 'actor' groups is currently striving to shape these networks according to their own priorities. That is, each seeks to stabilise the local network, (by defining the technical development pathway which best suits their aspirations), in order to better shape the global network. For example, the utility companies hope to find a technical development pathway which will make their business more profitable. This means they will finally choose a metering system with the appropriate levels of functionality and communications scope to allow them to both cherry pick lucrative customers and pursue smart network control. They may be less concerned to pick a system that facilitates environmental sensitivity without marginalising the utility poor. In this way the utility companies will try and install particular kinds of metering systems which 'lock' customers (and meter manufacturers, telecom providers etc. - i.e. the local network) into global networks of control aimed at enhancing profitability.

The goal of a socio-technical study of the development, implementation and use of smart metering systems is then to trace the building of both local and global networks around specific metering systems, highlighting the social, economic and environmental implications of particular forms of network closure.

New Research Directions

> Dedicated to understanding the working of actor networks, whose analysis is yet to be done, sociology will henceforth find itself on new terrain: that of society in the making (Callon 1987, p.100).

We would argue that at present there is not nearly enough scrutiny over, debate about, or regulation of the application of new metering technologies. Smart and pre-payment meters are being developed and implemented guided only by a narrow set of commercial imperatives shared by the utility companies, with little attention to the broader social, economic and environmental implications of such innovation. We believe there is an urgent need to start developing a more sociological assessment of the political, economic, civil liberties and equity issues being raised before the metering revolution stabilises along particular development pathways:

Firstly, there is the question of how will utilities respond to pressures from regulators to fit a new metering infrastructure? The RECs have now accepted the OFFER instruction to develop a smart metering infrastructure to open up the domestic market to competition and they are currently collaborating with meter manufacturers and communications companies to evaluate the technological and commercial feasibility of particular systems. Water companies are pursuing similar forms of smart metering demonstration projects but are concurrently fitting simple meters to new properties and retrospectively to those customers who request them. To date most water companies have now backed a way from the full commitment to water metering being sought by OFWAT. There is thus considerable uncertainty and diversity in utility responses to regulatory guidance on new metering systems across all sectors.

Secondly, a central issue concerns the type of communications media which will be utilised by the smart meter. Most existing domestic electricity meters, and what water meters exist, are at present physically visited by a meter reader. In the future, smart meters will rely on some form of communications media - either based on the telephone, radio, mainsbourne or some combination of each method. There are important technological debates about the effectiveness, reliability and capacity of each of these methods together with the question of whether utilities opt for one or two way communication, in real or delayed time. These technological choices will fundamentally shape the socio-environmental profile of the meter.

Thirdly, there is the question of meter functionality. While such choices will be closely related to the communications media chosen, the utilities will have to make specific decisions about the level of functionality - remote meter reading, remote disconnection, load surveys, appliance control etc. - that they desire from a smart metering system. The technological capabilities of different systems together with the scope of the communications device could restrict levels of functionality and thus limiting the positive societal potential of the meter.

Fourthly, relations between customers and utilities are being restructured by three forms of innovation, cherry picking, social dumping and demand side management. Each of these forms of development has important implications for different types of interaction between customers and meters. However, estimations of the potential of new metering technologies embody powerful assumptions about how customers will respond to the installation of smart meters.

Finally, the socio-environmental benefits of the meter will only be enjoyed if the utilities in both the water and energy sectors are given regulatory incentives which provide a commercial logic for the company to help customers improve the efficiency of resource use and even consider resource conservation. These decisions will be powerfully shaped by the availability, capabilities, costs of and economic returns of smart metering systems. Consequently, the environmental potentials of the meter depend on a complex mix of technological and economic factors.

Given the high levels of uncertainty, degree of technological choices and conflicting social, economic and environmental objectives it is necessary to highlight the technological development pathway that best exploits the positive technological potential of the meter. Without informed guidelines, it is likely that a complex patchwork of differing, and perhaps incompatible, metering systems will develop across water and energy sectors and between utility companies, meaning that one city may have a system that enables it to keep a downward pressure on water and energy consumption while a neighbouring city may have an entirely different system. There are 3 principal research objectives for the study of science, technology and society:

- Identify the institutions, agencies and specific technologies involved in the development of smart meters (i.e. the 'actors'), assessing individual commercial/regulatory aims and consequent technical objectives of each professional grouping, and the range of functionality and scope of communications media inherent in new meter technologies.
- Trace the full range of development pathways of metering technologies in water and energy sectors (i.e. the building of local networks), highlighting the priorities guiding the creation of each local network and the social, economic and environmental implications of each technical route.

- Produce recommendations for public policy, regulatory and commercial institutions for the co-ordination of development, implementation and use of metering technologies (i.e. the framing of global networks) to minimise social disenfranchisement while maximising economic and environmental benefits.

There are vital methodological issues at stake here. Bridging the theoretical gap between the social and technical features of technological innovation demands a more collaborative research agenda. Rather than relying on familiar research tools, surveys, opinion polls, statistical analysis etc. we need to start "peering over the shoulder" of the actors that make up the networks we are studying, to "follow innovators in their investigations and projects" (Callon 1987, p.98). For to transform academic sociology

> into a sociology capable of following technology throughout its elaboration means recognising that its proper object of study is neither society itself nor so called social relationships but the very actor networks that simultaneously give rise to society and to technology (Callon 1987, p.99).

New research should therefore be developed in collaboration with both the key players involved in the implementation and use of meters and the regulatory and policy offices responsible for setting the frameworks within which utilities operate. Projects should be designed to provide information and understanding which is vital to the development work of each of these beneficiaries. The resulting analysis could provide public policy- makers, regulators, private utility companies and consumer groups with a detailed technical map of the social, economic and environmental opportunities and constraints implicit in different development pathways for metering technologies. In this way social scientists could link the development of new metering technology with wider issues currently shaping energy and environmental policy. Given the pace of development of metering technologies over the coming years such research, is both timely and urgent[10].

10 See appendix 1 for a summary of a Centre for Urban Technology (CUT) project which explores these issues. Further details upon application to Simon Guy or Simon Marvin.

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Draft Figures

Figure 1 Utilities and Metering

Sector	Structure	Domestic customers	Metering Issues
Water	30 water companies	19 million connected to mains water. 94% households.	Debate about need for metering after year 2000
Gas	British Gas	17 million connected to mains. 80% households.	Not clear what role meterin will play in competitive markets in 1998
Electricity	12 Regional Electricity Companies	22 million connected to mains 99.5% Households.	Type of metering system ir 1998

Figure 3 Communicating with the Meter

Communications System	Provider	Advantages	Disadvantages
Power Line Carrier	Regional Electricity Company	REC owns network.	Reliability. Access. Additional comms.
Radio	Proprietary. 3rd party.	Reliable.	Cost.
Telephone	BT, Mercury, Cable Companies		
Smart card/token			

Figure 4 The Regulators and Metering

Regulator	Role Meter	Requirement	Technology
OFWAT	Water charges	Advice	Any
OFGAS	??	??	
OFFER	Choice supplier	Compulsory	Integrated

Figure 5 Re configuring Customers

Issue	Social Dumping	Cherry Picking
Access to the Meter	Dependent on utility policy Costs higher than ordinary meter, Prepayment	Customer choice. Ability to Pay. Credit terms.
Change in Behaviour	Manage access to services - through self disconnection and rationing, Additional Prepayment services.	Respond to price signals & information. Cost savings. Added Value Services.
Meter in Control	Programmed debt repayment.	Load & appliance control.

Figure ? Functionality of Integrated Meters

multiple tariffs

detection of fraud

programming of meter

meter reading

real time pricing

spot pricing

load surveys

debt repayment

The gas sector has a different attitude to prepayment meters. Since 1986 British Gas has wanted to phase out prepayment meters, only installing them in very special circumstances. However, the Gas Consumers Council regarded prepayment as vital, and advocate token meters. With the support of the Office of Gas Services (OFGAS), British Gas has now decided to offer prepayment services (Law et al 1990 p.4). In doing so the gas industry has developed a national standard - the Quantum prepayment meter - using a smart card with 6,000 charging outlets available. 50,000 of these meters will be in operation by end of 1992, and from 1993 a further 20,000 per month have been installed.

that the development of integrated metering technologies will produce major benefits for the customer in the form of automatic meter reading, more information about levels of consumption and charges and the ability to choose their own supplier together with the provision of "a new range of services and facilities" (OFFER, 1992, p.6). Improvements to the operation of utility company's include improved cash flow, more efficient system management, better financial management, prepayment metering, reduced meter interference and damage and significant new business opportunities.

Evidence from abroad seems to favour this position. In continental Europe, most water supply is metered and customers pay for their water on a volume basis (POST, 1993, p45). Studies from abroad highlight the demand management potential of metering water resources. In Denmark studies have suggested average reductions in consumption of between 20 and 50% due to metering (POST, 1993, p46). While per capita consumption in Denmark is higher than in the UK., 190 litres/day as compared to 136 litres/day, leading to enhanced savings, the environmental benefits to be reaped by metering British water are clear. Much of the debate over water metering in the British domestic sector has revolved around trials on the Isle of Wight. Here, a comparison over 3 years of metering in different areas occupied by different incomes groups highlighted potential savings of around 10% - 20%.

There are even proejcts extsnding the scope of prepayment systems such as British Gas using Quantum system for other service providers - PaySmart allows "genuine hardship customers to make small payments towards their TV licenses". Despite the potneital