Subtask 1
Smaller Customer Energy Saving by End Use Monitoring and Feedback

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EXECUTIVE SUMMARY

Smaller Customer Energy Saving by End Use Monitoring and Feedback

Background

Energy plays a central role in each of the everyday lives of residential and small business customers but our use of energy impacts our environment and contributes to global warming. Total energy consumption in the EU is approximately 20% higher than can be justified on purely economic grounds. Energy saving regulations and measures have been put in place in developed countries to assist the more effective use of energy in houses and small businesses. Savings are achieved from increasing the propensity of customer to purchase energy efficient end uses and also changing their behaviour so as to reduce thermostat settings and use hot water and lighting more wisely. One of the ways in which customer motivation to save energy can be developed is by identifying and presenting to customers, a breakdown of their individual end uses of energy, its cost and environmental impact (End Use Monitoring and Feedback, EUMF). In order to be effective, presentation of end use information needs to be made in ways which are not too intrusive for customers yet have a powerful impact at the right time.

Objectives

The objective of the study is to quantify what work has been carried out in participating countries on the topics of providing energy end use feedback for smaller customers. The task is to determine how successful it has been, what further measures can be implemented and whether disaggregation and feedback have a viable role to play in current thinking for energy saving. It is also to quantify the degree of disaggregation and feedback needed to motivate end use behaviour changes and whether the feedback needs to be automatically implemented with customers having override possibilities.

Approach

The study has analysed work carried out and results of trials involving real customers in order to quantify customer responses to end use energy saving motivators. It has also assessed the impacts on customer responses and energy saving of different levels of end use demand disaggregation and the way the information is presented.

Disaggregating energy end use into its constituent parts is difficult to carry out at low cost. Many techniques and methods have been analysed to assess their suitability as energy saving motivators.

Methods for applying EUMF as a cost effective and continuous methodology for motivating end use energy savings have been quantified using different levels of end use data disaggregation and presentation.

Results

Feeding back disaggregated energy end use information to smaller customers using a range of methodologies has been shown to motivate energy savings of the order of 10%. A survey in one country showed that 70% of smaller customers were prepared to make changes to save energy if they were advised how to do it and it involved little inconvenience. Monetary savings resulting from the application of EUMF to direct electric heating customers have been estimated to be worth 100 Euro per year per customer. Direct measurement of specific customer, end uses of energy on a continuous basis is probably too expensive for wide scale application to smaller customers. Estimates of the costs of face to face and Internet interviews with customers to collect data and feedback end use information and advice show this to be an attractive option. EUMF motivator messages have also been shown to encourage customers to replace energy inefficient end uses with efficient ones.

Implications

End use disaggregated energy data statistics which are available now for national populations in many countries should be added to smaller customer energy bills. This will help prepare customers for more detailed measures in future and start the education process of making customers more aware of end use energy costs and environmental impacts.

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1 BACKGROUND

Energy plays a central role in each of our everyday lives. We use electricity for lighting our homes and offices, for powering our fridges, ovens, televisions and computers. For most of the time we do not even think about it, it is simply there to enable us to carry on with our normal activities. However, our use of energy impacts on our environment and contributes to global warming.

The promotion of energy end use efficiency and conservation are regarded as necessary instruments to complement efficiency improvements on the supply side in the internal energy market in the EU.

It is estimated that, due to market barriers and imperfections, there is a large economic potential that remains to be earned in the EU in the form of unrealised energy savings. For industry this potential is estimated to be 17% of current final consumption, realisable by 2010. For the domestic and tertiary sector, it is 22%.

Energy savings impact positively on EU competitiveness by reducing costs and improving effectiveness and creating added value products for the home and export markets. In addition, employment has been calculated to increase measurably. The trade balance would also improve due to reduced energy imports, a factor working to prevent the increase in energy import dependency, which is 50% today.

Energy saving regulations and measures have been put in place in developed countries to assist the more effective use of energy in houses and small businesses. These measures include improved thermal performance of building structures through building regulations and retro fit insulation measures. They also include regulations to improve the efficiency of end use applications such as white and brown goods and in the use of standby power. Increased efforts are and will be made over the long term to improve the effectiveness of all of these activities. However, the situation is one of diminishing returns which requires greater and greater efforts and technology advances in order to achieve the same incremental improvements in energy savings.

In conjunction with these measures are promotional campaigns to encourage customers to replace inefficient appliances with more efficient versions, improve building thermal performance and install energy efficient lighting etc. These promotional measures are aimed at changing customer behaviour in terms of their spending priorities. Savings are achieved from increasing the propensity of customers to purchase energy efficient end uses and also changing their behaviour so as to reduce thermostat settings and use hot water and lighting more wisely.

A large part of the available energy savings potential that exists in the EU today for smaller customers can be realised by developing a market for energy services and other energy end use efficiency and conservation measures.

Many countries support municipal energy advisors that provide give free independent advice to customers and small companies in order to stimulate efficient use of energy and environmentally sound sources of energy.

Energy services include energy efficiency measures and the provision of information, guidance and evaluation. These measures often include energy audits, informative billing, etc. and include a strong element of energy-efficient end use technology and the necessary cost justification. Other measures to improve energy efficiency, such as efficient lighting, control systems and boiler replacement, can be combined as a service with the delivery of energy.

One of the main mechanisms to promote energy services is by supporting and accelerating the development of smooth functioning, commercially viable and competitive markets for providing cost effective energy efficiency.

One of the ways in which customer motivation to save energy can be developed is by identifying and presenting to customers, a breakdown of their individual end uses of energy, its cost and environmental impact (End Use Monitoring and Feedback EUMF). Feedback of end use energy consumption data to customers and their energy management systems can help in reducing energy consumption and also in moving elements of demand to lower cost periods. Studies have shown that presenting end use of energy provides a motivator to modify customer behaviour to reduce energy use and achieve cost saving from the most expensive uses. Studies have also shown that providing customers with more frequent billing can achieve part of this motivation because it is then easier for them to link the bill to energy use for applications such as space heating in colder periods.

Processes of EUMF operate by providing customers with a breakdown of their consumption and the cost and environmental impact of individual, everyday functions and services which they use. They also allow any significant changes customers make in their energy consumption and use pattern to be fed back to them so that they can see the results and value of their efforts. This end use feedback service is accompanied by promotional campaigns detailing the environmental benefits of saving energy. Energy audits and appliance diagnostics and monitoring are accompanying services which can assist energy savings. These services provide peer to peer and year on year comparison advice to customers and can identify faulty end use applications such as refrigerator thermostat permanently “on”. However, these activities require considerable data collection together with energy use corrections to take account of climate and temperature variations and other lifestyle factors.

End use information presentation can motivate customers to purchase more energy efficient appliances and applications. However, these activities require the customer to be receptive to saving energy and be prepared to modify their financial priority behaviour. These characteristics can be developed through well-targeted marketing campaigns which position customers as participating in saving the environment as well as cost saving actions. However, it is likely that energy saving campaigns will need to be a continuous activity in order to prevent initial gains from EUMF being lost due to apathy.

Government and regulatory measures are significantly directed at increasing the efficiency of energy end use applications. However, providing regulations that remove energy inefficient applications from the market is the relatively easy part of the process. Motivating customers to buy them is more difficult based on the potential financial savings. When new applications are required by customers due to the failure of existing ones or because they require a new appliance, customers will by exclusion, purchase a relatively energy efficient one. However, because many appliances have lifetimes of many years, persuading customers to replace inefficient ones which are still operational is much more difficult. The appliance purchase process is similar to that for providing energy saving insulation for walls and windows and for reducing thermostat settings. Consequently there is a marketing and information process needed in support of EUMF that draws the attention of customers to focus more on the value and need to energy audit.

In order to be effective, presentation of end use information needs to be made in ways which are not too intrusive for customers yet have a powerful impact at the right time. Associating energy saving motivators with the energy bill is likely to be effective for achieving impact although there probably also needs to be low level continuous motivators such as via advertising and promotions.

This study and report, which has been completed by six participating countries within Task XI of the IEA DSM Agreement analyses what has been carried out using elements of EUMF, the achievements realised and its viability for wide scale application.

The objective of the study is to quantify what work has been carried out in participating countries on the topics of providing energy end use saving motivators for smaller customers, how successful they have been, what further measures can be implemented and whether they have an economic role to play in current thinking for energy saving. It is also to quantify the degree of disaggregation and feedback needed to motivate end use behaviour changes and whether the motivators need to be automatically implemented with customers having override possibilities.

2 ENERGY SAVING AND EUMF

2.1 Potential for Energy Saving

Total energy consumption in the EU is approximately 20% higher than can be justified on purely economic grounds. Estimates in a SAVE study showed that energy efficiency measures and demand side management services can easily realise 75% of these cost effective savings, i.e. 15% in the medium term (10-15 years). The study also concluded that an accumulative target of 1% a year for improvements due to energy efficiency and energy services is a realistic minimum level for the EU as a whole and for individual Member States.

Without significantly changing comfort levels or standards of living, it is considered possible to reduce energy consumption by at least 20% at no extra net cost. In many cases the costs would be negative because the saved energy is sufficiently valuable to repay the cost of investment well within the technical lifetime of the investment and also cover interest charges. Today the savings of 20%, were it to be calculated in terms of primary consumption, would correspond to over 8,400 PJ/year, or 200 million tonnes of oil per year. It is estimated that the duration of the impact of efficiency measures is on average 8 to 10 years, with the impact of some measures longer.

It is estimated today that the average cost in many Member States of saving a unit of (off-peak) electricity in the domestic sector is around 2.6 Euro cents/kWh, compared to the average (off-peak) price for delivered electricity of 3.9 Euro cents.

Provision of energy saving information is significantly driven by energy suppliers in some countries, whose actions in turn are driven by either the need to gain competitive advantage or to conform to regulatory requirements.

Under current requirements, as stipulated in their licence conditions, suppliers in the UK are only required to read electricity meters once every two years. Thus, there is currently no clear economic advantage for them to use smart meters with remote meter reading capability. However, it is believed that if suppliers were required to provide accurate bills on a quarterly basis, then remote meter reading would be more economical. This would then 'open the door' for the introduction of smart meters with additional functionality such as time of use and customer displays.

In Sweden meters of profiled customers have to be read once a year. It has been decided that by July 1, 2009 meters will have to be read monthly. According to the investigation that preceded the decision, quarterly meter reading would not give the intended benefits. One important goal is to achieve accurate billing. Savings of 1 – 3 % of small customers energy use is expected from the new billing system, the higher figures if customers are supplied with statistics. Another goal is to further the use of remote meter reading. In order to encourage demand flexibility, the limit above which hourly metering is required will be lowered from 200 A/135 kW to 63 A by July 1, 2006.

Monthly meter reading will also make prices that follow wholesale prices on a monthly basis more interesting for customers and also encourage them to explore the possibilities for substitutes to electric space heating during high price periods. It is expected that many customers will be hourly metered which created the opportunity for new pricing products that could promote customer flexibility.

The requirement for accurate billing based on timely meter reads is a topic addressed in the EU Energy Services Directive, which is due to be transposed in each Member State's national law by 1 June 2006. In relation to metering and billing, the Directive states that:

- end-use customers must be provided with competitively price individual meters that accurately reflect the customer's actual energy consumption and time of use;

- billing reflects actual consumption in understandable terms; meter reads carried out frequently enough to customers to regulate their own energy consumption; and

- via bills and promotional materials, the following information should be available to customers:

  - current actual prices, and where appropriate, actual consumption;
  - where appropriate, comparison of the customer's current energy consumption with the same period last year, in graphical form;
  - comparison with an average normalised benchmark use for energy for the peer group and the environmental impact, such as CO_2, of energy distributed or sold for consumption.

2.2 Household Energy Saving Status, Policy and Regulation in participating countries

The political, environmental and customer awareness climate for saving energy at the smaller customer level is significantly different in countries participating in this project.

In order to understand the background against which end use of energy savings can be developed, it is useful to consider the changes in energy end use in domestic premises which have taken place over the past decade and longer. Figures available from the UK have been used to illustrate these changes, many of which are similar in principle in other developed countries.

- There are currently no regulations in place in the UK that require the collection of disaggregated end use of energy in households. Building Regulations set down requirements to collect end use of energy information for buildings other than households.

- Energy consumption in the domestic sector rose 19% between 1990 and 2001.

- Improvements in insulation and heating efficiencies between 1990 and 2000 mean that energy use for space heating was 26% lower than it would have been without the improvements.

- Average temperatures inside domestic dwellings increased from 16½° in 1991 to 18° in 2000.

- In 1996, 19% of dwellings were flats. Dwellings that are occupied by their owners use up to 60% more energy than rented dwellings.

- The average external temperature was 5.8°C in 1970; it had risen to 7.2°C by 2000.

- More households have central heating which has made internal temperatures easier to manage.

- In the domestic sector space heating accounted for 58% of energy consumed in 2000.

- Between 1970 and 2000, energy consumption in lighting and appliances increased by 157%, while energy use for cooking fell by 16%. The fall in energy consumption in cooking is explained by a change in lifestyle, more convenience foods being consumed and people eating out more.

- Energy efficient light bulbs in the early 1980's have led to energy savings; sales were over 4 million in 1999.

- Energy used by appliances has increased by 9% since 1990, due to increases in the total number of appliances bought as well as the increase in the number of households.

- Net national disposable income has increased by 30% since 1990. The higher the income, the higher the level of appliances owned by households. In 2000, 45% of households with a gross weekly income of over £500 owned a dishwasher, compared with only 12% of households with an income of £100 or less.

- In 2000, 72% of all houses had some loft insulation, 19% had some form of cavity wall insulation (cavity wall dwellings account for 69% of the housing stock with the remainder being largely accounted for by solid wall dwellings), 39% of houses had more than 80% of their windows double glazed and most houses with hot water tanks had hot water tank insulation.

In February 2003, the Government published its Energy White Paper which set out the long-term strategy for delivering the UK's energy policy goals. The Paper established the Government's intention to reduce carbon dioxide emissions by 60% from current levels by 2050. It recognised that a fundamental shift in the way energy is supplied and used is required in order to meet this target, which represents a significant departure from the emissions that would otherwise occur under a 'business as usual' scenario. Energy efficiency is seen as a priority area with regards to meeting emissions reduction targets. The current Climate Change programme sets a target of 10MtC reduction by 2010, with over half the reductions expected to come from the smaller customer sector, and a further 4–6 MtC is expected to be provided by this sector by 2020. The paper highlights energy services as a means of encouraging energy use improvements.

Under the Energy Efficiency Commitments (EEC), energy suppliers can receive a 50% support for energy efficiency measures promoted through energy service activities, limited to 10% of the suppliers EEC target. However, there is some reluctance by suppliers to pursue energy service contracts with smaller customers, with the main obstacle cited as customer churn. UK regulator, Ofgem, has begun consultation to establish a trial where suppliers will be able to lock in customers for up to five years provided that the package includes the installation of substantial energy efficiency measures that reduce the household's energy demand by at least 15%. The trial, which will run for a period of two years, will be restricted to 4% of a supplier's smaller customer base (or 50,000 customers if this is larger).

In Denmark energy conservation and saving of electricity have been dominant themes in energy policy for the last 30 years and have remained so during liberalisation of the electricity market.

The legal basis for Electricity savings in Denmark is law No 375 and its associated promotion of electricity savings in the electricity supply industry. The grid companies are obliged to provide information, advice and instruction to customers on energy savings. This is done by providing information and by mapping electricity consumption and savings against benchmarks. Both industrial and the domestic sectors are targeted. To fulfil this obligation, grid companies establish campaigns promoting energy efficiency and provide free of charge energy counselling. These activities are paid for through the electricity price. The DSM effort for the domestic sector is of the order of 10 million Euro per year. The estimated energy saving as a result of this is 45 GWh for the first year. The total expenditure, including the industrial sector is 25 million Euro per year, leading to a saving of 150 GWh in the first year, equivalent to a reduction in emissions of CO_2 of 140.000 tons. Campaigns and other nation-wide activities established by the grid companies are co-ordinated and managed through the utility companies' organisation ELFOR.

As well as establishing a legislative basis for DSM activities, the ministry has established an independent organisation, The Danish Electricity Saving Trust (Elsparefonden). This organisation is financed through the electricity price with the task of providing financial support to anyone, who wishes to substitute electric heating with other heating means, preferably natural gas or district heating.

Denmark has no direct requirement to carry out analysis of the end uses of individual customer appliances or processes. Specific campaigns are however launched on the basis of investigations of specific types of consumption, for example, ventilation, stand-by consumption, motors, etc. A vital source of information for this is the disaggregated energy use sample data collected and combined in a model of electricity consumption in the residential sector called "Elmodel bolig". This model contains comprehensive and detailed information of the consumption pattern and characteristics of appliances used in the domestic sector, their abundance and pattern of use.

The attitude in taken in general by the ministry that saving energy (electricity) is the main issue in the smaller customer sector. If that can be followed and promoted by saving money for the customer, this is valuable, but not the most important objective.

In Netherlands there is no statutory or regulatory requirement nor foreseen requirement to collect and feed back disaggregated energy use data to smaller customers.

The Ministry of Economic Affairs has invited the Dutch Normalisation organisation NEN, the National Metrologic Institute NMI and Dutch Energy organisation ENERGIENED to evaluate the feasibility of "Intelligent Metering" for households. Motivation for this discussion is a forecast possibility of black-outs in the Netherlands within a time scale of 5 years. This expectation is based on a study by the Ministry and caused by the annual increase in national electricity consumption without sufficient increase in power production capacity.

In the Netherlands, ONS Energie Services plans to act as a market player for delivering energy use savings for smaller customers: the *Billing structure and energy experiment*. The tools for realising the energy savings are a changed billing structure and financial incentives. A trial of 400 customers is being carried out to understand customer reactions to increased billing information.

Energy awareness and familiarisation with energy matters is not high on the agenda of customers in Greece. The way cities are organised and the daily routine and way of life do not in general favour the rational use of energy. Taking into consideration the development of energy use in other Mediterranean countries, it is concluded that the increase in energy consumption in Greece will be slower in future because serious effort is now being undertaken in energy conservation and the application of energy efficient technologies. Measures are being put in place that provoke awareness and familiarisation of energy matters which have the goal of creating a socially oriented conscience among customers.

In Greece, approximately 800,000 households are equipped with solar water-heaters. The 2.5 million square meters of installed collectors which operate in Greece save more than 1.3 million MWh per annum, reducing CO_2 emissions by 1.6 million tones per annum.

In the domestic sector, 20% of the 4 million households use solar systems to produce hot water. The rest use mainly electric water-heaters.

It is estimated that if the right measures were taken for the promotion of solar energy, by 2010, more than 5 million square metres of solar collectors could be installed in the smaller customer sector.

In Finland legislation and regulatory organisations do not have specific targets for energy saving. The electricity market act requires companies to promote effective and economic use of electricity.

The Ministry of Trade and Industry has established a working group to develop energy consumption legislation. Communication with and education of customers to achieve energy saving is considered important by energy companies and requires them to provide periodic feedback of energy consumption compared to suitable reference groups or previous consumption. Companies are also required to provide information about energy saving possibilities, means and implementation methods.

In Sweden energy saving and environmental concerns have been a priority part of energy policy since the first oil crisis during the early 1970-s. Initially, the top priority was to lower the dependency on oil. This has greatly been achieved with the exception of traffic. Two tendencies supported this shift. One was the shift from oil to electricity, the other was the expansion of district heating, increasingly powered with bio fuels. Single family houses are mainly heated with electricity. Efficient buildings are therefore one of the most important ways to reduce electricity consumption. Building regulations and campaigns have contributed to a high level of insulation.

The Swedish Energy Agency has also been active in the development of and providing information about energy efficient refrigerators, freezers and other household equipment. The Agency supports municipal energy advisors that give free independent advice to customers and small companies in order to stimulate efficient use of energy and use environmentally sound sources of energy. The advice is adapted to local conditions but does not for instance include audits of customer houses. According to a survey conducted 2004 on behalf of the Energy Agency, more than half the population knew about the advisors, and out of the respondents who had made energy saving investments many said that the advisors had made a significant contribution. As much as 26% of households said that they had made energy saving investments the previous year.

2.3 Smaller Customer Energy Saving Motivation

All the energy saving programmes in place in participating countries require customers to be motivated to voluntarily include energy use saving in their decision making. At present, except perhaps in Denmark, customers regard energy saving issues as minor factors in behaviour and purchase decisions. In order to raise awareness of the use of energy and its environmental impact higher up the agenda for smaller customers, major marketing and the provision of more and better information are needed.

Most smaller customers in Finland consider energy saving in principle to be important. From a customer point of view, the most reliable source of information for energy saving comes from energy companies; next comes advice organisations and the mass media. Means of disseminating information have been examined with feedback on consumption shown to be undeniably useful. Energy labels, education at schools, computer programmes and housing fairs are also regarded as valuable.

In Sweden, customer interest in energy savings is mainly concerned with the cost of heating single family houses. A number of programs have given economic support to the financing of retrofit insulation, efficient windows, heat pumps and conversion to district heating where applicable. Most households try to wait until the dishwasher or clothes washer can be run full. This is mainly a question of attitude. Campaigns in order to make people reduce the use of stand by mode in TV-sets, computers and so on have not been very successful. Here the only viable way is through better products.

In the UK, the provision of bills based on estimated meter readings and the lack of information such as annual energy consumption on bills are basic first issues that need to be addressed as a means of motivating customers to modify their behaviour. The UK energy regulator (Ofgem) recognises the importance of providing better information for smaller customers. In a recent report, the reasons why customers are reluctant or unwilling to change supplier, even though this would lead to reduced energy costs, are reviewed. The main obstacle is the lack of information, and Ofgem considers that “informed customers are a pre-requisite for the efficient operation of competitive markets”. The problems associated with inaccurate and/or estimated meter reads is cited as a major influence on customer behaviour. *Energywatch*, the independent watchdog for gas and electricity customers considers that “bills are so complicated or inaccurate that many customers do not know what they are consuming and at what price. Research commissioned by Ofgem identified customer preferences for and against a range of feedback information, including:

- a general dislike of comparison of overall household consumption against national averages or other homes

- a strong preference for simple bar charts on bills to compare energy use in the most recent quarter with either the same quarter the previous year or the whole of that year

- an interest in receiving feedback as part of an annual or bi-annual energy report

- given the right feedback, customers would examine the reasons for changes in consumption and may take action to reduce it

Feeding back information to customers on why they should save energy formed part of the INDEL study carried out in Spain which resulted in the following observations:-

- Customers who are already interested in energy saving agree and support programmes to reduce end use of energy

- Customers (79% of cases) are more motivated by environmental protection than price as long as the measures they are expected to take do not significantly influence their comfort

- Many customers are already taking measures to save energy because the price of energy for smaller customers compared with industrial customers in Spain is the highest in Europe.

The presentation of disaggregated end use of energy bills would make a major contribution in assisting customers understand energy end use costs, environmental impact and help motivate them to try and achieve saving. If presented on a frequent basis, disaggregated energy end use can also show what the impact has been of any energy saving actions carried out. However, the cost-effective collection and presentation of disaggregated energy use information for smaller customers is a serious technical and economic challenge.

Many different approaches have been studied in many countries for disaggregating end use energy demand. These include :-

- Thermal modelling of buildings linked to behaviour studies of occupation and ownership of appliances, etc.

- Sub metering of major end use loads

- Non-intrusive monitoring of specific loads through energy use and power signature analysis and correlation

- Face to face interviews between customers and energy advisors and Internet based data collection regarding lifestyle and end uses

3 ENERGY END USE FEEDBACK TO MOTIVATE ENERGY SAVING

3.1 Engaging Customers

Engaging smaller customers in energy saving measures in response to promotional forces and signals requires a combination of technical and marketing drivers. Nearly all energy saving actions implemented by smaller customers incur some minor inconvenience or negative impact on their lifestyles. A major difficulty in motivating changes in their end use behaviour is a lack of understanding of the end uses of energy at individual customer premises. Another factor is a lack of understanding of the potential for change in end use behaviour in response to stimuli. Consequently market drivers for behaviour and energy use changes need to be very obvious and/or applied automatically to end use applications and demand.

The electricity bill is not economically important to the majority of domestic customer, particularly those which do not have electric space heating. Energy conservation needs to be uncomplicated and economically beneficial. <u>For many customers it is sufficient to have the feeling of saving money and doing the right thing at the same time.</u>

It is generally understood that electricity is not consumed for its own sake, but to provide services and people are only interested in the services not the electricity. Most loads do not incorporate significant energy storage, except hot water storage, so that the service is provided as and when needed. Therefore, the only way loads can exhibit price elasticity is if the households change their behaviour, such as reduce or shift their demand for cooking, heating, etc.

Elasticity of demand in the context of this report is the incremental change in motivator to save energy compared with the incremental saving in energy use. Price is the motivator that is easiest to quantify in terms of its effect on energy use because the relationship between demand and price can be observed. Many studies have attempted to measure the price elasticity of domestic and other customers but the elasticity of customer demand to motivators other than price remains elusive.

Modification of energy demand for smaller customers can be motivated if appropriate incentives and motivators are put in place to make it happen. The critical issue is whether the elasticity of demand for smaller customers can be utilised by means of cost-effective incentives. Incentives include motivators based on environmental considerations and saving money.

Price elasticity can be both a self elasticity and a cross elasticity. A 'self price' elasticity of -0.1 means a 10% increase in motivator in a particular time period leads to a 1% reduction in demand for that time period. A 'cross elasticity' relates changes in motivator in a particular time period with changes in demand in a different time period. For example, a 'cross price' elasticity for period x, with respect to period y, of 0.1 means a 10% increase in the price of electricity in time period y would lead to a 1% increase in the demand for electricity in time period x.

A study carried out in Greece estimated the short-term and long-term price elasticity of demand in a 1 and 3 year timescale.

The study showed a short term price elasticity for smaller customers of –0.18 (1 year) and a long term elasticity (3 years) of –0,65 indicating that price change programmes may take time to achieve lasting impact.

The results of another study also carried out in Greece (1) showed short term and long term elasticities for smaller customers of –0,73 and –0.65 showing an opposite view but that the impact can be quite large. The study results also emphasised the importance of the way the electricity energy tariff is presented to customers as much as the actual size of the increase in price. A number of other issues were also highlighted:-

- Any pricing policy aimed at saving energy succeeds with customers with relatively larger elasticity (domestic/commercial)

- Energy supplier profits are maximised and energy saving is achieved if customer with smaller elasticity are subjected to the higher prices. This is in contrast with normal pricing based on social criteria (for example industry has low elasticity but obtains lower prices).

3.2 Customer Perceptions and Energy Saving Motivators

Smaller customer perceptions of energy savings and their potential to save money and CO_2 fall broadly into three categories:

- Customers believe energy saving to be important and are looking for opportunities to participate.

- Customers are too busy and disinterested to take much action to save energy but will accept minor inconvenience as a result of automatic and semi automatic actions to save energy. Financial savings are not key motivator but if positive, allow the societal side of saving energy to emerge and the “feel good” factor to prevail.

- Customers have no interest at all in energy saving.

General Issues which can motivate and help customers to make energy savings are:-

- Price of energy
- Energy saving promotion (environmental damage)
- Bill disaggregation presentation and energy savings advice and methods

- Peer comparison information based on dwellings, occupancy and lifestyle questionnaire
- Air conditioners which can be "turned down" easily
- Year on year and period on period comparisons of energy use (temperature corrected)
- Intelligent appliances which can be "turned down" easily (heating and cooling)
- Water and space heating which can be "turned down" easily

3.3 Energy Saving Intervention Possibilities:

Actions which customers may take as a result of motivation being applied to save energy are:-

- Turn off/down lights when not needed or purchase energy efficient lighting
- Turn down space heat thermostats, install insulation
- Part fill kettles, etc
- Turn down air conditioning.
- Reduce shower/bath water
- Use fewer washing and dishwashing activities
- Purchase energy efficient appliances
- Modify cooking appliance use
- Turn down water heating thermostats

3.4 Energy Use Feedback to Motivate Savings

Feedback and presentation of energy use can take many forms but generally within the categories of:-

- General feedback and presentation of energy saving motivators based on global/country end use data

- Targeted feedback and presentation of energy saving motivators based on estimated and derived end use data which is reasonably accurate for individual customers and customer groups

- Individual customer, feedback and presentation of specific customer energy saving motivators based on accurate, monitored and derived energy end use data

3.4.1 General Feedback (Global Statistics of End Use Data)

Most electricity bills provided by suppliers in participating countries contain only the minimum level of information such as units used in the last billing period and standing charge information. Most bills do not include even basic information such as annual energy consumption. Customers wishing to know their annual energy consumption have to refer to their previous bills over the relevant year and calculate the total[1]. In all participating countries, general energy use statistics and information are fed back to customers in support of marketing and energy saving promotion campaigns. The campaigns usually take the form of offering financial support for energy efficient lighting and improvements to thermal insulation for buildings as well as free energy audit services. This energy use feedback is not targeted at specific customers because the information on customer lifestyles and property types is not known. Consequently, it relies for success on customers recognising that the benefits promoted can accrue to them specifically if they participate. These programmes could be supported by metering data which compared temperature corrected, year on year energy use in billing periods for each customer. This would allow customers to at least be aware of trends of their energy use even though they would not in general know what caused the noticeable changes.

Denmark has a process where energy counselling is given by grid companies free of charge as part of an agreement with the regulatory authorities. Companies are further legally obliged to provide information to customers on the electricity bill in the form of a so called "Informative electricity bill". The electricity consumption represented on the bill is compared with broadly comparable types of users, and the development with time in the consumption of the specific customer is made visible. Also information concerning the different types of costs on the bill are displayed and explained, as is the environmental impact of the total consumption. Individual companies are free to make their own choice of how to present the information and may add further information.

Several utilities offer green energy in the form of "Natur strøm" (Nature-current). Customers can order this for a higher price, and the utility buys electricity in accordance with the consumption of the customers in the form of certified power produced by wind or other renewable energy.

One utility offers green energy in the form of electricity produced by solar panels. The product is called "SOL-STRØM" (Solar-current) and customers who buy it pay an additional price; the extra money obtained in this way is guaranteed to be used for installation of solar panels.

In Denmark it is also considered very good business for utilities to rate electricity savings very highly particularly in the smaller customer sector. Advice activities like information to schools on energy efficiency, information to customers about economical cooking and of energy efficient appliances etc. were established by utilities before market liberalisation and before any legal obligation was put on them to participate. This positive attitude has survived the liberalisation process. It is also regarded as important for the utility companies, to have a "green" image, especially in the eyes of domestic customers.

[1] In Sweden, the estimated yearly electricity use has to be provided on the bill.

Campaigns have been established in Denmark for specific periods to promote energy savings. Their content and conduct is tailored to the target group, being industry/ service or the domestic sector. Usually a combination of media are used, i.e. Web-based information, brochures, handbooks, promotion on technical fairs etc. and to reach the domestic sector, promotion in Radio or TV. Often a “positive-list” is presented which is a list of appliances recommended due to their high efficiency,

A typical campaign could be to target standby consumption. The electricity companies have recently established an information campaign to reduce the standby consumption of domestic appliances. The background to the campaign is the rising standby consumption of increasing numbers of electronic equipment in the home, i.e. TV sets, PC´s etc. The campaign is co-ordinated with activities from the Danish Electricity Saving Trust. Great potential energy savings can be achieved if standby consumption can be reduced. The activities in connection with this campaign comprise written information material, a list of standby consumption for different appliances, etc. The information material is sent to customers by direct mail. The plan is to carry on the campaign for a reasonable length of time, as experience shows a considerable delay before an effect can be seen. The Danish Electricity Saving Trust has developed a power panel, which, plugged into the USB port of a PC, turns the peripheral equipment like printers, modems, scanners, screen etc. off whenever the PC is turned off.

“Power – questions and answers to energy issues” is an educational software package which handles production, distribution and use of energy. It was designed by teachers in Finland for 15-16 years old pupils. Usefulness and applicability of this software has been investigated in a study “To save energy by means of education”. Pupils answered the same questionnaire before and after using the software. Comparison of the answers provided information about how the programme was received and how it motivated saving energy.

The results showed an increased anxiety towards using oil and coal in energy production, increased support for developing public transport, sparked up discussions about energy saving in families and increased agreement on the effects of personal consumption behaviour on energy use. Girls were more willing than boys to act personally to save energy. The software programme was perceived as an effective way to reach this target audience.

Also concluded was that the provision of information about energy labelling needs to be delivered with great clarity and accuracy. Sales staff need basic information about the grounds for energy labelling and the measurement of performance. Also needed is general information about the working principles of domestic appliances and their electricity consumption.

Promoting Energy Efficient Fridges

Promotion of energy efficient refrigerators is carried out in the Netherlands and other participating countries. A number of studies are being carried out to help understand how to motivate customers to purchase more energy efficiency equipment to achieve energy end use savings. For this purpose Sales Promotion, Info & Advice tools are used, such as: publicity campaigns, subsidies, discounts, rebates, CD's, TV commercials & shows and replacements appliance.

There are two principal actors in these studies in Netherlands: the Dutch Energy Branche Organization EnergieNED and some utilities. The three sales promotion oriented projects for replacement of old refrigerators and lighting were carried out by EnergieNED. Information & Advice oriented projects were carried out by utilities.

The target for improving the market share of energy efficient fridges and freezers was 20%-40%. The average energy saving was calculated to be about 110 kWh a year per fridge or freezer replacement.

Another replacement of household appliances study also carried out in the Netherlands provided advice which focussed on four major appliances. The study was carried out to understand how energy is used in 100 households with four major energy efficient household appliances. When not meeting the standards, the old appliances were replaced by the utility. During the experiment, the customer regularly received advice and information. The costs were about dfl 80,000. The study is not yet complete. As a comparison, the same experiment was done for households who did not get the additional information to assess its value.

Greece has harmonised its regulatory/statutory framework for the consumption of energy and other resources by household appliances. This information is helpful in evaluating end use of energy by customers and helps customers choose more energy-efficient appliances.

Information on energy saving and the promotion of these methods is delivered to customers through:-

- Booklets distributed with energy bills, TV adverts, poster messages, daily press publications, video film production for schools.

- Collaboration with the “Greek Solar Industry Association” (GSIA) for the promotion of solar heaters with the energy bills.

In 2003 the programme for all customers achieved a 2% saving in the consumed electrical energy for the country.

Promoting Energy Efficient Lighting

In all participating countries, energy efficient lighting is heavily promoted using national statistics of end use of energy for lighting to support campaigns.

In Netherlands, utilities have a combined national campaign to promote the use of compact fluorescent lamps. The national promotion uses TV commercials and a special show on lighting. During the active period, lamps are available at reduced prices. In Greece, all the municipal lighting has been replaced with low energy lamps. In Finland, Motiva (Energy Information Center for Energy Efficiency and Renewable Energy Sources) and lamp manufacturers have a shared campaign to promote energy efficient lighting in 2002.

However, the price for energy efficient lighting remains a barrier for low income customers despite all the promotional campaigns. TV commercials have been the most successful information medium in the campaign in the Netherlands. In Finland more lamps were purchased in 2003 than in 2001.

3.4.2 Targeted Customer Feedback(estimated individual customer end use data)

Targeted customer feedback is the feeding back of individual customer end use data and energy saving information to those customers most likely to take advantage of it. In this way the material provides a specific marketing message which can encourage individual customers to take notice. The message can include peer to peer and year on year comparisons of energy use and estimates of the individual financial and environmental savings which specific actions can deliver.

In order to obtain this individual customer end use data to feedback, it has to be derived from more collected information from customers. This additional information can be obtained by more frequent meter reading and customer questionnaires (Internet or face to face) to collect property, lifestyle and end use appliance data.

Billing Structure Changes and Energy Saving

Studies carried out in Netherlands fed back detailed energy use information using the bill together with promotions to save energy. The objective was to realise financial savings in direct energy consumption of 7% within the target group. The behavioural changes in energy consumption pattern needed to achieve the savings was achieved through financial incentives. Each month the actual cost for the electricity was based on the actual Time of Use consumption and actual/market prices. It was expected that energy use reductions would take place because of changes in attitude of the group towards energy savings as well as their consumption patterns. This part was motivated through the distribution of information packages regarding electricity savings including practical tips for changing consumption patterns as well as through customer meetings. The study is still ongoing.

Another study was carried out in the area of Schiedam in Netherlands. Four groups of 100 households were set up having similar socio-demographic characteristics. The target group comprised Dutch households of a low-to-median yearly gross income of <€27.250. This included single parent households, families with a single breadwinner and/or families on social security benefits. The group represented about 3.4 million households nationally (approximately 50% of the total) which account for an annual electricity consumption of approx. 10.5 Twh (approx. 12.5% of the total).

Results showed that 70-90% of the participants became more aware of their electricity use. About half of the participants considered the price of electricity before switching on appliances. The use of stand-by electricity was reduced by about 40%. The result of the trial produced a measured reduction in demand of 6% of the total load on one distribution substation.

Another study being carried out in the Netherlands is to reduce energy consumption of 300 households in the city of **Groningen** by changing their behaviour through more detailed metered data, promotional campaigns and financial incentives. The target for energy saving is 5%. The motivators are the provision of information about the possibilities and advantages of energy saving and feedback of the results of the efforts of the household to save energy and also by rebates. To provide the specific information and feedback an interactive internet page was used. Firstly the page helps analyse the energy consumption and profile of the household. Secondly, relevant energy saving measures are determined. Thirdly changes in the energy profile are defined and based on the saving measures. Determination of the effectiveness of different ways of intervention (information and feedback targeted at individual customers for customer group as a block or a general persuasive message) is an important part of the project. Rebound effects are also a subject of study as well as the contribution rebate systems can make on reducing these effects.

The study delivered an energy saving of 8%. The difference between the group that received individual feedback and the group that received feedback as a group are small. During the project the money saved by using less energy use was invested in energy savings. In this way acceleration was introduced and the rebound effect was reduced. The website information of the programme was judged to be very positive and provided a valuable tool for marketing energy savings.

Community Action as an Energy Saving Motivator

Further study was carried out in two other districts in the Netherlands to understand how and if the energy behaviour of households is influenced by a community approach. The energy saving motivator instruments were aimed at households, schools and shopkeepers. In this approach, local advisors supported households; shopkeepers were involved by offering energy saving equipment to households; utilities were also involved. In order to make selling and buying energy saving equipment attractive, a reward system was used.

Results of the study showed that participation was less than expected. Customers want to be contacted in a less general way and not from a distance. Contacts and publicity need be created slowly and locally. Knowledge of the campaign by potential participants improved at the end of the project. Measurable results were limited, but a change seems to have occurred in the end. Experiences have been used to design an improved project. Fifteen local municipalities are interested in the new model and the project has started. The website www.eco10.nl has been visited frequently, especially by local government organisations.

Similar study is also being carried out in Netherlands which involves a mobile exhibition visiting neighbourhoods to present information and advice on energy savings. In the month in which customers receive their energy bill, the mobile exhibition visits the neighbourhood. About 1,000 people in 44 towns annually visit the exhibition and get advice. It is not known how much energy savings the advice motivates. The annual cost is about dfl 80,000. Because of the high investment costs in providing the mobile exhibition, the programme will have to run for about 8 to 10 years.

Conclusions from a monitoring project in the Hague, Netherlands to assess promotional material is that more frequent feedback of energy consumption results in more energy savings. The study used improved metering and communication to collect customer data. Customer face to face interviews were also conducted to collect and provide end use data and energy saving advice. The measured savings after 1 year were more then 3% reduction of the electricity consumption and about 5% reduction of the natural gas consumption. Furthermore it was also concluded that there is a limitation to the interest in feedback information and energy saving advice by customers.

The results and the conclusions of another promotional material monitoring project in Amsterdam were almost the same of those in The Hague: frequent feedback of energy consumption data results in energy savings (about 3% electricity and 5% natural gas). It also concluded that there is a limitation to the interest by customer in feedback information. This was concluded by remotely checking the number of times customers looked at the information displays in the home. Additionally, sending information by post resulted in very few responses from customers.

In Northern Ireland a study of key-pad prepayment meters was carried out in preparation for replacing a life-expired prepayment meter population.

The new key-pad meters were initially trialled in a small number of households in the Belfast area. As a result of the favourable feedback received from those involved in the initial trial, Northern Ireland Electricity decided to go ahead and replace all its pre-payment meters with the new keypad meters. The features particularly liked by customers were the ability to locate the remote display anywhere in the household and the ability to obtain continuous information about their electric usage. This additional information about electricity costs led to an 11% reduction in electricity bills.

A similar evaluation of an electronic meter card with feedback on customer consumption is being evaluated in the Netherlands based on:-

- Pilot to develop and test an electronic meter card to complement the normal paper meter card
- The card is in a field test-phase by 50 employees of the utility and 300 customers

- Advantages: quick feedback to customers
- An electronic meter card is to be developed and based on the Internet to provide automated energy auditing and advice for smaller customers.

3.4.3 Internet-based Energy End Use Feedback

At the present time, simple Internet audit possibilities are available in some utilities in participating countries. A detailed service called "Electricity Doctor" is available in Finland. Small residential customers with and without electric heating can make an energy audit of their homes through the Internet. In the first pilot of "Electricity Doctor", customer opinions were asked using a questionnaire which was filled in by customers through the Internet. A small group of customers were also interviewed face-to-face. For suppliers the key objectives are the improvement of energy efficiency at customers and a hoped for increase in customer loyalty. A second objective is to carry out voluntary agreements with the government to improve energy saving and decrease CO_2 releases. The energy audit is part of the utility, Internet homepages. The customer goes to the audit pages by means of a confidential password. The audit calculation model gets the actual annual electricity consumption data from the customer data system of the supplier. The questions asked relate to the house, people living in the house, heating system and equipment in use in the house. After answering the questions the customer gets feedback on the division of his consumption in to the different end uses, a comparison with peer group and hints for energy saving.

Many utilities in Denmark have established Internet homepages, where customers can find energy use and saving information. The Danish Electricity Saving Trust has a special homepage, similar to that in Finland, where it is possible to sign on and have your individual consumption analysed and compared. Through a combination of remote reading of the meters and direct and targeted information to individual customers a reduction in consumption of more than 10% is anticipated.

The Utility companies in Denmark have established a database of household appliances called ELDA. This database is kept updated almost in real-time as new products are launched and it contains every type of appliance available on the Danish market. It contains functions which make it possible for an energy counsellor to calculate the electricity consumption over the lifetime of appliances and the capitalised costs of the electricity and water consumption. This data is used together with the price of the appliance to advise customers on the most cost effective appliance.

The Danish Electricity Saving Trust and electricity companies have established Internet platforms with information of where the cheapest A-market appliance of specific types can be purchased.

3.4.4 Individual Customer Feedback (measured end use data)

Techniques are available to collect continuous disaggregated end use energy data for smaller customers. These can be the sub metering of individual power circuits or end uses in houses or the correlation of power signatures of individual end uses with stored models at the meter position. These techniques are described in chapter 4.

The major advantage of feeding back to customers their individual end use of energy is that energy saving programmes can be tailored to achieve maximum impact for each individual customer. It is also possible to advise and reward customers as a result of their individual energy saving actions. These end use disaggregation techniques are already used to monitor sample groups of customers to obtain general end use statistics. The cost of applying these techniques to whole populations on a continuous basis is likely to be high.

Some grid owners in Sweden have installed hourly remotely read meters for all their customers (in Sweden metering is the responsibility of the grid owner, not the supplier). They have also provided their customers with access to a web page where they can get detailed information of their overall energy use hour by hour. However, few customers actually use this opportunity to obtain electricity time of use data. The overall savings are small but significant.

3.5 Review of feedback studies (Darby)

Darby in 2000 reviewed 38 studies to compare the effectiveness of different types of feedback on domestic energy use.

The studies were sub-divided into three groups according to the type of feedback employed, namely:

- direct feedback, with information on energy use available directly within the home as and when required;
- indirect feedback, with raw data processed remotely and sent to customers with the bill;
- other, including inadvertent feedback such as learning by association, and energy audits.

The studies showed that the range of energy savings achieved varied considerably among the studies, with some studies showing no energy savings while others showed savings of 20%. The range of energy savings achieved by the 38 studies reviewed is shown in Table 1.

Table 1 Savings Demonstrated by the Feedback Studies

	Number of projects			
Savings	**Direct Feedback**	**Indirect Feedback**	**Other Forms of Feedback**	**Total**
20%	3	-	-	3
20% of peak	-	-	1	1
15 – 19%	1	1	1	3
10 – 14%	7	6	-	13
5 – 9%	8	-	1	9
0 – 4%	2	3	1	6
Unknown	-	3	-	3

Source: S Darby, Making it Obvious: Designing Feedback into Energy Consumption

The results shown in Table 1 above suggest that direct feedback is the most promising in terms of the amount of energy savings delivered, with almost all (19 out of 21) of the projects involving direct feedback delivering savings of 5% or more. The highest savings were achieved using the following methods of directly feeding back information on energy use to customer:

- a table top interactive cost and power display unit
- a smart card prepayment meter
- an indicator showing the cumulative cost of operating an electric cooker.

The review found that those studies not employing a special display of household consumption, and thus relying on reading standard household meters were not as effective in encouraging a reduction in electricity consumption.

The importance of customised advice is also highlighted in another more recent study published by Darby. The paper analyses the ways in which householders make sense of domestic energy advice. A number of households were given domestic energy advice via one of the following three ways:

- face to face advice in the home
- advice given over the telephone
- general information via self-audit

Although the energy savings achieved by the householders was not rigorously audited, the results showed that customised face to face energy efficiency advice was the most effective. For example, one low income household achieved a 20% reduction in fuel costs after receiving very simple advice on where energy is used within the home, and how energy costs could be reduced. The advice included tips such as not filling the kettle unnecessarily, switching of lights when not needed, using the washing machine at night when electricity is cheaper and keeping curtains closed to keep in the warmth.

4 Monitoring and Disaggregation of Energy End Use

4.1 Introduction

Continuous disaggregation of customer demand and the allocation of energy consumed to individual applications is technically challenging especially when individual appliances can be supplied from different points in the dwelling and the population and types of appliances change with time. Studies have shown that general household building, thermal and occupancy behaviour modelling can produce estimates of end use of energy even when end use applications and population are only reasonably understood. Studies have also shown that signatures and patterns of end use energy and power for individual appliances can be correlated with stored signatures to determine actual appliance use from the meter position. Sub metering of individual appliances is also possible with end use data collected at the meter position. However, these systems are expensive for continuous application at smaller customer premises.

The degree of end use energy disaggregation which it is possible to achieve includes:-

- Complete identification of all end uses by means of extensive sub metering.

- Estimated end use of energy derived by means of defining customer household type and lifestyle. Each customer group data is then combined with a data base of end use information against household types obtained from statistical sampling.

In between these two methodologies are a range of possibilities for estimating end use energy consumption based on collecting questionnaire information, sometimes via internet sites, and linking it to normal meter reading information.

The more accurate the end use data, the stronger the feedback messages which can be given to customers advising them of appropriate energy saving measures. If end use disaggregation data is based on statistics, meter readings and household type, then only general energy saving messages can be delivered. However, these can still focus on typical actions which may be appropriate for customers to consider. Peer comparisons can also be carried out to advise customers about the general level of energy use for their customer group. This requires some property and lifestyle information to be collected.

Major end use applications can be sub metered and data sent via a “home communication bus” to the main meter or gateway to be remotely monitored. From an energy-saving perspective, it is only really required to define and disaggregate the major energy consuming end uses. These can be loosely categorised as space heating, cooling, cooking, hot water, washing clothes and dishes and lighting. Sauna is a major load in some countries and air conditioning is also becoming a significant load. Energy consumed by standby applications is also significant. In Nordic countries two hours electric heating of car motors and inside of cars before starting in the mornings is common during wintertime.

Presentation of information to customers regarding energy use can be via a more comprehensive bill, strategically yet unobtrusively located household displays again using a communications bus inside premises and face to face interviews.

4.2 Overview of Demand Disaggregation Techniques

Various methods and techniques are available which can and are used for measuring and estimating disaggregated end uses of energy.

- end-use monitoring, where the electricity consumption of individual appliances is directly metered (sub metering)

- non-intrusive monitoring, where the electricity consumption of individual appliances is inferred from measurements made on the electricity supply at the meter position and correlated with appliance signatures;

- diary or questionnaire methods, where customers keep records or report the usage of specific appliances and lifestyle. This data is used in conjunction with the normal meter reading to estimate end use.

- sample customer data collection to produce national customer or group statistics which can be combined with the normal meter reading to produce very approximate end use data.

4.3 Sub Metering of Energy End Use

Sub metering of end use demand is a straightforward process of installing additional meters at strategic points within a metered installation. These meters are not used for billing purposes but for allocating the total energy consumed to specific end uses. This is a regulatory requirement for commercial and industrial sites in some countries but is not yet a requirement for domestic premises. A major problem with sub metering installations is the cost-effective reading of the sub meters. Communication techniques are being developed to help in this regard with the main billing meter acting as a data concentration point for the sub metered data. With the development of "home bus" communication systems for providing wide ranging customer services, sub metering as a continuous activity could be a valuable methodology for end use monitoring and feedback in future.

A new methodology for sub metering is now being developed in Denmark. The Danish Electricity Saving Trust has chosen "visualising electricity consumption" as a particularly important focus area for 2004. This project targets mainly two types of customer – offices and households. The system contains several technical solutions. One solution is based on a number of small energy meters which communicate with a central PC unit in the house. The PC has the option of sending the information back to the metering or energy management company using an external communication system. The communication from the sensors to the central unit is either by PLC over the 230 V power lines installed in the house or by radio. Another solution is the use of autonomous data loggers at the relevant monitoring outlets. The data from the loggers can then be fed into a PC through the USB port.

The aim of the project is to develop a system which is cheap, legal and viable to install without the need of authorised or skilled persons. The accuracy of the measuring system is high and provides quality information for motivating energy awareness

Danish legislation demands that buildings are classified in accordance with their energy consumption. The classification is done by authorised advisors. An evaluation of the electricity consumption of the household is part of this classification, where the consumption is compared to what could be expected from this type, use and size of house.

4.4 Signature Analysis and Correlation of Energy End Use

An alternative approach to sub-metering individual appliances is non-intrusive appliance monitoring which derives individual appliance usage from changes on the supply, such as step changes in real and reactive power. More exact identification of appliance energy use is possible, if harmonics and/or electromagnetic switching pulses are recorded. Some additional data is also required in support of the recorded data, which may include a schedule of the appliances installed, and the real and reactive power they each draw.

In 1990, a non-intrusive monitoring system was developed in the US for installation at the meter though at a very high cost of $2,500. A similar system was also developed by EDF in France using the power signatures of appliances. The USA system, which now appears to have been developed into a commercial product, uses the power signature of appliances and samples waveforms at the rate of 1.5kHz. An alternative approach was taken by Caciotta et al in Italy, who sampled the real load over 15 minute intervals, measurements which are well within the scope of normal electronic meters. They then used a neural network to identify appliance use, which was first trained using laboratory tests of appliances. The technique worked well, but was helped considerably by the fact that residential demand in Italy is often limited to a maximum of 3kW. As a result few large appliances are used simultaneously which make identification easier.

The need to collect appliance signature data is common to the approaches listed above. Bons et al describe an alternative that does not require the collection of signature appliance data. The technique involved inferring the underlying sequences from the load data, using a best fit approach. Load is considered to be the result of a series of state changes of appliances and appliance components (such as heaters or motors). The causes of these changes of state are treated as an unknown, stochastic process where the next state only depends on the current state – i.e. there is no memory involved.

Non-intrusive energy end use derivation methodologies have also been studies extensively in Finland using new techniques which correlate and compare energy use signatures with stored energy and power profiles. "Signature Analysis of Steady-State Power Values" or Non-Intrusive Appliance Load Monitoring (NIALM) from the meter position is based on the idea that the operating schedules of individual loads or groups of loads are determined by identifying times at which electrical power (real and reactive) changes from one nearly constant (steady-state) value to an another.

These steady-state changes, known as events, nominally correspond to the load either turning on or turning off and are characterised by their magnitude and sign in real and reactive power. An edge detection algorithm is used to identify changes in steady-state levels. A key requirement here is that the procedure must not be affected by start-up transients which often accompany steps. Recorded events build up positive and negative clusters of similar magnitude in the ΔP-ΔQ plane. They are paired to establish the operating cycles and energy consumption of individual appliances. This two-dimensional signature-space technique relies on the assumption that different loads of interest exhibit unique signatures in the ΔP-ΔQ plane. The greatest challenge of this cluster analysis is to pair unmatched clusters or events which can be the simultaneous switching of two or more different loads or a load which signature is not known. The probability of simultaneous events is smaller in monitoring a household of three-phase installation than single phase. Also simultaneously occurring single phase and symmetrical three phase (e.g. motor load) events are quite simple to distinguish from each other.

Loads which can be detected non-intrusively are classified into two main groups:-

- two-state loads that turn on, consume energy at a relatively fixed on-state power level, and turn off

- multi-state loads that have more than one on-state power level and the state powers are combinations of transition powers

Loads which are under 50 W or are always on cannot be recorded. Continuously varying loads, such as variable speed drives (VSDs) or combinations of many electrical space heaters with electronic thermostats, may never settle to a steady-state and therefore are not possible to monitor with this technology.

Because of the many limitations, the exact accuracy of non-intrusive monitoring is not easy to quantify. It depends on the type of supply, single or three phase, the type and number of different loads at each monitoring site, etc.

In Finland a large percentage of households (detached houses always) have a three phase power supply because of the many installed three phase loads such as electric saunas (6 kW ….15 kW), hot water storage heaters (3 kW …. 9 kW), heat pumps (2 kW …. 6 kW) and electric cookers. Also electrical space heating of dwellings and under-floor electrical heating cables in bathrooms are common.

The error of NIALM in estimating daily load consumption of individual appliances in households with a three phase supply varies from 1 to 10 % for simple two-state loads like water boilers, saunas, cooling appliances etc. The cycles of washing machines or other complicated multi-state appliances can be identified, but usually estimation of energy consumption is not very reliable.

Usually an appliance survey in the monitored house is not necessary if the monitoring target is limited to common appliances. Data analysis software is not automatic and every analysis needs to be done manually by a skilled person who is acquainted with the technology.

Results are shown in Figures 1 and 2 of non-intrusive analysis of the three phase supply to a flat with and without the district heating switched on. During renovation, two electric heaters were installed, one in the bathroom and the other on a balcony for indoor plants. Both heating elements were under-floor heating cables controlled by thermostats. The figures show the feedback information to the householder. Daily electricity end uses of energy from two different days are shown; the first day with the heaters switched off and the second day with them switched on. This shows that the major end uses can be disaggregated under both conditions.

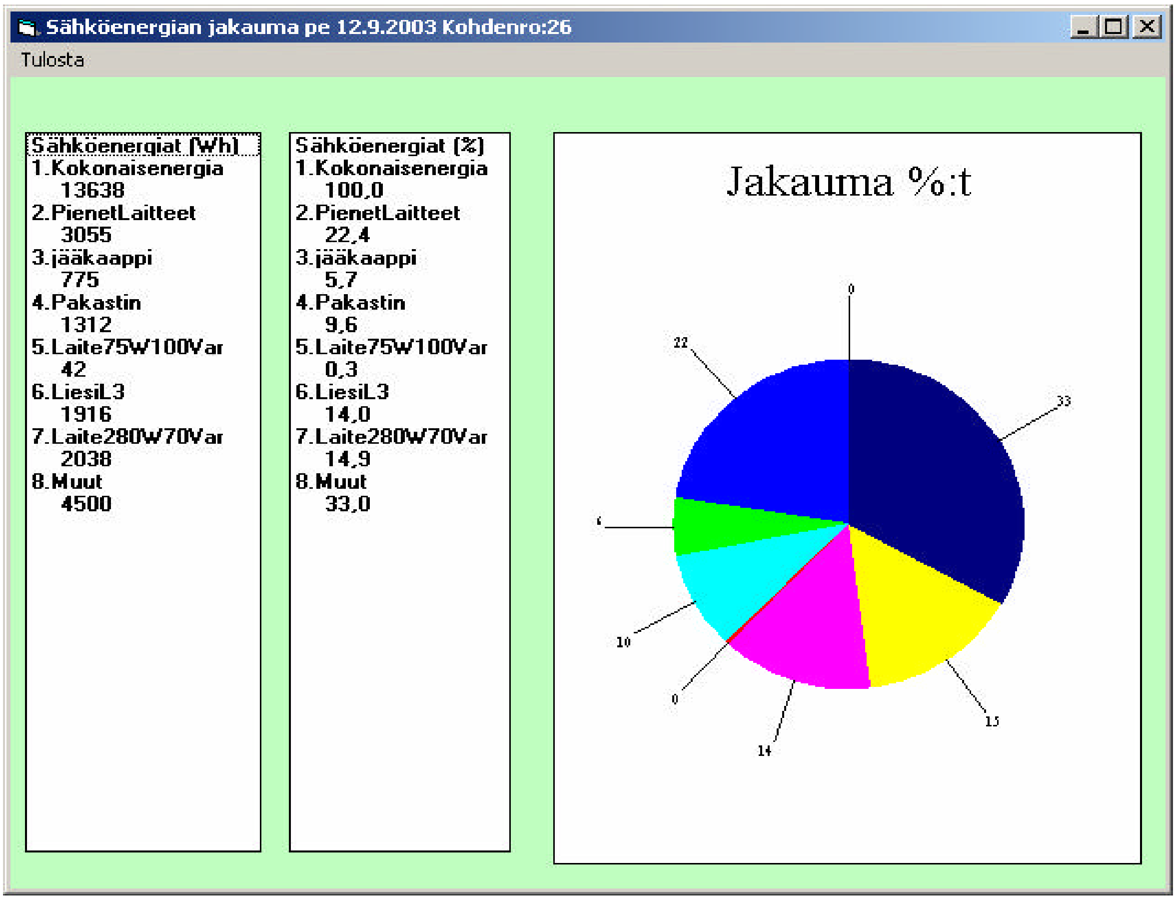


Figure 1 Example of daily electricity use (Wh) 12 of September 2003 in a flat before heating season

1. **Total electricity**
2. **Small appliances 50-200 W (lights,TVs)**
3. **Fridge**
4. **Freezer**
5. **Appliance P=75W,Q=100 VAr,**
6. **Electric cooker in L3**
7. **Appliance P=280W, Q=70 Var**
8. **Other (standby + all other appliances)**

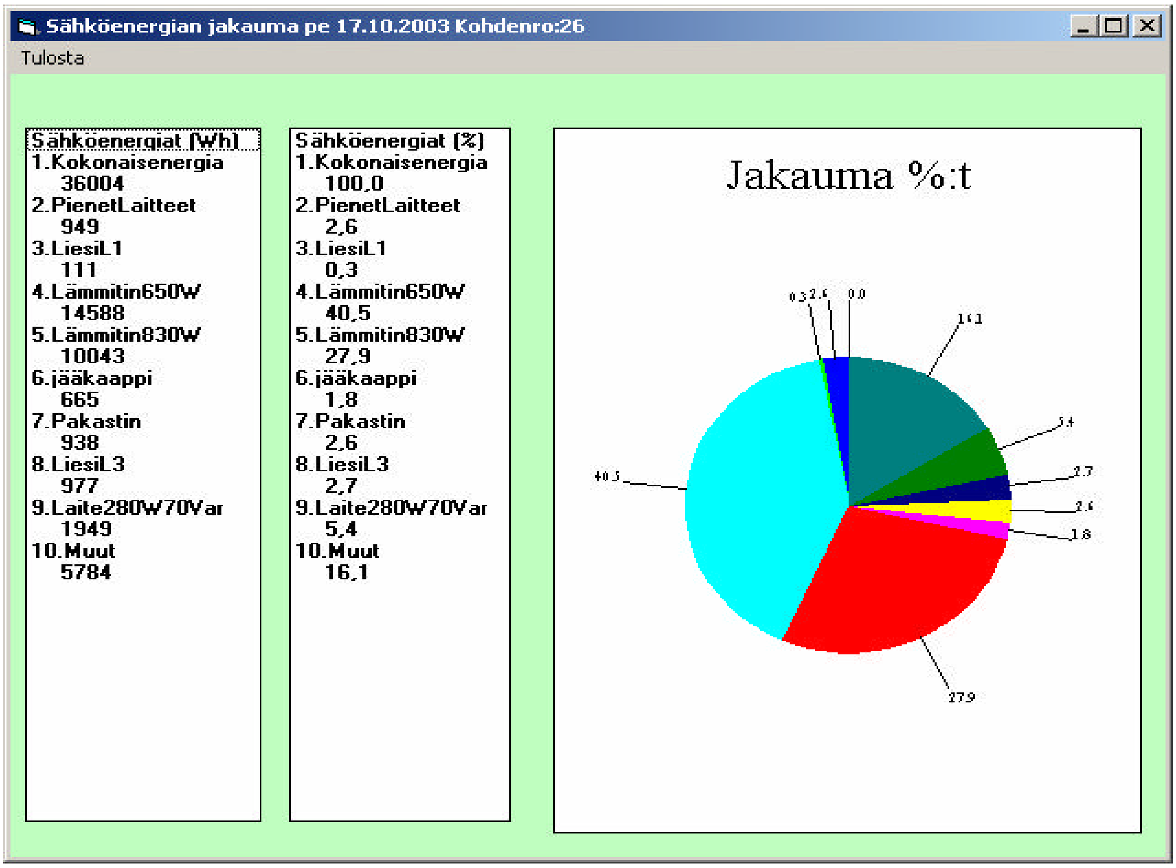


Figure 2 Example of daily electricity use (Wh) 17 of October 2003 in a flat during heating season

1. Total electricity
2. Small appliances 50-200 W (lights,TVs)
3. Electric cooker in L1
4. Heater P=650 W
5. Heater P=830 W
6. Fridge
7. Freezer, 5. Appliance P=75W,Q=100 Var
8. Electric cooker in L3
9. Appliance P=280W, Q=70 VAr,
10. Other (standby + all other appliances)

4.5 Individual Customer Data and Increased Meter Reading Frequency

End use disaggregation estimates can also be made by combining the normal meter reading with customer interviews to collect lifestyle and end use appliance population data. These interviews can be carried out face to face or using Internet based questionnaires. Estimates of end use can also be made although less accurately without conducting questionnaires if the meter reading and billing frequency is increased to, say, weekly. This allows customers to more closely relate their usage of energy and behaviour to the size of the bill and cost of energy. It also assists them to understand what savings have been made based on a behaviour change.

A feasibility study has been carried out in Netherlands with the objectives of investigating the reliability of power line communication (PLC) for collecting data and the effect of providing more frequent metering data to customers. This last objective was to understand whether reducing existing energy consumption (Electricity & Natural Gas) by household customers is possible as a result of more frequent and detailed energy use data. The tool to achieve this objective is more frequent feedback of energy consumption information by using a remote meter reading system. Normally these customers get a bill once per year based on manually read meter data. The rest of the year they pay an estimated amount each month for used energy. This poor feedback means that household customers do not have any insight into their consumption behaviour.

The study is being carried out in the city of The Hague with 300 selected households living in a mix of different types of houses (old and new houses/apartments/stand alone houses/houses in rows etc.). The customers are divided in to three groups with different feedback frequency of used energy consumption: once a week to once a month. All the customers receive the monitored energy consumption data, including energy saving tips and advice, via postal mail. The PLC system provides the hourly consumption data from the 300 electricity and 300 gas meters during the 12 month pilot period.

In a complementary study, investigation of the reliability of PLC communication to provide more frequent meter data information for customers is also being carried out in the city of Amsterdam with 250 selected household customers living in a typical residential quarter. The customers are divided into 5 sub groups each with a different feedback frequency of used energy consumption: once a week to once a month. All customers receive the monitored energy consumption data, inclusive of energy saving tips and advice, via postal mail. Furthermore a group of 50 customers receive real-time & historical information via an electronic display, plugged into an existing wall socket. The PLC system collects the hourly consumption data of 250 electricity and 250 gas meters during the 12 month pilot period.

A study was carried out in Finland in 1993 in order to investigate the variation of annual electricity consumption of different types of households and what the main factors are which affect consumption. The basis of this study was the data gathered from 2,100 households about their use of electric appliances and their attitude to energy saving. A study group was formed from 400 households and their daily use of appliances was monitored over a two week period. The use of different appliances was written down by the householders themselves. Also electricity use of different appliances in 100 households which belonged to the group was monitored during two weeks in November 1993 in different parts of Finland. In this study flats, terraced houses and single-family houses were investigated.

Power distribution companies of the monitored households installed temporarily kWh-meters in the supply to fixed appliances. Meter reading was manual and was performed at the end of the two week monitoring period. The following appliances were monitored: electric cookers, micro wave ovens, coffee makers, cold appliances, dish washers, clothes washers, electric saunas, consumer electronics (TVs, video players, radios, microcomputers). The consumption of lighting was not measured. The residual energy when the consumption of all measured appliances was subtracted from the total was mainly lighting, but also included small appliances.

By using the measurements and consumption models the electricity consumption of different appliances was calculated for many different types of households. According to the study a typical household used about 3 400 kWh of electricity in 1993.

It was found that in households with the same number of occupants and the same appliance stock the electricity consumption varied widely. Typical Finnish households and their electricity use are very difficult to estimate. Households are very individual and the differences will become even greater in future.

Some households included very old and inefficient cold appliances, especially freezers which can consume over 1200 kWh per year. Most households have a positive attitude to energy saving. In this study no correlation between the electricity consumption and the attitude to energy saving by the customer was found. One reason for this could be that the large consumption of old cold appliances cancelled any savings that took place from installing energy saving lamps.

The results of this study formed the basis for developing a programme to analyse household electricity usage called “Electricity Doctor”. Many utilities now have this programme available on their internet websites.

A smaller study was performed in Finland during the year 2000. In a housing company of 31 flats, every household was installed with a remotely readable total electricity meter. Both householders and utility had access through the Internet to consumption figures. In order to make a detailed analysis of consumption one minute load profile data was gathered over a four months period in 2000. Total electricity load profiles of every flat were gathered every minute from the beginning of February to May 2000. At the same time a measurement campaign was carried out using electricity sub meters in order to monitor individual appliances in homes. This campaign was based on the activity of inhabitants of the flats. 19 inhabitants with 31 measured appliances provided information about their appliance stock. Focus for measurement was especially targeted at refrigerators and freezers which use energy at night because standby power of appliances was determined by using measurements and calculations of night time use. In each flat only one measurement unit was available and it was changed from one appliance to another. Typically refrigerators, freezers, television sets and washing machines were measured.

A special method was developed to estimate standby power of homes by analysing the available total load curves at one minute intervals at every home. Based on these load curves, the time when power was at its smallest was determined. During this time all automatically cycling appliances and all other non-standby load was either measured or assumed to be switched off. The data on appliance stock gathered from inhabitants was also used to identify special appliances that were always on. The annual electricity consumption in year 2000 in flats varied between 1415 and 5938 kWh (average 3240 kWh). The estimated standby power in flats varied between 5 and 80 W (average 33 W, annually 290 kWh). Estimated standby electricity as % of total annual electricity use varied between 3.2 and14.8% (average 8,2%).

Daily electricity consumption in unoccupied flats consists of refrigerator, freezer and standby power of appliances. Average annual electricity use of cold storage appliances (refrigerator, freezer) was 830 kWh or 27% of total annual electricity use in flats. This conclusion is based both on measurements of individual appliances and on estimation made from load profiles. Cold storage appliances use the most electricity of all appliances in homes and they offer the greatest saving potentials. It was estimated that if all existing cold storage appliances in the 19 homes were replaced by energy efficient units, (A-class appliances), the average annual electricity use of cold storage appliances in these homes would drop from 880 kWh to 360 kWh resulting to 520 kWh average annual savings per flat. These high energy consuming appliances could be identified from the total load profiles of the flats.

4.6 Statistical End Use Customer Data and Normal Meter Reading

Collecting data from sample groups of customers allows only very inaccurate individual customer energy end use data to be estimated. However, it does enable national, area and possibly specific customer group programmes for energy saving to achieve some focus in targeting energy end uses.

The National Statistical Service of Greece carried out a study to determine the statistics of energy end use in Greece and published the “Research of consumption in Households” in 1993. This research was carried out using the method of systematic sampling using customer questionnaires and covered all the regions of country.

The goal of the research was to collect data and extrapolate the results in order to understand present and future energy use in households with regard to:

- The characteristics of their residences

- The finances and their social characteristics
- The energy appliances population
- The forms and the uses of energy
- The frequency of use of basic electric appliances

The households were informed of the research and its goals by means of media briefings and posters which were displayed in central points of cities and on public transport.

The research sample was 0.21% of the total population. The sample consisted of 6,550 households, and covered all the regions of the country.

Personal interviews were used for the collection of customer lifestyle and building information.

The energy consumption in the main residence of an average household in an average four-month period in Greece is :-

Table 2 Energy Consumption in main residence of average household in average 4 month period in Greece

	Percentage of customers (%)	Percentage of Consumption (%)
With null consumption	10,6	0,0
From 0 till 800 kWh per four-monthly period	52,8	28,2
From 801 till 1600 kWh per four-monthly period	28,4	44,6
From 1601 till 2000 kWh per four-monthly period	4,1	10,3
From 2000 kWh and more per four-monthly period	4,1	16,9
TOTAL	100	100

The allocation of electric energy consumption to household end uses is as follows:-

-	Refrigerator + freezer	21%
-	Electric cooker	14%
-	Lighting	15%
-	Washing machine	10%
-	Electric heater	18%
-	Television	9%
-	Other appliances	13%
		100%

A study in Spain of end use of energy by smaller as well as larger customers (INDEL) has been carried out by the System Operator. This study was to obtain disaggregated energy end use data to assist the prediction of future generation, transmission and distribution network demands. The study also investigated the willingness of customers to save energy based on financial and environmental savings.

A wide and representative set of data was collected from 1500 customers over an eight year period. Each customer load curve was recorded hourly and their end use equipment and time of use data was obtained by personal interviews. Small samples of household consumption from appliances were collected individually and a multivariant model developed for the analysis. The end use of energy in Spain is shown in Table 3 below :-

Table 3 End Use Data in Spain

Segments and uses	Annual consumption	Maximum weight of the segment		Weight in the peak
	%	%	Time	%
Large industry	25	30	5	10
Restaurant	1.7	3	22	2
Food Commerce	1.2	6	12	4
Rest of industry and services	52.1	59	11	50
Residential	20	52	23	34
Space	1.9	16	22	11
Lighting	4.7	9	1	9
TV	2.3	9	22	4
Warm water	1	4	8	2
Fridge	5.5	4	5	3
Other	4.6	8	14	6

Another study carried out in Spain (ECOUSO) showed that customers have a positive attitude to reducing the environmental impact of electricity consumption.

A study in Finland was carried out by Imatran Voima Oy between 1994 and 1998 to examine the end use energy consumption of electrically heated houses. The study used measurements from 48 single-family houses and 49 terraced-house apartments. All houses were divided into groups based on the heating system. Water-circulating heating systems were separated from room-specific heating systems and new houses were handled separately from renovated houses. Terraced houses were also handled separately.

A monitoring system was connected to sub-meters installed in forty houses. Data was collected at 15 minute intervals. Sub meters were installed in order to distinguish electricity consumption of space heating and water heating. In some houses, sub-metering of the following end uses was carried out; household appliances, electric sauna, inside lighting and consumption outside the houses, (outside lighting, car engine and interior heaters used during winter time, etc.)

All houses were equipped with the latest electric heating technology. In new single-family houses the space heating was delivered through under-floor water circulating heating. In new houses, with room-specific heating, the heating systems were combinations of under-floor, ceiling and electrically heated windows.

In new houses with room-specific heating systems, the average total energy consumption was 48 kWh/m^3 per annum, of which 27 kWh/m^3 per annum was space heating consumption. 71% of the total energy consumption in these houses was consumed during the night-time period (11 p.m. – 7 a.m.). The corresponding figure for space heating energy was 75%. In new houses with water circulated heating, the total energy consumption was 52 kWh/m^3 per annum, of which 80 % was consumed during the night-time period, and the corresponding figures for space heating consumption were 37 kWh/m^3 per annum and 90%.

The average consumption of warm water heating was 2900 kWh/a, which is 950 kWh/person per annum. An increase in family size raised the yearly consumption by 420 kWh/person per annum. The marginal consumption of water heating decreases as the family size grows with the dependence non-linear.

In a new 500 m^3 single-family house with four residents, the average yearly household electricity consumption was about 7000 kWh and divided into the following parts: cold appliances 1000 kWh, inside lighting 1500 kWh, cooking 500 kWh, electric sauna 1000 kWh, outside house consumption 500 kWh and other 2500 kWh (washing machine, dish washer, consumer electronics, other household appliances). An increase in family size raised the consumption of household energy 600...1000 kWh/person per annum. The consumption of household energy during summer months was only half of the consumption during wintertime. The degree of use of house-internal heat from household appliances was high, 60...90%. The deciding factor was the proportion of house-internal heat produced and heat losses of the house.

A number of studies to derive energy end use statistics for households have been carried out in the UK using end-use monitoring.

Data on electricity end use by domestic appliances was produced as part of a programme of work carried out by the University of Oxford Environmental Change Institute. The primary aim of the project was to understand how emissions of carbon dioxide from smaller customers could be reduced. The basis of the work was a detailed end-use model of domestic electricity use for lighting and appliances. The model contained global information on the ownership, sales, usage and electricity consumption of the following appliances:

- fridges and freezers;
- washing machines, tumble dryers and dishwashers;
- televisions, videos and audio equipment;
- cooking hobs, ovens, kettles and microwaves;
- lighting.

The study combined information about the ownership and use of end uses, collected directly from customers and covered changes in technology, behaviour and demographic factors to give a detailed breakdown of electricity consumption and the resultant emissions of carbon dioxide. Although the model is a bottom-up analysis, the data has been used to determine the breakdown of total domestic electricity consumption in the UK by end-use, rather than to disaggregate the consumption of individual households. However, the project highlighted several behavioural aspects that influence electricity consumption that could prove useful in providing customers with information about end-use consumption. For example, avoiding reboiling of kettles is estimated to reduce the energy consumed by kettles by 10%. Other examples of the effect of behavioural changes on end use consumption include:

- more efficient loading of washing machines, tumble dryers and dishwashers could reduce the energy consumed by these appliances by 10%, 7% and 17% respectively; and

- regular defrosting of fridges and freezers could result in a reduction in their energy consumption by approximately 2%;

Limited information is available in the UK on current activity by electricity suppliers to feedback information to smaller customers on their energy use. Much of this may be due to a reluctance by suppliers to release information that may be commercially sensitive. A recently published report by the Centre for Sustainable Energy points to proposals by two suppliers (Powergen and British Gas) to install smart meters at the premises of their customers. Powergen's programme was announced in 2001, but it is believed that the programme is currently on hold due to the uncertainties created by meter liberalisation in the UK. There is also reference to work by British Gas to install advanced meters, but information on this is also limited. British Gas are planning a pilot scheme to read gas and electricity meters remotely in approximately 50,000 households in London and Manchester. However, the results of the trial may not be publicly available.

The Electricity Association's Load Research Group in the UK carried out a monitoring programme for smaller customers and their end uses of energy. The programme concentrated on appliances that represent the major electricity uses in the household, with 600 to 700 appliances monitored half-hourly. In addition, each customer was presented with a questionnaire every two years so as to determine the total number and age of appliances and levels of household thermal insulation.

The main purpose for the data collection and end use disaggregation was to assist the prediction of future network demand and the development of load profiles for smaller customers. These profiles form the basis of financial settlement and payment of suppliers in the competitive electricity market for smaller customers.

The end-use data was collected using a data collection system which comprising a central unit to control and collect data from up to 1000 Local Collector Units (LCU) within participating households. Each LCU receives end use data from up to 16 individual 'end-use' meters. Communications between the 'end-use' meters and their LCU is by low power radio, and communication between LCUs and the central unit is via telephone lines. A schematic of the system is shown in Figure 3.

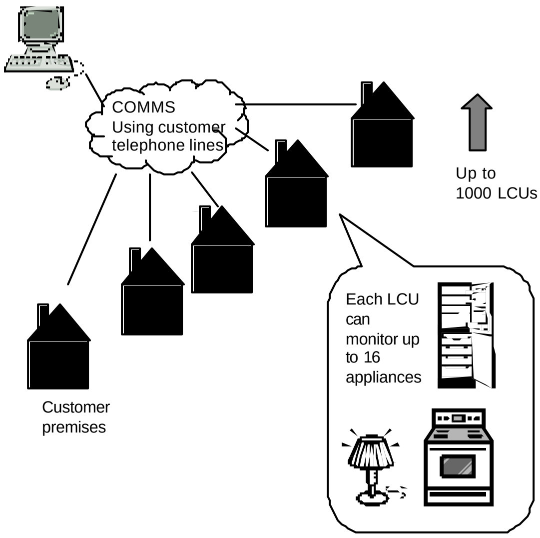


Figure 3 Schematic of domestic POEM system

In addition to annual consumption figures, the results of the appliance monitoring project are commercially available in the form of half-hourly demands and weekly and seasonal load profiles.

In Denmark, the ELMODEL-bolig has been developed which is a bottom-up model for predicting electricity consumption in households. The total electricity consumption in all Danish households is calculated as the sum of small estimated contributions from estimated stocks of appliances in all households.

The model is based on time series and is used to describe and analyse the annual consumption from the 1970's and to forecast future consumption by making assumptions about future levels and frequency of use of appliances. At present the model contains 27 different appliances, 4 different dwelling types (single family houses, flats, farmhouses and weekend cottages) and two geographic zones (east/west of Denmark). This results in 216 single forecasts. For each of these forecasts a simple model equation is used:

Electricity consumption	=	Stock of appliances	X	Specific consumption	X	Frequency of use

All factors are a function of time. Thus the stock of appliances is updated every year with new sales and the number of "dead" appliances, the latter estimated through an assumption of a normal distributed longevity for each type of appliance. Specific consumption and frequency of use are tied together for some appliances, e.g. cooling, where the appliance is switched on all the time.

In addition to sales figures, factors are estimated from survey data about average sizes, daily usage, specific washing programme choices, etc. The survey data is collected every second year, where more than 2000 households are asked about their appliance stock, sizes, ages, frequency of use, etc. The data are then weighted and processed and input to the model. This results in a large up-to-date database of information about electricity use in Danish households. The model and results are used in developing energy saving programmes.

The model has been developed and is being maintained in co-operation between the Danish Energy Authority, the Danish Electricity Saving Trust, Eltra, Elkraft System and ELFOR. These organisations also conduct the surveys every second year.

5 FIELD TRIALS OF EUMF IN PARTICIPATING COUNTRIES

Field trials of EUMF have been carried out in participating countries to assess and understand customer responses to energy saving motivators and the technology required to implement them. These trials have focussed on acquiring end use of energy data and then feeding back to customers messages and information based on that data to produce behaviour change and energy saving.

5.1 Effect of feedback and focused advice on household energy consumption

Although Denmark does not have any field trial projects which directly address the estimation of demand elasticity and input of EUMF for smaller customers, a project is being carried out which comprises 1000 family-houses which have electricity producing solar panels installed. Customers are allowed to sell the power they produce back to the supply company for the same price as they bought it. Measurement of import and export is accomplished through a kWh meter which runs in both directions (net metering). The houses are provided with a centrally placed panel containing three lamps, yellow, green and red. The green lamp indicates when they are delivering energy to the network and the red when they are importing. During the test period, the participating customers showed great interest in keeping the green lamp on. Analysis of the production and consumption of the houses, after a period of time, showed a general reduction in electricity consumption in relation to the situation before the equipment was installed. It was concluded that customers wished to reduce imports, keep the green light on and make energy and environmental savings.

A recently finished investigation carried out by ELFOR in Denmark on the attitudes to electricity savings by smaller customers showed that households can be divided into four groups in relation to behaviour:-

- A: 13% of customers will save a lot
- B: 60% of customers will save to some extent
- C: 19% of customers will save only rarely
- D: 8% of customers will never save.

These four groups react quite differently to messages and campaigns. The investigation shows, that campaigns and information on energy conservation from utilities has the greatest effect on groups A and B, as they to a large extent read and use information from utilities. Less effect was observed on groups C and D. Group A and B are reached by campaigns and information, and can be influenced to change behaviour and buy energy efficient appliances. The trial also illustrated that to reach the average customer, the messages and the information must be concrete and very easy to bring into use.

A field trial to determine the effect of feedback advice on household energy consumption and saving has been carried out in Finland. Monitoring was carried out in 105 district heated, single family households. It should be noted that participating households were chosen because they were interested in their energy consumption. Houses were divided into four groups, all householders sent in their end use consumption data and three of the groups received feedback. Two groups received focused advisory material, either on video or as literature. The trial was to analyse changes in energy usage habits and consumption between the different groups.

75% of households were willing to save energy in the beginning of the monitoring programme and stated their wishes to get advice on specific issues. In practice, changes in habits were made in other ways than those intended. Receiving feedback about end use consumption reduced electricity consumption by 17-21%, apart from heat consumption which was reduced on average by 5%. In both cases after feedback, focused advice on energy saving had no further influence. If only advice was given (no feedback), savings were smaller. Video was useful especially in guiding customers in the correct use of heating and air-conditioning equipment and was more useful than literature material in advising how to use technical equipment.

In a follow up research programme, a detailed inquiry was sent 2.5 years after the study was completed to households which participated in the study and energy usage habits were requested. Metered information about electricity, heat and water consumption was received from utilities. The objective of the study was to determine the long time effects of feedback and focused advice on household energy consumption. The trial followed up the energy usage habits and energy savings to determine the constancy of adopted changes in consumption. Almost half of the households were still achieving energy savings in at least one sector (heat, electricity and or water). Voluntary monitoring of consumption was still frequent, and most frequent in households which managed to decrease both electricity and water consumption. Information material was hardly used any more. (Haakana et al. 1998)

With regard to heating for those households who had changed their habits during the first study, consumption habits had generally stayed energy saving friendly or changed to more saving. In electricity and water consumption habits there was more variance on how permanent changes had been. Most households have maintained energy saving habits, but some have returned to energy wasteful habits, especially in washing dishes and using the sauna.

Another field trial involved using energy experts to promote savings locally and was started in the middle of the 90's in a co-operation project "Energy aware housing" between Motiva and VVO (limited company providing housing services). It was seen that there was important link missing between property maintenance and residents use of energy.

Energy experts were volunteer residents, educated at Motiva or energy agencies. No previous experience was required, only motivation and enthusiasm for learning. Experts received an information package, work book, brochures, necessary meters for water flow, temperature and valve position and pressure difference monitoring. The task of the experts was to deliver energy information to residents, board of housing corporation, housing manager and building maintenance company. The energy expert was required to find out the energy consumption of individual houses and identify possibilities for saving energy. The expert is not allowed to make any financial decisions, but may give proposals for improving energy use. The expert provides and gathers energy related information and also helps residents to understand their own consumption habits. Energy expert activities have been productive; on average saving between 5 and 10% in heating energy, 5% in electricity and 20% in the consumption of water.

In the LINKKI 2 Research programme a follow up study of the energy relationship and communication between owner-occupied flats and the experiences of energy experts was evaluated. Regardless of the positive results, some customers consider energy experts activities to be paternalist and insulting of their independence. Also withholding information and lack of co-operation was noticed. One solution could be a clearer definition of tasks and responsibilities. More focus on the social skills of energy experts was needed.

5.2 Customer behaviour

An analysis trial was carried out to understand the quality and impact of energy saving information given to customers when they purchase new end uses of energy. A study "The domestic appliance salesperson as the consumer's information source" surveyed what kind of information is given to customers by domestic appliance sales staff and how staff adapt information to the needs of customers. Material was collected and recorded by test shopping in 58 stores. Among many other things energy consumption issues were discussed in 77% of cases when purchasing fridge freezers, washing machines and tumble dryers, in 72% of cases when purchasing cookers, and 46% for television and 23% for video tape recorder purchases. Generally information provided by sales staff varied from inadequate and misleading to accurate and practically applied. In order to raise the level of knowledge of sales staff, more training is required.

In 1995, a field trial of "Energy saving and customer decision making" was also carried out in Finland in order to understand how customers use and understand energy saving information when they purchase electrical end uses. 60 persons participated in survey and they were divided in three groups according to their knowledge about energy: novices, average and experts. The general level of knowledge on energy issues on average was fairly low. In the survey customers chose one of four refrigerator-freezers on the basis of brochures and one of four household property renovation solutions.

Customers believed that energy conservation is a positive issue but it is not usually considered when alternatives are rated and decisions made. Only Experts considered long term costs. Novices with low level of knowledge wanted a quick on-the-spot saving.

According to the survey, energy saving information should be in monetary terms, not only in kilowatt hours which are not important in customer decision making. Also in this trial customer relied on the expertise of sales persons to give important and meaningful information.

A trial to quantify customer reactions to fuel switching has been carried out in Finland to help understand customer flexibility in using energy and their interest in end uses. The trial aimed at activating the use of wood in support of electricity in domestic space heating, especially during peak electricity demand periods. Two different approaches were tested.

In the first group, information displays were installed to inform customers of the time periods when the use of wood burning was preferred by the electricity company. Three factors were being measured as hourly average values: the surface temperature of the wood stove (to find out when it was used), electricity consumption and outdoor temperature. In addition, the amount of wood used was estimated by the participants themselves by filling a form defined by the electricity company.

The second group of customers received in advance a payment of an amount of money equal to their annual energy bill and the price of their electricity was doubled for the test year. If electricity consumption did not change, their economic balance did not change and the net payment equalled that of the previous year. However, if they used less electricity than before then they obtained an economic benefit and vice versa.

Results of the study showed that in the display group the outdoor temperature compensated electricity use between 1995 and 1996 decreased by 8% and the night time use of electricity increased from 65% to 68%. According to the data analysis (including detailed time-series analysis of each participant) 15% of the wood energy replaced electricity on average, but the variations were large, from 6% to 47%.

In the doubled energy price group the majority of participants did nothing but paid the doubled energy bill with the advance payment. There were some who bought wood or new electric equipment or had a boiler repaired, etc. For this group, the outdoor temperature compensated electricity consumption decreased by 21% and at the same time the share of night time electricity use increased from 59% to 66%.

The results indicate that doubling the price of electricity gives suitable incentives for some customers to change their timing of loads as well as putting up with the inconvenience of fuel switching to the use of wood for heating. The information display did not succeed in timing the use of wood. Because the thermal time constant of wood stoves is large, it cannot be used for demand peak clipping in the traditional sense. It can be used instead as a means of decreasing the overall consumption during a longer cold period during which actual short-term demand peaks occur.

In the field trial of Internet advice services (called “Electricity Doctor”) in Finland, Vatajankosken Sähkö, the utility informed smaller customers of the service by sending them a letter. About 500 customers visited the site during the two week trial period. 180 customers gave their opinions about the service after they had done the audit by answering the Internet questionnaire. 81% of them found the information on the Internet service very or quite useful and about 45% were going to change their electricity consumption habits. 10 customers attended face-to-face interviews. Adato Energia Oy is now selling this internet-based energy audit product to other utilities to be put on their Internet Web pages.

5.3 Billsaver Trial

The Billsavers trial, which began in the UK in 1992, focussed on identifying opportunities for using energy-efficiency measures as a means of combating fuel poverty. However, in order to attract investment to fund the purchase of energy efficient appliances for low-income households, it was necessary to prove that the cost associated with running inefficient appliances outweighed the cost of purchasing new appliances. Therefore, accurate end-use data was collected about the energy used by individual appliances.

In the first phase of the trial, the energy used by existing appliances and lighting was monitored over a period of 12 months in 100 low income households in Edinburgh. Traditional meters were installed in the supply to the major appliances, i.e. washing machines, fridges, freezers, cookers. Lighting circuits were also metered. The meters were located out of sight, so that the householders themselves were not readily able to access information on the energy use of their appliances. During the 12 month trial, the meters were read fortnightly and householders were asked to keep an energy diary documenting the usage of their appliances on a week by week basis.

At the end of the 12 month period, various energy saving measures were implemented in the houses and monitoring continued for a further 12 months. The energy saving measures implemented were:

- replacement of selected incandescent light bulbs with energy efficient compact fluorescents in all households
- provision of appliance specific energy advice to all households
- replacement of inefficient appliances with more efficient models in selected households

The Billsaver trial generated a significant data on the end uses of energy, and a summary of some of the results of the project is shown in Table 4 and Table 5. The Tables show the mean annual energy consumption by specific appliances over two 12 month periods for two groups of households; the control group and the group of households in which selected appliances were replaced. The first 12 month period (i.e. the ‘Before’ column) represents the base-line consumption, and the second 12 month period (i.e. the ‘After’ column) indicates the energy consumed after the replacement of inefficient appliances in selected households.

Table 4 Mean changes in annual appliance energy consumption for low income households

Appliance	Control Group			Appliance Replaced		
	Mean annual kWh			Mean annual kWh		
	Before	After	Difference	Before	After	Difference
Fridge	262	269	2%	534	209	-61%
Freezer	398	436	10%	780	402	-49%
Washing Machine	153	148	-3%	527	505	-4%

Table 5 Mean changes in annual appliance energy consumption for higher-income households

Appliance	Control Group			Appliance Replaced		
	Mean annual kWh			Mean annual kWh		
	Before	After	Difference	Before	After	Difference
Fridge	243	246	1%	383	237	-40%
Freezer	434	455	5%	803	391	-51%
Washing Machine	202	192	-5%	170	183	7%

The results of the trial show that where inefficient fridges and freezers were replaced with newer, efficient models there was a marked reduction in energy consumption associated with these appliances. However, these results were not replicated when inefficient washing machines were replaced, with no significant differences in energy consumption found between the two 12 month periods. This is thought to be due to the influence of behavioural factors.

All households were offered energy efficiency advice in the form of leaflets at the end of the first 12 month period. However, the results of the trial suggest that these leaflets had no discernible impact on energy consumption in the following 12 month period. While this may suggest that such information is ineffective, it does not take into account the possibility that participants involved in the trial may simply have become more aware of their energy consumption during the trial, particularly through the completion of their energy diaries, and that energy savings could have been realised earlier in the project.

5.3 Energy Management Unit Trial

A field trial involving 500 domestic customers was carried out in the UK to test the effect of feedback on energy consumption. Multi-rate meters with a customer display were installed and customers were allocated one of two multi-rate tariffs, one having seven different rates, and the other with three different rates. During the 12 month trial, the resultant change of load shape of the customers and their attitudes to multi-rate tariffs was evaluated together with the field trial performance of the multi-rate meters.

The results of the trial showed that for those customers previously on a standard flat rate tariff there was no discernible change in consumption, but their annual bill was reduced by an average of 8%. In the case of customers previously on a night/day tariff, there was a slight reduction in electricity consumption but only a slight reduction in annual costs of 1%. However, it is important to note that a reduction of 4% in electricity costs would have been achieved by customers previously on the flat rate tariff if they too were on the night/day tariff. There was some evidence of customers shifting their pattern of energy use in response to the multi-rate tariff.

A field trial of Energy Management Units in the UK involved econometric analysis to determine the price elasticity of domestic customer to understand their attitude towards multi-rate tariffs. The analysis showed that the 'self-price' elasticity of those taking part in the trial was between -0.1 and -0.5, with the 'cross price' elasticity found to be smaller. It is important to note that the energy consumption of customers taking part in this trial was only monitored for a period of 12 months, so that these results only provide an indication of short term behaviour.

5.4 Energy Management Unit Trial

The impact of feedback on customer energy consumption was evaluated in a field trial in the city of Bath in the UK involving 120 households. The trial compared six different forms of feedback. The households were divided into seven groups, with six receiving feedback of their energy consumption on a monthly basis and the seventh receiving no feedback, i.e. the control group.

The six forms of feedback comparisons were evaluated during the trial were:

1. **self versus others comparison**, where the households received feedback on their energy consumption compared to the average of other similar households in the trial

2. **self versus self comparison**, where households received feedback on their energy consumption compared to their own consumption in the same period during the previous year, corrected for weather

3. **financial feedback,** where the households received a monthly statement of their energy consumption in both kWh and monetary terms

4. **environmental feedback**, where the households received a monthly statement of the environmental impact of the energy they consumed

5. **general feedback,** where the households were provided with a full literature pack containing general energy advice leaflets at the start of the project, together with a monthly graph of their energy consumption

6. **computer feedback,** where the households where provided with a PC displaying information on current consumption, a comparison with consumption in the previous year and general energy saving information

As well as performing statistical analysis on the relationship between rented or owner occupier, number of occupants and energy efficiency attitudes on energy consumption levels before the trial, the study also included an analysis of factors affecting the change in energy consumption level during the trial. The study found that medium and high energy users were more likely to reduce their consumption than low energy users. However, in terms of the effect of the different forms of feedback, the only significant difference was in the case of the feedback via computer. Within this group, over 80% of the households reduced their energy consumption compared to only 55% averaged across the other groups, and they also made the biggest savings in energy consumption.

5.4 Mansouri and Newborough Trial

An interesting study was carried out by Mansouri and Newborough during the late 1990's. Their study was concerned with reducing energy consumption of the existing stock of domestic electric cooking appliances by influencing consumer behaviour at the point of use. Therefore, their study is somewhat unique in that they did not seek to promote the uptake of more energy efficient appliances, but to promote the adoption of more energy efficient practices. Cooking was chosen as it was felt that this presented the best opportunity for householders to modify their behaviour in ways that would lead to a reduction in energy consumption. For example, in terms of behavioural changes, there are very limited options that householders can take in relation to the operation of appliances such as fridges and freezers. However, there is a range of energy saving measures that householders can take in order to reduce the energy consumption for cooking, such as:

- using a microwave oven instead of a conventional oven
- using a toaster instead of a grill
- switching off the oven or hob a few minutes before the end of the cooking time
- using well fitting lids on pans
- simmering instead of boiling

They selected a sample set of houses and divided them into four groups with three of the groups receiving feedback and the fourth acting as a control group. Each of the three feedback groups were exposed to a different method of influencing end-use behaviour, namely:-

- **Group1:** A detailed energy information pack giving advice on the energy consumption of cooking appliances, energy consumption comparisons for different cooking methods and electricity saving tips. The information pack also enabled users to estimate the electricity consumption of cooking appliances in their home.

- **Group 2:** An energy consumption indicator (ECI), giving information on actual energy consumption and its associated cost, together with a comparison against historical usage

- **Group 3:** Households within this category received both the information pack and the ECI

- **Group 4:** Control Group, in which the householders received neither the information pack nor the energy consumption indicator

The electricity consumption of the cooking appliances in these three groups was monitored for a minimum of 16 weeks, with 8 weeks monitoring before introducing the feedback and 8 weeks afterwards. The control group was monitored over a period of 12 months to collect information about the statistical variation in consumption both between households and within households across the different seasons.

It was not known how customers would want to interact with the ECI, so it was designed to be as flexible as possible. In particular, the design was such that it would cater for those users who wished to interact with the display while cooking, e.g. to observe changes in energy consumption while cooking, but also to allow users to interact with the display after an event in order to determine the energy consumption associated with that event and make comparisons with historical events. The final design of the interface is shown in Figure 4.

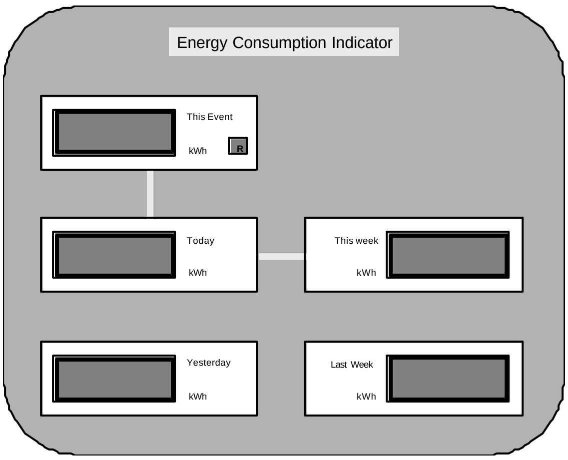


Figure 4 An energy consumption indicator

The energy values were derived from a current transformer attached to the mains supply cable to the cooker, with an assumed voltage of 240V. Thus the following results relate to the electricity consumed by the cooker. The study does not appear to take account of any additional electricity consumption by appliances such as toasters or microwave ovens that might be used as alternative means of cooking.

The sample size was very small[*], which makes it difficult to obtain statistically meaningful results, particularly when factors such as the number of occupants are also taken into account. Of the 12 households in Group 1 (i.e. those receiving only the information pack), eight households achieved a reduction in their average daily energy consumption, with three households achieving a reduction of greater than 10%. The average energy savings achieved with Group 2 were substantially higher (14%), with 7 out of the 10 households achieving a reduction in their average daily energy consumption of more than 10%. In Group 3, the average daily energy reduction across the 9 households was 4%, but this was distorted by an increase of 31% in one household due to a lifestyle change during the course of the trial. Excluding the results of this household, the average daily energy consumption for the remaining 8 households was 9%, which is less than that achieved by the householders within Group 2. A summary of the results of the trial is shown in Table 6.

Table 6 Summary of the results of the trial

Group	No. of households in trial	Average change in energy consumption	Range of energy reductions achieved*
1: Information Pack	12	-3%	-1% to 13%
2. ECI	10	-14%	-5% to -39%
3. Information Pack and ECI	9	-4%	-2% to -27%

(*) for households with a reduction in energy consumption

Although care should be taken due to the small sample size, the results indicate that the ECI is more effective than the information pack at motivating householders to modify their behaviour and reduce their electricity consumption. However, there does not seem to be any compound effect of providing householders with both the ECI and the information pack. It is important to note that during the study, householders were not given any specific instruction to save energy. Thus, those householders in Group 2 who did not receive any tips on how they may be able to reduce their energy consumption, identified ways themselves to achieve average savings of 14%. It is not clear why the energy savings achieved by Group 3 (information pack and ECI) were less than that for Group 2 (ECI only), but one possibility is that Group 2 householders were simply "over-whelmed" by the amount of information available to them.

6 ANALYSIS OF EUMF METHODS, COSTS AND IMPACT

The previous chapters have identified and presented techniques and methodologies for disaggregating energy end use demand and feeding the information back as an energy saving motivator.

Energy end use data feedback methods quantified were :-

- Additional data on the energy bill
- Customer display of end use
- Face to face interviews and advice
- Internet based feedback
- Local area action group feedback
- National programmes combined with environmental damage messages

Energy end use feedback information content considered :-

- Individual customer end use disaggregated demand and impact on cost and environment together with energy saving tips for each end use

- Peer to peer comparison of total energy used and disaggregated energy use

- Individual customer information on what the impact has been of taking end use energy saving measures

- Total energy used comparison within a customer group and loose peer to peer comparison of end uses of energy. Targeted energy saving advice provided based on group end uses and lifestyles

- Information based on national or area statistics of general end uses of energy. The environmental impact of general population end use of energy and ways in which it can be reduced. Customers split mainly into electric and non-electric heated homes so as to loosely target energy saving information.

Energy end use disaggregation methods quantified were :-

- Correlation at the individual meter position of the actual, major end uses of energy for each customer

- Sub metering and data collection of the major end uses of energy for each customer

- Periodic face to face or Internet based interviews to derive estimates of the statistical end uses of energy for individual customers. This end use estimated data would be combined with the total, metered, energy used to produce estimated end uses of energy. More frequent meter reading would increase the accuracy of this methodology

- Estimated disaggregation of end uses for global populations based on samples of customers on a national or area basis and applying these to electric and non-electric heated households. This would enable very approximate end uses of energy to be derived for each customer by applying the national or area data statistics to total KWh meter readings.

6.1 Cost and Benefits

All the above techniques and methods for collecting, deriving and feeding back end use of energy data and statistics will cost money. Generally, the more refined and detailed the information, the more expensive will be the process for collecting it. However, the more accurate and customer specific the feedback data, the more powerful and targeted can be the energy saving messages which can be delivered and probably the larger the savings.

6.2 Analysis of Saving Benefit

In order to identify a path through the application of the different options, estimates of the benefits of savings made from financial, environmental and societal perspectives have been made. These potential benefits from reduced and wiser energy use by smaller customers can be estimated using national data for CO_2 savings, based on energy savings from electricity production. This national data depends, for electricity, on the mix of generation sources used. For the UK with a mix of coal, gas, nuclear and small amounts of hydro and wind power, the average CO_2 emitted per kWh is 0.37kg. A figure of 60 Euro per 1000 kg of CO_2 is used in evaluation studies to estimate the financial value in CO_2 in terms of energy saving measures. This is a societal value based on perceived benefits of CO_2 reduction.

Based on these figures, the value in monetary terms of saving KWhs and CO_2 using EUMF for smaller customers can be estimated. Other country generation mixes can be very different to that of the UK so that different figures need to be used for each country. However, figures used in several of the participating countries are likely to be lower in many cases than in the UK because of larger hydro contributions. Consequently, the use of UK figures provides a somewhat optimistic value of what can be attributed to savings. Offsetting this to some extent is that where hydro power is most prevalent is where the climate is generally colder. Consequently the energy use for smaller customers is likely to be greater and actual savings in KWhs greater based on the same percentage savings.

On the basis of an electrically heated household consuming 10000 KWhs per annum and a 10% saving as a result of EUMF, the total financial saving per annum from KWhs and CO_2 are :-

Financial Savings per annum = Savings on KWh + CO2 savings

$$= 10000 \times 10\% \left(0.1 + \frac{0.37 \times 60}{1000}\right)$$

= 122 Euro per annum

10 Euro Cents per KWh has been used in this calculation as the price of electricity for smaller customers.

The majority (80%) of the savings result from the saving in KWh rather than from environmental benefits. The savings would be less for non-electric heated households and also where off peak (half price) electricity was used for space heating (storage).

Impact of Savings Valuation on EUMF Viability

An important objective of this study is to address how much EUMF can be justified in order to deliver the saving valued of 122 Euro per annum. Who should actually pay for the investment is beyond the scope of this report.

Because the majority of the financial savings accrue to customers, and only 20% to society as a whole, there is logic in saying that investing in energy saving measures and lifestyle changes should be left to customers and market forces. However, as has been presented in many of the field trials described in Chapter 5, customers in general do not consider energy end use costs as high priority for saving based on the financial benefits. More saving impact has been obtained by promoting the environmental value to society of saving and using energy more wisely. Maybe the societal monetary value used for CO_2 saving is too low.

Quantifying the detailed impact of EUMF resulting from the different levels of disaggregation and feedback is not possible from the data contained in the field trial studies. Also the costs of applying different EUMF methodologies on a wide scale, to millions of customers are not possible to quantify from the field trial information. In order to make some sort of estimate of what may be reasonable in terms of providing customers with EUF data, a breakdown of how the different EUMF methods could be applied has been carried out.

6.3 Presenting End Use Data and Energy Saving Advice to Customers

6.3.1 Energy End Use Data on the Energy Bill

Adding end use disaggregated data to the energy bill is not likely to be a particularly expensive option in itself. Also included on the bill would need to be energy saving advice based on energy end use breakdown. Obviously there are physical limits to what can reasonably be included in the bill while acknowledging that the bill and its payment are the most important items. There is also a limit as to how much additional information customers are prepared to absorb from the bill. However, the additional costs of promoting end use disaggregation and energy saving data on the bill should not be a major factor in preventing its delivery.

6.3.2 Customer Display of Energy End Use Data

Providing customers with an easy to understand electronic display of end use of energy together with energy saving advice is likely to be quite expensive for smaller customers. For the display to be valuable and have impact it needs to be regularly updated which probably means that it must be linked to a communications system. The display could be part of a “smart” meter but meters are generally not readily visible in order for the messages to have impact. Using the TV as a display medium has attractions and is possible if linked to an “in house” communication bus.

The cost of this remote display option is likely to be high compared to the financial value of the energy savings. However, with the growth of remote meter reading techniques and remotely managed home services, the incremental cost of adding end use energy and saving data could be relatively small in future.

6.3.3 Face to Face Interviews to Feedback Data

This option would require a periodic visit to each customer by an energy advisor. The advisor would collect and process end use appliance and lifestyle data and produce disaggregated end uses of energy and the cost of using each appliance together with the environmental impact and specific advice to deliver savings. The cost of this activity is difficult to quantify at this stage but is similar to the Netherlands trial of community based energy advisors. This service could be an Energy Service Company (ESCO) function which is used now for larger customers to deliver energy audits of industrial processes. It could be carried out on a shared savings basis although the relatively small financial savings estimated in this report may not be sufficient for commercial viability. An approximation to the costs of such a service can be approached by considering the manual meter reading task currently performed for smaller customers. The cost of this service is a few Euros per year per customer. An ESCO service would take many times longer than to read meters and would also require more skilled personnel. However, if these additional requirements resulted in a 20 times increased in the cost of the ESCO service, it results in a cost of perhaps 100 – 500 Euro per customer per visit. The service is unlikely to be accepted by customers more frequently than once every several years.

6.3.4 Internet Based Feedback of End Use Data

This is a service which requires customers to take positive action in order to get energy saving data and advice so that the major disadvantage is that it is likely only to appeal to the seriously energy conscious customers. Linking the customer metered data to an Internet based questionnaire and data analysis and feedback process should not be particularly expensive and has already been done in Denmark and in a trial in

Netherlands. Access management to confidential meter data would be an important issue but is unlikely to be particularly expensive per customer.

6.3.5 Local Area Action Group Feedback of End Use Data

This is a sub set of the face to face interview process but would have the additional feature of area meetings and peer pressure to deliver energy savings. The public exposure would not be welcomed by many customers as confirmed in the Netherlands study. The process could be lower cost to implement than the individual face to face interview option but may be less effective in achieving customer participation.

6.3.6 National Feedback of Energy End Use Data

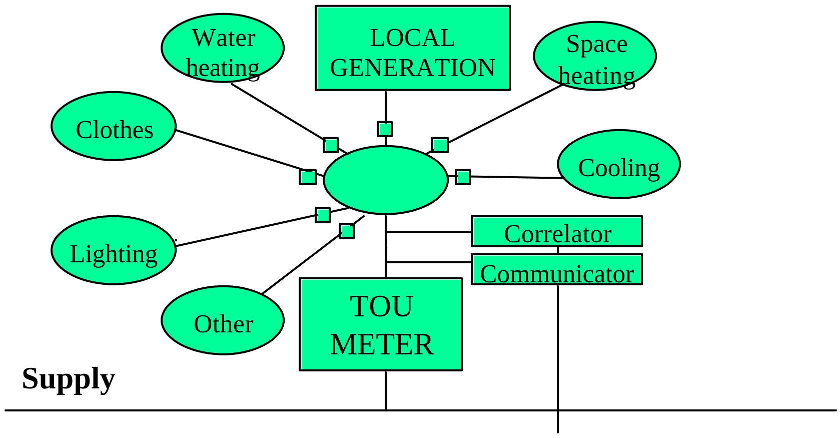
This option provides feedback of energy use statistics to customers based on estimated disaggregation of the national demand. Feedback information presented in TV adverts or included in the energy bill is likely to be relatively low cost per customer to implement. However, it is also likely to be only marginally effective in motivating customers to save energy. This process is already carried out in countries participating in this project. However, if the disaggregated data was linked to the energy bill and the environmental impact of end uses by the average customer also presented, this could increase the energy saving impact.

6.4 Collecting and Deriving Energy End Use Data

6.4.1 Correlation of End Use Signatures to Collect Data

This process is described in detail in Chapter 4 and is capable of collecting at the meter position, end use data of the major loads. However, it is likely to be relatively expensive for permanent installation at smaller customer premises. It is also likely that remote communication systems would be required to read the data. A cost of possibly 2000 Euro each has been estimated as the cost for small numbers. However, even if reduced by a factor of four for mass production, units would still be quite expensive in the context of smaller customer energy savings. The upkeep of an end use signature database would also incur a reasonable cost.

Figure 5 End Use Data Collection



6.4.2 Sub Metering to Collect End Use Data

Sub metering of energy end uses is a straightforward process of installing simple current or kWh accumulator devices in the supply to end uses. The process can be carried out with less accuracy by installing timers in each major end use. However, the end use accumulators require accessing in order to collect the stored data. This process will be relatively expensive for smaller customers and probably requires an "in house" communication bus. Again the cost of this process would not be high if a communication bus were already in place to deliver other household services such as alarms, etc. These systems are likely to be common in the not too distant future.

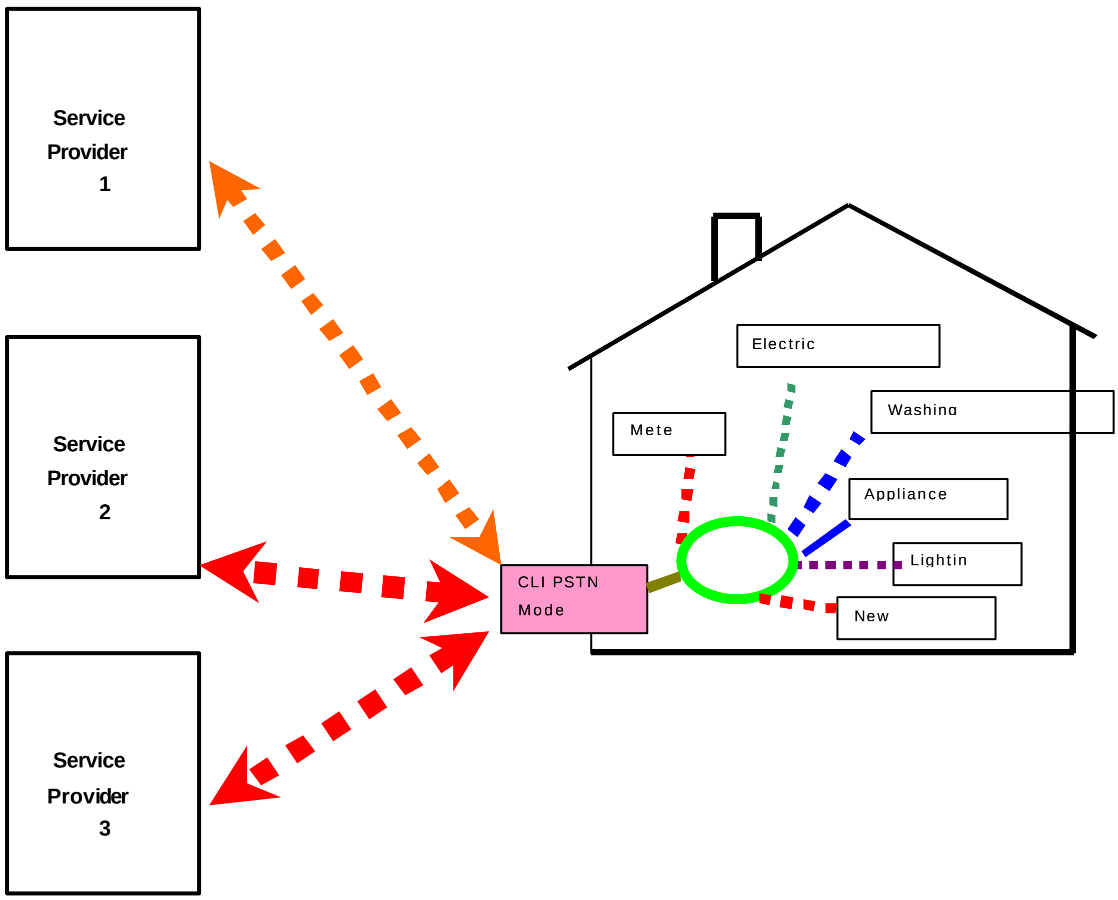


Figure 6 End Use Customer Services

Another possibility for the future is to require manufacturers of end use devices to provide a display on the actual appliances of environmental impact in KWhs, CO_2 or some other variable. The display part of this requirement would be inexpensive at the manufacturing stage but deciding what should be displayed could be more difficult and politically sensitive. The calibration of the displayed data in environmental terms could also be a factor as more renewable energy is used.

6.4.3 Periodic Face to Face and Internet Interviews to Collect End Use Data

This process requires a trained person to periodically interview customers regarding end uses of energy and the specific impact on their lifestyle. This process could be made relatively automatic based on key questions and answers. The process could also be carried out using the Internet. The data collection and feedback processes would need to be carried out at the same interview so as to minimise costs and maximise impact. Estimated costs for this face to face data collection, disaggregation feedback and energy saving advice are the same as those for the face to face feedback option. These are of the order of several hundred Euros per visit. Visits every few years are likely to be required.

6.4.4 Collecting National Statistics on End Use Data

This process is carried out already in most of the participating countries using samples of customers and extensive monitoring using remote communication. The process of creating estimated end uses of energy for the average customer is relatively inexpensive per customer but only provides general statistical data. One of the UK field trial results concluded that customers did not attribute much value to comparison of their energy use against general statistics.

Table 7 Summary of EUMF Options

METHOD OF DATA COLLECTION	COST OF DATA COLLECTION	POTENTIAL IMPACT	END USE DATA QUALITY	FEEDBACK METHOD
Correlation or End Use Sub Metering	High	High	Specific customer end use data. Accurate data	Bill and/or Display
Face to Face or Internet Interview	Low to Medium	Medium	Specific customer end use estimates. Reasonably accurate specific customer data	Face to Face
Monitoring of Sample Customers	Low	Low	General customer end use data. Inaccurate specific customer data	Bill and/or Adverts

7 CONCLUSIONS

Energy efficiency and energy saving are recognised as having fundamental roles in the goals of Governments to reduce carbon dioxide emissions, with the smaller customer sector expected to make a substantial contribution to the overall targets. While there are many measures and policies in place to increase thermal insulation in houses and improve energy efficiency of appliances, the behavioural impacts of customer is recognised as having a key-role in reducing energy consumed by households. There is still a long way to go to achieve the optimum economic balance, especially with energy prices reduced by competitive markets. Significantly increasing energy prices to include environmental damage factors is difficult politically, with a requirement of governments also to protect low income households. Consequently in order to complement and augment the energy saving measures already carried out, there is an opportunity to encourage customers to make minor lifestyle changes in order to save energy.

Feeding back detailed information to customers using a range of methodologies has been shown to this study to motivate energy savings by smaller customers of the order of 10%. The results of the field trials work in this report suggest that customers respond well to direct feedback of information on their energy use. For example, in the Mansouri and Newborough study the energy used for cooking was reduced by more than 10% in 7 out of 10 households that were provided with a display providing information about the energy use of their cooker. Similarly, the installation of key pad meters in households in the Northern Ireland Electricity trial led to an 11% reduction in electricity bills. Denmark has been promoting lifestyle energy savings among all customers for the past 30 years using advertising and promotional campaigns. A survey showed that 70% of smaller customers would make changes to save energy if they were advised how to do this and it also involved little inconvenience.

No definitive method for feeding back end use data and energy saving motivator advice has emerged from this study. Improved metering and display has been shown to be attractive to samples of customers. Adding general, national, end use statistics to the energy bill is not highly regarded by customers but specific customer end use information is regarded highly. Consequently there is a major technical and economic challenge to collect and derive cost effective end use data and feed it back to customers. If systematic and reliable end use information for individual customer were established, and this was combined with simple and effective advice and messages, then EUMF would be an important methodology in influencing demand.

From the information and analysis of end use disaggregation and feed back methods and field trials presented in chapters 3, 4 and 5 it is possible to make broad conclusions about the potential viability of EUMF to motivate savings of energy for smaller customers. From the summary of findings and analysis in Chapter 6, the financial savings available to justify investment on a commercial basis are quite small. The savings resulting from the application of EUMF to direct electric heating customers was estimated at 100 Euro per year per customer. In order to consider financial, ball park viability for the different methodologies, estimates have been made of relative costs for the energy end use data collection feedback methods. These relative estimates indicate that actual direct measurement of specific customer end use of energy on a continuous basis is probably too expensive for wide scale application to smaller customers. This direct measurement process includes end use sub metering and end use signature correlation methods. The only situation which contradicts this view is where individual appliances are fitted with a direct display when manufactured, showing the financial and environmental cost of use. This is only true if a communication system is not required in order to update the display.

Estimates of the relative costs of face to face and Internet interviews with customers to both collect data and feedback processed end use data and advice show this to be an attractive option with low to medium costs yet having potentially high impact. It is a role similar to that carried out by ESCOs where shared savings are used to off set some of the costs. In order to be effective, a computer model would be required to process the face to face collected data immediately and deliver end use derived data and saving advice together with projected benefits to customers. Estimates of the cost saving and environmental value of national disaggregated end use data targeted at broad customer categories such as those with electric heating are considered to have only a low impact. However, all participating countries have this data available, particularly as a result of competitive energy markets where understanding actual profiles of energy use allows competitive tariffs to be offered. This information and advice could be included in the bill at little extra cost. Although the impact is likely to be low, it would help develop customer awareness of energy use and potential savings.

EUMF motivator messages have been shown to encourage customers to replace energy inefficient end uses with efficient ones. This has required customers to change their spending priorities so that end uses have been changed not just because they were life expired but because they were energy inefficient. These messages can also motivate customers to increase the expenditure priority of such things as improved thermal insulation of their houses. This is the same motivator which encourages customers to draw curtains at night, ensure that thermostats are not set too high, minimise draughts, part fill kettles, use low temperature wash programmes where possible, etc.

With the general progress of remote metering scheme implementation in many countries, as well as the prospect of smart homes which include communication buses, the collection of actual energy end use data will become a lower cost activity in future. Customer displays will also become more common within households in order to provide access to smart home systems. These displays can be used for end use data and energy saving advice feedback and presentation.

Within the next 5 years in Denmark will change at least 700.000 meters in the domestic sector to remote reading and provide bi-directional communication; this corresponds to almost 25% of all meters in the sector.

By 2009, the meters of all profiled customers in Sweden will be read monthly, probably to a large extent remotely. This will lead to a monthly bill based on factual consumption. Consumers will also have additional information on Internet or on the bill.

7.1 Summary of Conclusions

Broad conclusions from this study can be summarised as:-

- Domestic energy use has risen sharply over the past few decades. It is likely to continue to rise. Motivating customers to save energy can reduce that projected rise.
- EUMF can be used to motivate smaller customers to achieve a 10% saving in energy use.
- Different energy use, feedback and saving presentation methods have been assessed with the face to face customer interview being a preferred method.
- Different energy use disaggregation methods have been assessed with the face to face customer interview together with total metered data preferred.
- Field trials of EUMF show that customers can be motivated to save energy if they are presented with easy to absorb information and the required actions needed are easy to carry out. Customers are also likely to require continuous reminders to save energy.

8 RECOMMENDATIONS

Studies should be carried out to quantify the specific energy saving impacts resulting from the different methods of energy end use disaggregation considered in this report. This would help answer the question of how accurate the end use data needs to be to have significant impact. This would also deliver more accurate estimates of the implementation costs for EUMF and the energy saving benefits of each method.

Studies should be carried out to quantify the specific value of the different feedback methods described and analysed in this report. Assessments should be made of the costs of implementing the different processes and the impact of each process on customer motivation and demand elasticity. Consideration should also be given to increasing the financial value attributed to the saving of CO_2.

Detailed costing of the face to face interview methodology for collecting and deriving approximate end use data and delivering feedback and energy saving advice should be carried out. Of particular relevance would be how to motivate customers to attend the energy saving interviews. It may be possible to include the saving of other resources such as water in the same process to help achieve viability.

End use disaggregated energy data statistics available now in many countries for national populations should be added to smaller customer energy bills in order to prepare them for more detailed measures in future and to start the education process of making them more aware of end use costs and environmental impacts.

Models should be developed or existing ones enhanced so as to quickly convert information collected at a face to face customer interview into end uses and energy saving advice.

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"Econometric investigation of the electric energy consumption in Greece", study assigned by of Public Power Corporation S.A. in Economy University of Piraeus (1989).

"Pricing measures for the electric energy saving" by Dimitrios Voumvoulakis Ass. Manager of the Retail Department (March 1999) supported in the "Estimates on the demand and offer of energy in period 1986-2000" by A. Diavolitsi and S. Balfousja (Hellenic Centre of Economics Researches 1986) and in the "Econometric investigation of the electric energy consumption in Greece", by Economy University of Piraeus (1989) about the price elasticity of the demand are the following:

Netherlands

Spain

Overview of the International Energy Agency (IEA)
and the IEA Demand-Side Management Programme

The International Energy Agency

The International Energy Agency (IEA), established in 1974, is an intergovernmental body committed to advancing security of energy supply, economic growth, and environmental sustainability. The policy goals of the IEA include:

- diversity, efficiency, and flexibility within the energy sector,
- the ability to respond promptly and flexibly to energy emergencies,
- environmentally-sustainable provision and use of energy
- development and use of more environmentally-acceptable energy sources,
- improved energy-efficiency,
- research, development and market deployment of new and improved energy technologies, and
- undistorted energy prices
- free and open trade
- cooperation among all energy market participants.

To achieve those goals, the IEA carries out a comprehensive program of energy cooperation and serves as an energy forum for its 26 member counties.

Based in Paris, the IEA is an autonomous entity linked with the Organization for Economic Cooperation and Development (OECD). The main decision-making body is the Governing Board, composed of senior energy officials from each Member Country. A Secretariat, with a staff of energy experts drawn from Member countries and headed by an Executive Director, supports the work of the Governing Board and subordinate bodies.

As part of its program, the IEA provides a framework for more than 40 international collaborative energy research, development and demonstration projects, known as Implementing Agreements, of which the DSM Programme is one. These operate under the IEA's Energy Technology Collaboration Programme which is guided by the Committee on Energy Research and Technology (CERT). In addition, five Working Parties (in Energy Efficiency, End Use, Fossil Fuels, Renewable Energy and Fusion Power) monitor the various collaborative energy agreements, identify new areas for cooperation and advise the CERT on policy matters.

IEA Demand Side Management Programme

The Demand-Side Management (DSM) Programme, which was initiated in 1993, deals with a variety of strategies to reduce energy demand. The following 17 member countries and the European Commission have been working to identify and promote opportunities for DSM:

Australia	Italy
Austria	Japan
Belgium	Korea
Canada	The Netherlands
Denmark	Norway
Finland	Spain
France	Sweden
Greece	United States
	United Kingdom

Programme Vision: In order to create more reliable and more sustainable energy systems and markets, demand side measures should be the first considered and actively incorporated into energy policies and business strategies.

Programme Mission: To deliver to our stakeholders useful information and effective guidance for crafting and implementing DSM policies and measures, as well as technologies and applications that facilitate energy system operations or needed market transformations.

The Programme's work is organized into two clusters:

- The load shape cluster, and
- The load level cluster.

The 'load shape" cluster includes Tasks that seek to impact the shape of the load curve over very short (minutes-hours-day) to longer (days-week-season) time periods. The "load level" cluster includes Tasks that seek to shift the load curve to lower demand levels or shift loads from one energy system to another.

A total of 15 projects or "Tasks" have been initiated since the beginning of the DSM Programme. The overall program is monitored by an Executive Committee consisting of representatives from each contracting party to the Implementing Agreement. The leadership and management of the individual Tasks are the responsibility of Operating Agents. These Tasks and their respective Operating Agents are:

Task 1 International Database on Demand-Side Management &
Evaluation Guidebook on the Impact of DSM and EE for Kyoto's GHG Targets
Harry Vreuls, NOVEM, the Netherlands

Task 2 Communications Technologies for Demand-Side Management - *Completed*
Richard Formby, EA Technology, United Kingdom

Task 3 Cooperative Procurement of Innovative Technologies for Demand-Side Management – *Completed*
Dr. Hans Westling, Promandat AB, Sweden

Task 4 Development of Improved Methods for Integrating Demand-Side Management into Resource Planning - *Completed*
Grayson Heffner, EPRI, United States

Task 5 Techniques for Implementation of Demand-Side Management Technology in the Marketplace - *Completed*
Juan Comas, FECSA, Spain

Task 6 DSM and Energy Efficiency in Changing Electricity Business Environments – *Completed*
David Crossley, Energy Futures, Australia Pty. Ltd., Australia

Task 7 International Collaboration on Market Transformation
Verney Ryan, BRE, United Kingdom

Task 8 Demand-Side Bidding in a Competitive Electricity Market - *Completed*
Linda Hull, EA Technology Ltd, United Kingdom

Task 9 The Role of Municipalities in a Liberalised System *Completed*
Martin Cahn, Energie Cites, France

Task 10 Performance Contracting *Completed*
Dr. Hans Westling, Promandat AB, Sweden

Task 11 Time of Use Pricing and Energy Use for Demand Management Delivery
Richard Formby, EA Technology Ltd, United Kingdom

Task 12 Energy Standards
Frank Pool, New Zealand

Task 13 Demand Response Resources
Ross Malme, RETX, United States

Task 14 White Certificates
Antonio Capozza, CESI, Italy

Task 15 Network-Driven DSM
David Crossley, Energy Futures Australia Pty. Ltd, Australia

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Also, visit the IEA DSM website: http://dsm.iea.org