Task XI

Time of Use Pricing and Energy Use for Demand Management Delivery

Final Report

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International Energy Agency Demand-Side Management Programme
Task XI: Time of Use Pricing and Energy Use for Demand Management Delivery

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IEA DSM REPORT - EXECUTIVE SUMMARY

TASK XI FINAL REPORT

TIME OF USE PRICING AND ENERGY USE FOR DEMAND MANAGEMENT DELIVERY

Background

Many countries are concerned that liberalised markets may not deliver adequate peak electricity generation and network capacity. The domestic sector consumes between 20% and 40% of electricity in developed countries and is very attractive for energy saving. Customers can save energy by reducing use and shifting use from high to low demand times. Savings are achieved by increasing the propensity of customers to purchase energy efficient end uses, changing their behaviour to reduce thermostat settings, use hot water and lighting more wisely, reduce system losses and reserve generation and increase off peak space for wind generation.

Objectives

The objectives of Task XI are to determine whether and how smaller customers can participate in demand markets and change end use behaviour to deliver energy saving, reduced energy costs and maintain supply security.

Approach

Three mechanisms, by which smaller customers can save energy and assist system security have been developed and evaluated.

- End Use Monitoring and Feedback (EUMF), where customers are presented with a breakdown of their individual end uses of electricity, its costs and environmental impacts.
- Time of Use (TOU) and Dynamic TOU pricing, where customers are presented with different prices at different times and respond by shifting demand from high to low price periods.
- Demand Side Bidding (DSB), where customers participate in energy trading, by contracting and delivering specific demand changes in response to requests by System Operators or Suppliers.

This study has analysed work carried out and results of trials of EUMF, TOU pricing and DSB involving smaller customers in the participating countries. It has also considered the impact that dynamic demand changes could have on profile settlements systems and methodologies for validating that participating customers have responded to requests for demand change. Analysis has also been carried out into end use demands which could respond to dynamic TOU pricing, aggregated and made available to System Operators as part of DSB processes.

Response modelling and communication and metering mechanisms, to enable payments to be made to customers participating in DSB, have been considered for each Demand Response (DR) delivery process.

Approach (cont'd)

Five reports have been completed:

Subtask 1 - Smaller Customer Energy Saving by End Use Monitoring and Feedback (July 2005)
Subtask 2 - Time of Use Pricing for Demand Management Delivery (Sept 2005)
Subtask 3 - Demand Side Bidding for Smaller Customers (Sept 2005)
Subtask 4 - The Impact of Dynamic Demand Changes on Profile Settlement Systems (Oct 2007)
Subtask 5 – Demand "available" and "turndown" Mechanisms for Market Bidding of Smaller Customer Demand (Oct 2007)

Results

Task XI has quantified the potential of EUMF, TOU pricing and DSB mechanisms to deliver demand reductions and energy savings. It has also provided routes dealing with dynamic profile changes in profile settlement for systems and rewarding DSB participation.

Monetary savings resulting from the application of EUMF (Task XI Subtask 1) to direct electric heating customers have been estimated to be worth approximately 100 Euro per year per customer. Clever and very "smart" meters have been considered for the provision of limited, demand disaggregation information as alternatives to customer interviews.

Task XI Subtask 2 has estimated the financial viability of implementing different TOU pricing regimes by equating reliable and flexible demand shift with scheduled generation, transmission and distribution network construction costs. The financial benefits, available to motivate smaller customers to participate in TOU pricing, are not large.

Task XI Subtask 3 has shown that there is a role for smaller customers to bid demand to assist system operation, improve supply security and reduce supply costs. The study has shown that unobtrusive as well as obtrusive management of end uses of energy may be possible in order to enable smaller customers to be "available" for automatic "turn down" of demand.

Dynamic TOU and Critical Peak pricing, if widely applied, will have an impact on profile settlements as examined in Subtask 4. If the profile settlement error becomes unacceptable, new, dynamic profiles may be needed to reduce it. This would be technically feasible by feeding the dynamic control signals into the settlements process.

Task XI Subtask 5 has shown that validation requirements of DR, in order for it to be used as DSB, should not present a fundamental barrier for smaller customers. In principle DR validation can be estimated based on control group measurement, statistical modelling and Grid substation measurements of demand "turndown" in response to DR motivator signals on specific days and at specific times. Various meter "smartness levels" have been considered for this process.

The ESCO (Energy Service Company) route to delivering smaller customer DR is considered very attractive in moving forward.

Implications

Motivating customers to buy energy efficient end uses and use them in a price flexible way to save energy and assist system security, is a difficult challenge. EUMF and TOU pricing have very important roles to play in this process. End use disaggregated energy data statistics, available now in many countries for national populations, should be added to smaller customer energy bills to start the education process of making them more aware of end use costs and environmental impacts.

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Summary

Energy plays a central role in everyday lives of residential and small business customers but its use impacts our environment and contributes to global warming. Many countries are concerned that liberalised markets may not deliver adequate peak electricity generation and network capacity in future. In this regard, smaller customer energy saving and behaviour change in response to financial and environmental stimulii can achieve energy savings, reduce peak demand and increase electricity supply security.

Customers can save energy by reducing its use and by shifting demand from high to low, system demand times. Savings in energy occur as a result of reduced system peaks which contribute to reduced system losses and more effective use of generation capacity. The shifting of demand to low demand times enables wind generation to make a greater contribution in some countries.

Three mechanisms follow from this by which smaller customers can be motivated to change behaviour, save energy and be rewarded for making the changes.

- End Use Monitoring and Feedback, EUMF
  - customers are presented with a breakdown of their individual end uses of electricity, its costs and environmental impacts and are motivated to make general energy savings

- Time of Use (TOU) electricity pricing
  - customers are presented with different prices for electricity at different times and respond by shifting demand from high to low cost price periods. A variation of this motivating mechanism is Dynamic TOU pricing where customers can change their use of electricity with reasonably short notice times (typically 24 hours notice) in response to notified price changes.

- Demand Side Bidding (DSB)
  - customers participate in energy trading, by contracting specific demand changes in response to requests by System Operators or Suppliers. Dynamic TOU pricing is a valuable motivator for delivering DSB, which can deliver energy saving as a result of reduced system losses and reserve generation capacity and overall increases in operational efficiency.

IEA, DSM, Task XI study has analysed work carried out and results of trials of EUMF, TOU pricing and DSB involving smaller customers in participating countries in order to understand their responses to these end use energy saving motivators and identify cost effective implementation solutions. It has also considered the impact that dynamic demand change profiles could have on profile settlements systems. Key to delivering DSB is a methodology for validating that participating customers have responded to requests for demand change.

Methods of applying EUMF as a cost effective and continuous methodology for motivating end use energy savings have been quantified for different levels of end use data disaggregation and presentation and levels of metering "Smartness". Demand disaggregation methods have been reviewed including the use of "Very Smart Metering". Face to face interviews between customers and energy advisors has been identified as being a very effective method for end use data disaggregation and motivator for customers.

TOU pricing and metering have been evaluated by considering three main types, Tariff, Dynamic and Real Time. Individual end use demands and micro generation have been evaluated for their potential to be remotely switched and inhibited for infrequent, short periods. Particular attention has been paid to whether customers are allowed to manually override remote demand switching commands.

The study has estimated the financial viability of implementing different TOU pricing regimes by equating reliable demand shift, including operation of embedded generation, with scheduled generation and transmission and distribution network construction costs. The results show that these energy saving and supply security maintaining measures can be cost effective but that automatic switching of demand based on customer/supplier contracts is likely to be the most effective mechanism for delivering reliable demand participation. "Smart metering" has a role to play in each of these mechanisms.

Analysis has been carried out into potential smaller customer end use demands which could respond to dynamic TOU pricing and which could be aggregated and made available to System Operators as part of DSB processes. Successful participation by customers depends on the development of cost effective mechanisms for aggregating their demand and validating and rewarding the customers which actually deliver end use demand changes. Smart metering has a role to play in delivering these energy saving mechanisms. The study showed that there is a role for smaller customers to bid demand to assist system operation, improve supply security and reduce supply costs. Savings in CO_2 may also be possible.

Dynamic and Real Time pricing measures result, if successful, in dynamic changes to customer usage profiles and this will impact profile settlement systems used in competitive supply markets. Profile settlements in Netherlands, Spain and the UK have been analysed for their potential to accommodate dynamic demand profiles of smaller customers resulting from TOU pricing.

Modelling and communication mechanisms to enable payments to be made to customers participating in DSB have been studied for each Demand Response (DR) delivery process.

1 Background/Introduction

Energy plays a central role in the everyday lives of residential and small business customers yet 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. The domestic sector consumes between 20% and 40% of electricity use in developed countries and is very attractive for consideration of energy saving and system operation processes.

End uses of energy and smaller customer behaviour change in response to financial stimuli are very important in achieving energy savings, reducing peak demand and increasing electricity supply system security. Energy saving regulations and measures are in place in developed countries which assist with more effective use of energy in houses and small businesses. Savings are achieved in many cases by increasing the propensity of customers to purchase energy efficient end uses and also in changing their behaviour so as to reduce thermostat settings and use hot water and lighting more wisely.

The financial benefits shown to be available to motivate smaller customers to participate in modifying end use behaviour are relatively small. No definitive studies have been identified which have analysed customer reaction to the disabling of appliances for short periods a few times per year and the financial incentives required. Reducing demand for short periods a few times per year can have significant benefits in reducing critical peak demands. This is illustrated in Figure 1 which shows, for Spain, that the last 1600 MW of generation peak capacity was used for only 6 hours in 2004/2005. Similar capacity utilisation is the case in other countries.

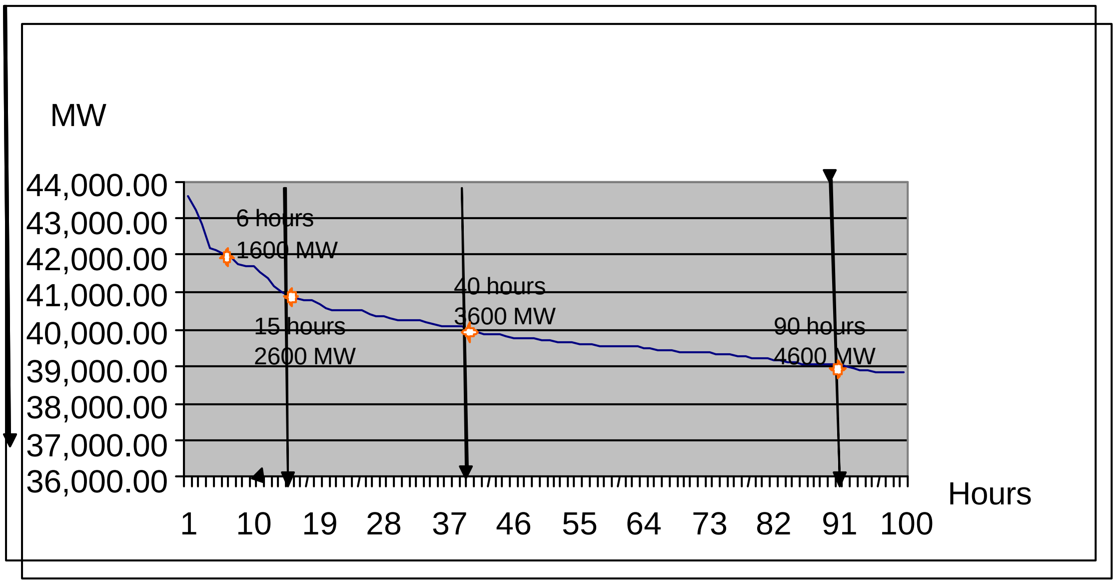

Fig 1 Annual Duration of use (hours) of generation capacity 2004/2005 (maximum 100 hours)

Demand profiles of customers will change as a result of applying demand response motivating tariffs and controls. Smaller customers demand profiles are used in competitive supply markets to settle the accounts between Suppliers and Generators on a time of use basis. New profiles will be required for Suppliers to gain benefit from motivating Demand Response. The actual demand response will be uncertain if customers have control of power usage and may choose to use power at times of high price by overriding the remote switching commands. The change in profile shape may be mixed and possibly reduce over time. With remotely variable, dynamic tariffs, Suppliers could increase the price differential to encourage customers to continue to smooth their demand profile.

Subtask 4 report describes the profile Settlement systems developed in Netherlands, Spain and UK, together with mechanisms implemented, the number of profiles in use, the way these profiles are kept up to date and what factors are used to modify profile shape on a daily basis to account for seasonal changes, embedded micro generation and demand switching. The compatibility of profile settlements and Dynamic Demand Response is investigated.

Customer profiles are also used to estimate the real time demand of each Supplier on a continuous basis. Metering systems with added intelligence are being implemented for smaller customers in some countries and can be considered for Supplier Settlements as an alternative to profile settlements. The balancing of these issues determines the viability of smaller customer dynamic demand side participation using TOU metering or dynamic profiles for settlements.

DR in its simplest form is an optional activity carried out by customers to save money by shifting demand in response to, for example, TOU pricing. TOU pricing signals can also be linked to automatic processes where the change in demand is carried out automatically in response to price or other motivator. Participation of the demand side in the form of DR is particularly challenging for smaller customers where energy use and cost are not generally regarded as major priorities. The degree of interest by smaller customers over the long term in DR activity is unknown. However, estimates have been made based on limited studies which show that most smaller customers are not very interested in manually managing demand based on TOU pricing.

Demand Side Bidding (DSB) is the formalisation of DR whereby contracts are put in place between customers and System Operators/Suppliers so as to deliver more reliable DR, which can be used in emergencies to meet capacity constraints or as alternatives to generation. DSB contracts usually specify the size, duration and delivery time for specific DR. This makes DR more predictable and reliable and hence more valuable to System Operators/ Suppliers. Specific payments and penalties by System Operators/Suppliers for delivery and failure of delivery are being put in place as incentives for customers to meet their contracted demand changes.

Mechanisms are required to validate both that demand is “available” as a Demand Side Bid and that the demand was “turned down” as defined in the contract. Validation is a significant challenge for smaller customers in part because an Aggregator is needed in order to bid sufficiently large demand blocks to be of interest to System Operators and Suppliers. The Aggregator collects blocks of demand from groups of smaller customers and is responsible for managing delivery of the DR as contracted in the DSB. An Aggregator is likely to have a portfolio of customers and demands from which to deliver a contracted demand “turndown”. DR delivery processes to meet DSB contracts are likely to be by remote or automatic switching of demands.

Three major issues require solutions in order to drive energy saving and System capacity enhancing behaviour change by smaller customers. These are :-

- Provide end use feedback information to assist customers understand the financial and environmental costs of their energy end use activities
- Provide TOU pricing, metering and control mechanism information to assist customers modify times of use of energy so as to save money and reduce peak demands
- Provide mechanisms and information for customers or their agents to bid their DR measures into System Operation so as to save money and possibly save CO_2.

Motivators for potential customer participation are:-

- Environmental concern (CO_2 saving) and saving money from reducing energy use
- Saving money and helping environment as a result of peak capacity reductions
- Being paid for "availability" and implementing demand "turndown" and start up of embedded generation

Customer response to TOU pricing is likely to be both an energy reduction and a demand reduction. The extent to which this happens, and therefore the impact on profile settlements, is not known. It is also not known, the extent to which profile shape changes take place when individual end uses are remotely switched. In order to bid demand as equivalent to reserve generation capacity, it is necessary to pre-determine (estimate) the demand change potential "available" to be delivered and the demand change actually delivered by specific switching instructions or price signals.

Task XI has quantified the potential and viability of EUMF, TOU pricing and DSB mechanisms for delivering demand reductions and profile shape changes. It also provides routes to dealing with dynamic profile changes in profile settlement systems and rewarding DSB participation.

2 Objectives

The objectives of Task XI are to determine whether and how, smaller customers can participate in demand markets and change end use behaviour to deliver energy saving, reduced energy costs and increased supply security. This involves quantifying and developing mechanisms to motivate smaller customers to save energy through energy end use presentation, modify their energy demand profile through time of use pricing and bidding, contracted Demand Response into energy markets.

Task XI has analysed and quantified all of these issues by means of five Subtasks.

Subtask 1 EUMF (April 04 to July 05)
Subtask 2 TOU pricing (April 04 to Sept 05)
Subtask 3 DSB (April 04 to Oct 05)
Subtask 4 Profile Settlements (Oct 2006 to Oct 2007)
Subtask 5 Demand Validation (Oct 2006 to Oct 2007)

Subtask 1
The objective of Subtask 1 was to quantify work carried out in participating countries to provide energy end use feedback for smaller customers, how

successful it had been, what further measures could be implemented and whether disaggregation and feedback have a viable role to play in current and future thinking for energy saving. It was 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.

Subtask 2

Subtask 2 had the objective of quantifying TOU pricing and manual/remote switching of demand as methodologies for motivating and delivering obtrusive as well as unobtrusive changes in specific energy end uses and embedded generation. It also has the objective of evaluating the costs and benefits of implementing tariff, dynamic and real time, TOU pricing systems.

Subtask 3

Subtask 3 had the objective of quantifying the feasibility and viability of DSB for smaller customers. DSB is a process for formulating, delivering and validating demand changes at customer premises in order to benefit System Operators, Suppliers and customers. It allows demand changes to be predicted, made to happen on a reliable basis and be built into schedules as alternatives to generation in meeting system demand.

Subtask 4

Subtask 4 had the objective of quantifying the potential for existing profile settlement systems to deal with demand profile changes resulting from smaller customers participating in Demand Response

Subtask 5

The objectives of Subtask 5 were to identify and develop mechanisms which can be used to validate that smaller customer demand is "available" for demand change and also, following instruction that the demand was "turned down".

3 Approach

IEA, DSM, Task XI has analysed work and results of trials of EUMF, TOU pricing and DSB involving smaller customers carried out in participating countries in order to understand their potential for motivating demand changes, develop mechanisms for their implementation, identify obstacles to that implementation and find solutions. Each motivator mechanism has been evaluated for its delivery of energy saving, by reducing energy use because of better information and shifting energy use in time to reduce system peaks and constraints and participate in system operation.

3.1 End Use Monitoring and Feedback

One of the ways in which customer motivation to save energy can be developed is by presenting them with a breakdown of their individual end uses of energy, their costs 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 powerful impacts at the right times. If end use demand profile shape for smaller customers can be reliably and dynamically changed, the change can reduce the requirement for peak generation capacity and spinning reserve and more effectively enables demand participation in balancing and reserve markets. With the growth of embedded generation, there is an added motivator for local areas to become "self balancing" in terms of local demand and local generation. The potential electricity savings and the options available for delivering demand aggregation have been estimated and reviewed as have the costs and benefits.

3.2 Time of Use Pricing

Time of Use (TOU) electricity pricing is a mechanism for encouraging electricity demand profile shape change. It is not generally used by smaller customers where electricity use, “settlement” costs among suppliers is achieved using demand “profiles”. Single rate and sometimes two rate tariff metering is generally used for smaller customer billing. The demand elasticity in response to price of smaller customer end uses of energy is largely unknown, particularly the financial incentives needed to mobilise specific end use demand changes. The scale of the required incentives, the specific end uses which can be influenced and the size of the resulting demand changes will be different for different households.

Individual end use customer demands and micro generation have been evaluated for their potential to be remotely switched and demand possibly inhibited for infrequent, short periods. The costs and benefits of demand change resulting from TOU pricing have been estimated.

Figure 2 illustrates the smaller customer end use components of demand contributing to system peak demand in Spain.

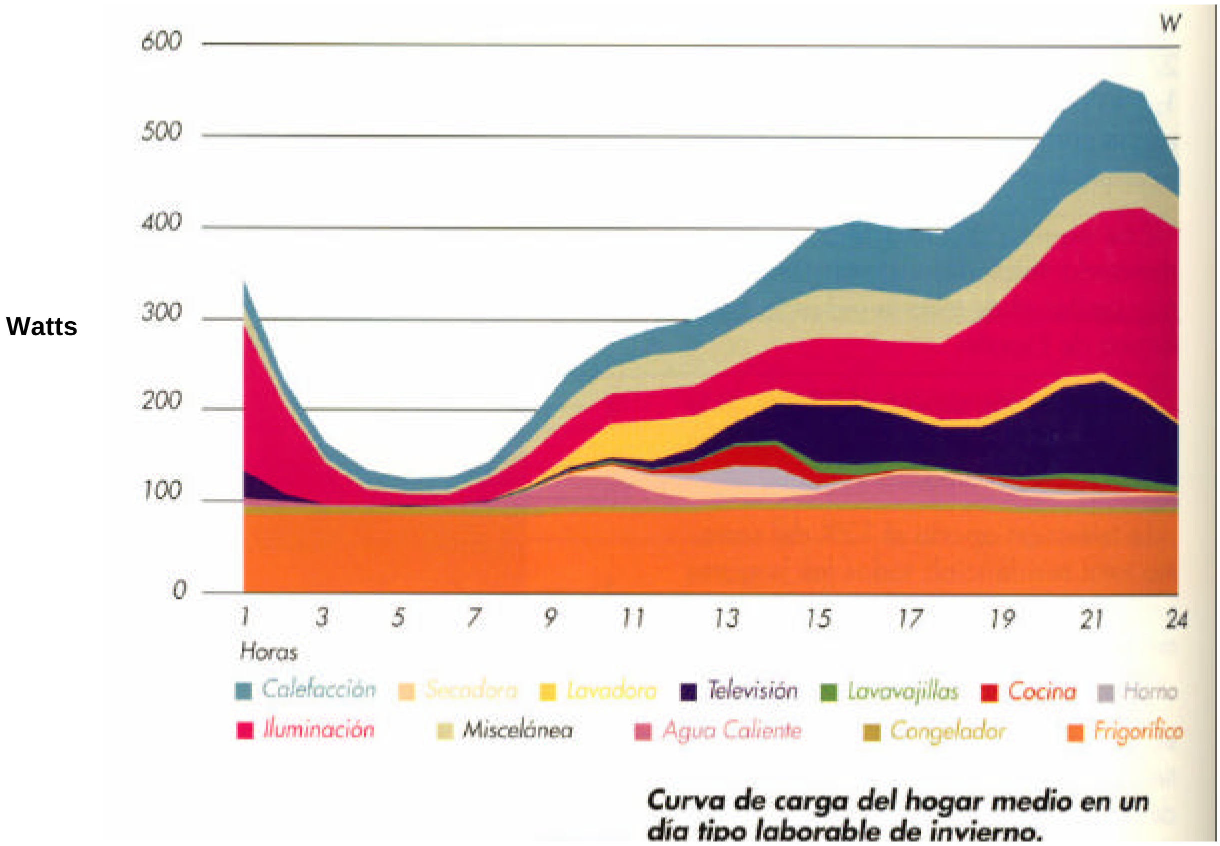

Fig 2 Smaller Customer End Use Contribution to Peak Demand in Spain (watts)

This curve shows demand contributions from:-

Spanish	English
Calefaccion	Space Heating
Lavavajillas	Clothes Washing Machine
Secadora	Tumble Dryer
Television	Television
Lavadora	Dishwasher
Cocina	Cooker
Horna	Oven
Illuminacion	Lighting
Miscelanea	Miscellaneous
Agua Caliente	Water Heating
Congelador	Freezer
Frigorifico	Refrigerator

The range of average demand per customer on peak in different countries has been investigated in IEA, DSM, Task XI, Subtask 2 and shown to be between 450 and 2000 watts.

3.3 Demand Side Bidding

Many countries are concerned that liberalised markets may not deliver adequate network and peak generation capacity in future. Greater participation of the demand side is a very important mechanism for making contributions to solving this issue and improving overall system balancing. Demand Side Bidding mechanisms have already been developed for larger customers in many countries. Customers participating in DSB are rewarded for making demand "available" and for implementing demand "turndown" when required.

Smaller customer demand Aggregators have an important, perhaps fundamental, role in the implementation of successful DSB schemes for smaller customers because purchasers of DSB specify minimum demand block sizes which can be bid. This is usually a minimum of several MW. In order for Aggregators to have sufficient incentive to become involved, the income derived from DSB needs to more than offset the costs incurred in setting up bidding schemes and infrastructure. Task XI Subtask 3 has identified and developed possible mechanisms by which smaller customer demands can participate in markets for generation. The more effective and predictable demand changes are, as a result of automatic switching, the more valuable they are to System Operators.

3.4 Profile Settlements

Profile settlements is a potential obstacle to the implementation of smaller customer DR because DR changes the shape of participating customer profiles. Profile settlements is used in competitive supply markets to settle accounts between Suppliers and Generators and is a problem which potentially reduces the scope for smaller customer DR. The impact on profile settlements resulting from DR is influenced in part by what motivators are used to deliver it. This is because the settlements process relies for its accuracy on the stability of the demand profile for large numbers of smaller customers. This issue has been analysed in Task XI, Subtask 4 by considering DR against the profile settlements systems in Netherlands, Spain and the UK. Solutions have been identified and proposed.

3.5 Demand Validation

DR can only participate in DSB markets if it can be validated as being “available” for demand change and also that demand “turndown” has taken place following a request.

Validation of demand “available” and “turned down” is a requirement of System Operators in order to give confidence that DSB can be used in place of generation. This validation requirement potentially inhibits the participation of smaller customers in the market for generation because individual customer validation using 2 way communication is expensive and may not be possible. Subtask 5 has analysed the situation regarding the use of customer demands identified in Task XI, Subtask 2. The demands have been considered for DSB using a range of methodologies for delivery and validation.

These methodologies, using different metering “Smartness” levels and demand change modelling, remote/automatic control and communication of price signals have been evaluated.

3.6 Completion of Task XI Deliverables

Task XI has completed the five Subtasks by means of the following analyses and studies:

- Quantified mechanisms and technologies to motivate smaller customer, energy reduction through feedback of end use information.
- Quantified energy end use disaggregation methods and their value for providing feedback to customers to achieve energy savings.
- Analysed TOU and Dynamic TOU pricing for smaller customers and differing levels of meter “smartness” to deliver energy savings.
- Assessed the potential impacts of Tariff TOU pricing, Dynamic pricing and Real Time pricing on smaller customer end uses.
- Defined technical, system and smaller customer requirements for bidding aggregated demand and local generation into energy markets.
- Considered mechanisms for implementing customer demand changes using DR as DSB and dealing with customer over ride.
- Estimated costs and benefits of energy end use monitoring and feedback, TOU pricing and DSB for smaller customers.
- Estimated the impact on profile settlement systems of the use of Tariff and Dynamic TOU pricing.
- Quantified methodologies for demand change validation to enable smaller customer DR to be used as DSB.

4 Results

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 behaviour 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.

4.1 EUMF

Feeding back detailed information to customers using a range of methodologies has been shown in Task XI to motivate energy savings by smaller customers of the order of 10%. The results of field trials work analysed in Task XI 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 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 it and it involved little inconvenience. Technology developments now allow more detailed information and potential environmental savings to be displayed to smaller consumers.

Adding general, national, end use statistics to the energy bill is not highly regarded by many customers but some customers have an interest. 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 could be established, and this was combined with simple and effective advice and messages, then EUMF would be an important methodology for influencing energy saving.

EUMF motivator messages have been shown to encourage customers to replace energy inefficient end use with efficient ones. This has required customers to change their spending priorities so that end use 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 and use low temperature wash programmes where possible.

Many EUMF 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 demand disaggregation and presentation. Monetary savings resulting from the application of EUMF to direct electric heating customers have been estimated to be worth approximately 100 Euro per year per customer.

From the information and analysis of end use disaggregation and feed back methods and field trials presented in the Task XI Subtask 1 report, 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, the financial savings potentially available from EUMF to help justify the investment needed on a commercial basis are quite small. 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 uses of energy on a continuous basis is probably too expensive for wide scale application to smaller customers. This direct measurement process includes the use of sub-metering and end use signature recognition and 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 costs of face to face and Internet interviews with customers to both collect data and feedback processed end use data and advice based on models, show this to be an attractive option with low to medium costs yet having potentially high impact. Shared saving schemes by ESCOs may be an attractive way of delivering these services. It is a role similar to that carried out by ESCOs for larger customers where shared savings are used to off set some of the costs of energy saving. In order to be effective, computer models are 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, many participating countries have this national 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 electricity bills at little extra cost. Although the impact is likely to be low, it would help develop customer awareness of energy use and potential savings.

Improved metering and display have been shown to be attractive for presenting electricity consumption data to samples of customers. Clever and very “smart” meters can be considered for the provision of demand disaggregation information as alternatives to customer interviews. However, this process is complicated and probably not cost effective. Very “smart” meters may be able to perform limited demand analysis to guide customer demand reductions and assist making savings.

With the general progress of remote metering for smaller customers 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. Combinations of

TOU metering data and customer behaviour modelling may be able to deliver some valuable but limited demand disaggregation.

Within the next 5 years, 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. Customers will also have additional information presented on the bill regarding energy saving advice. Netherlands are also installing TOU metering for all smaller customers.

4.2 TOU Pricing

Time of Use Pricing has an important role to play in motivating and delivering energy savings by smaller customers.

Task XI Subtask 2 identified that, other than direct space and water heating demand shift by reducing thermostats, air conditioning, lighting and some domestic appliances are end uses, which could in principle be moved off-peak. Customer small scale micro generation also has an important role to play in generating outside normal heat led times and made responsive to TOU energy pricing.

Notice times required by customers in order to accept remotely switched demand changes as well as reward mechanisms have been considered and assessed. Quantification of the benefits of Dynamic TOU pricing, in reducing peak demands and the costs of implementation of individual end use switching have been carried out. The benefits have been compared with the cost of new peak supply capacity.

Consideration has been given to relating together the three main types of TOU pricing: Tariff, Dynamic and Real Time. The study showed the difference between them to becomes very unclear if no customer override option to the automatic demand shift is allowed and a single rate tariff is used for billing. With this scenario, some customer end uses could respond automatically to real time prices (thermostat reduction), yet be billed using a single rate tariff. If a customer override option is allowed, then multi rate metering is required for billing purposes. The question of whether the cost savings associated with not providing customers with an override option are sufficient to overcome customer reluctance to participate needs further study. The answers to this question are likely to be end use specific. Thermostat set point changes are relatively unobtrusive. Lighting reduction and appliance disabling are obtrusive and would cause customer inconvenience. This inconvenience would be small if only applied for a few hours per year. However extensive marketing campaigns would be required to persuade customers to participate.

Communication has not been identified as a major technical constraint on the implementation of TOU pricing but is very important in the financial viability of these measures. Low cost communication is needed based on both broadcast radio technologies which communicate directly to end uses or on hybrid systems which use separate external and internal to the premises communication systems for the control of the many different services and energy end uses. These separate systems are linked together using customer gateways. The choice between these two approaches depends mainly on economics and whether the communication infrastructure is shared by other services, such as alarms and monitoring etc. The more the cost of communication and control can be reduced, the more feasible it becomes to apply demand management to smaller end uses.

Task XI Subtask 2 estimated the financial viability of implementing different TOU pricing regimes by equating reliable and flexible demand shift with scheduled generation, transmission and distribution network construction costs. In order to do this, the study estimated the costs of implementing TOU pricing regimes per kW of demand shift and the ball park cost of new supply side construction. Based on comparison of these estimates, on average, annual payment to customers of €234 is available as an incentive and motivator for them to participate. This is very much a global figure and will vary greatly in specific situations in different countries. It will be reduced if customers with direct space and water heating are not included. However it is likely that TOU implementation routes would be based initially on targeting customers with the largest demands.

4.3 Demand Side Bidding

Task XI Subtask 3 has shown that there is a role for smaller customers to bid demand to assist system operation, improve supply security and reduce supply costs. Savings in CO_2 may also be possible. Aggregation of smaller customer demands into minimum blocks of several MW is a requirement for DSB participation. The study has shown that unobtrusive as well as obtrusive management of end uses of energy may be possible in order to enable smaller customers to be "available" for automatic "turndown" of demand. No real understanding has been obtained as to whether and to what extent smaller customers would be prepared to accept end use inhibits of every day appliances for relatively short durations even if 24 hours notice is provided. Automatic temperature changes of the space environment and refrigeration appliances are regarded as unobtrusive and the most likely energy end use demands, the management of which could be accepted by customers. The management of washing machines and other white goods is technically feasible but is relatively obtrusive and less likely to be acceptable to customers. The management of lighting by making small changes to illumination levels would be obtrusive but may be accepted by customers. However, the extent to which customers could be influenced by extensive marketing and promotion so as to allow management of these end uses and the incentives required are not known. If smaller customers can be motivated to participate in demand management of everyday end uses of energy, a demand of between 0.5kW and 3kW per customer is potentially "available".

An important factor in the acceptability of DSB schemes in system operation and supply contract balancing is that market players have confidence that contracted demand is "available" for management and will "turn down" when requested. This confidence can only be provided by demonstrating that aggregated demands and embedded generation from large numbers of smaller customers can be predicted with reasonable accuracy.

Task XI Subtask 3 analysed the requirements and mechanisms for validation of blocks of smaller customer demands which could be aggregated and made available by customers to System Operators. Consideration was given to payments made for demand "turndown" by smaller customers and possible costs of implementing automatic systems.

The technical feasibility of carrying out DSB for smaller customer space heating has been demonstrated in country field trials using two-way communication. Rewards and costs for customer participation in DSB have been presented based on payments made to larger customers and the results of earlier communication studies. These studies showed that the economic case for smaller customer DSB is marginal using two way communication to achieve validation of demand change. Two-way communication and detailed monitoring of demands and override switches allows validation that customers are participating in DSB and meeting their contractual obligations and agreements. However, the validation of end use devices such as washing machines may not be so feasible using communications because of the requirement not to interrupt the cycle once started. One way communication is significantly lower in cost than two way communication but requires validation of customer participation to be carried out using statistical methods. This may require that customers, once contracted to deliver automatic demand changes, cannot override that option at short notice. This also removes a requirement for TOU metering.

Task XI Subtask 3 identified potential barriers to implementing wide scale DSB for smaller customers. These included the making of a viable business case which provides cost effective mechanisms for validating demand “available” and “turned down”. They also include the need to make a powerful marketing case to persuade smaller customers to participate. This study identified the system infrastructure and control requirements likely to be needed in such a business evaluation. The use of Aggregator businesses, possibly linked to ESCOs, may be the way forward for smaller customers. Profile Settlement Systems were also identified as an inhibiter of DSB for smaller customers.

4.4 Profile Settlements

Profile settlements used in competitive supply markets will be impacted by demand changes delivered by customer behaviour change, TOU pricing and DSB.

If Demand Response is delivered by means of presenting end use energy information and costs to customers, then the customer profiles are unlikely to change much in shape but more in amplitude. This volume error will be included in profile settlements reconciliation processes based on normal meter readings. Consequently the impact on profile settlements accuracy of this energy saving measure should be small.

If Demand Response is delivered by Tariff TOU pricing alone, then it is likely that peak demand will be reduced and therefore profile shape changed. If the TOU pricing is based on fixed times and prices and manual actions are required by customers to modify demand then some customers will modify their end use behaviour to save money. Customer profile shape changes resulting from fixed TOU tariff times and prices are likely to be a flattening of the profile. However, this change is a result of manual actions by customers, so that the actual amount of change is likely to vary significantly. The overall impact on profile settlements could be significant if a large percentage of customers opted for this metering arrangement and were prepared to alter their behaviour over the long term. TOU metering could be considered instead of profile settlements for settling Supplier accounts. Profile settlements may still be required in order to calculate real time Supplier demand. New customer profiles could be developed for Tariff TOU metered customers based on measured profiles of selected groups over a period of time.

If Dynamic TOU or Critical Peak pricing, together with remote switching of end uses is used to deliver Demand Response, there will be a significant impact on customer profiles. The impact and its predictability will be influenced by whether a demand switch override option is allowed for customers. With this option allowed, the results could be similar to that for TOU metering without remote switching, although the price signal may dissuade customers from exercising the override option. If the override option is not allowed then demand changes will be more predictable.

The proposed way forward for these Dynamic Demand Response motivating mechanisms within profile settlements is to monitor their impact in field trials of real but limited implementations. If the profile settlement error becomes unacceptable then new, dynamic profiles may be needed to reduce it. This would be technically possible. It would also be possible to mandate that TOU metering is required for Dynamic Demand Response customers.

4.5 DSB Validation

Task XI, Subtask 5 showed that the driver mechanisms for converting DR to DSB were dynamic TOU pricing with manual or automatic switching of demand in response to price.

Manual responses to DR motivators are considered unsuitable for delivering DSB except possibly together with intelligent Maximum Demand limiters as used in Spain where manual, demand switching is needed to restore supply. These systems can also be linked to automatic "in house" management of end uses so as to maintain demand below the trip level. For all other motivators, there is a technology requirement for "in house" communication with remote control enabled end use devices such as white goods and heating and cooling thermostats. Some of these end uses, such as heating, air conditioning, showers, some white goods are available on the market already equipped for remote switching (enabling and disabling). However, infrastructure investment is needed to enable them to be used for DSB.

It is evident from the Task XI Subtask 5 study that validation requirements of DR in order for it to be used as DSB do not present fundamental barriers to the adoption of smaller customer, DSB in generation markets. In principle DR validation can be estimated based on control group measurement, statistical modelling and Grid substation measurements of demand "turndown" in response to DR motivator signals on specific days and at specific times. It can also be carried out by using remotely read, TOU metering and the Aggregation of groups of participating customers, in order to measure the demand change. However, there is a significant need to understand and develop customer behaviour change and participation in DR measures.

Summary of Reports for Task XI

Five reports have been completed and made available to the participating countries, viz:-

Subtask 1 - Smaller Customer Energy Saving by End Use Monitoring and Feedback
Subtask 2 - Time of Use Pricing for Demand Management Delivery
Subtask 3 - Demand Side Bidding for Smaller Customers
Subtask 4 - The Impact of Dynamic Demand Changes on Profile Settlement Systems
Subtask 5 – Demand "available" and "turndown" Mechanisms for Market Bidding of Smaller Customer Demand

5 Conclusions

Saving energy use by smaller customers is an important objective of governments in all developed countries. Three major issues require solutions in order to drive energy saving and System capacity enhancing behaviour change by smaller customers and these have been identified and analysed by Task XI. These issues are:-

- How to provide information to customers on how they actually use energy, its costs and environmental impact.
- How to provide motivators to encourage customers to move electricity use from high to low cost times to save money and CO_2
- How to provide mechanisms for aggregating, contracting, validating and delivering DR as DSB and information for customers to participate and save energy and CO_2.

Task XI has concluded that disaggregated end use presentation of energy end use to customers is the most powerful motivator for customer behaviour change but expensive to implement. A compromise solution is for an energy advisor to conduct face to face interviews with customers regarding energy use behaviour and convert the results immediately into an estimated end use disaggregation of demand. Models have already been developed to do this conversion in Denmark. It may also be possible to cost effectively provide some limited disaggregation of demand to assist customers understand large and small demand end uses. This may be possible using "smart" metering where step changes in demand could be recognised without actually knowing what the specific end use was that caused it.

National statistics on overall disaggregated end uses of energy, which are available in many countries, should be presented now on customer bills as an introduction to EUMF and to assist customer decision making regarding the purchase of new, energy efficient end uses.

Task XI has analysed the possibilities and cost benefit for TOU pricing as a motivator for demand profile change and saver of energy and proposed mechanisms to deal with manual and automatic switching of demand. Some customers will manually respond to price changes. However many customers prefer automatic/remote control switching of end uses in response to price but with an over ride option available to them if required. These systems require that remotely controlled end uses are enabled for communication, which is not the situation at the present time. Intelligent Plugs, which can be switched by a broadcast signal, are a possibility.

With Dynamic TOU pricing, manual response to the price changes is not really practical so that automatic/remote control switching is required. Dynamic Demand Response is more valuable to System Operators than Tariff Demand Response because the times of the price changes can be varied to suit system operations. TOU metering with possibly only two rates may deliver the majority of Demand Response using Tariff or Dynamic motivator mechanisms and would be simple for customers to understand.

Tariff and Dynamic TOU pricing regimes will change customer demand profiles and if widely adopted will impact on profile settlement systems used in many countries as part of the competitive supply market. Task XI has considered the options for dealing with this by means of new profiles or Suppliers accepting the additional error in settlements. It is considered that a prudent way forward is to monitor the impact of TOU pricing and metering on existing profile settlements error and if and when that becomes unacceptable, new profiles for TOU pricing customers are developed. This will be a complicated process especially for Dynamic TOU pricing where the actual price switching signals would need to be input to the profile generation process and customer override options would need to be included. This methodology is already being considered for some other remotely switched demands in some countries. For countries with competitive markets just starting for smaller customers, the use of remote TOU metering should be considered for settlement processes.

DSB can deliver energy saving as a result of reduced reserve generation capacity requirements, reduced system losses and an overall increase in operational efficiency. It can also provide CO_2 savings by enabling more wind generation to operate at off peak times. Reward to customers for participating in DSB can be made by direct payment or through the tariff. In order for System Operators to use DSB effectively and with confidence, validation is needed both of the actual demand "available" for change and the response "turn down" following a request. Task XI has evaluated the options available for this validation process and considers that direct monitoring of demand "available" and "turned down" to be expensive and difficult to implement for countries already having profile settlements infrastructure. The validation methodology proposed is for modelling and measurement of demand changes in response to a range of motivators at different times, days and seasons. Dynamic TOU metering and pricing is regarded as the main motivator of demand change, which can be used for DSB. It is not considered to be the most suitable mechanism for validation. With experience, confidence in delivery of Dynamic Demand Response could be developed to such a level that smaller customer DSB plays an important role in contributing to system capacity. Providing information to customers on:-

- End use demands and potential savings;
- TOU pricing, potential savings and ways to do it;
- DSB, potential rewards and ways to participate

are the preferred ways of providing energy saving motivation.

Task XI has shown that in principle, demand shift and energy reductions based on EUMF, TOU Pricing and DSB for aggregated smaller customers are technically feasible and could be made available and reliable in sufficient quantities to significantly contribute to peak demand management. However, the financial incentives for customers to participate in energy saving measures are not large. Significant marketing and promotion will be needed to motivate smaller customers to participate. The use of ESCOs is considered to be an attractive route to the development of smaller customer energy saving and demand profile change infrastructure as well as for demand aggregation and marketing. A number of areas where further study is needed have been identified.

6 Implications

Governments in the developed world are committed to delivering energy savings and maintaining system security. Providing regulations that remove energy inefficient end uses from the market is the relatively easy part of the process. Motivating customers to buy energy efficient end use and use them in a price flexible way to save small amounts of money and assist maintaining system security, is more difficult. Marketing and information effort is needed to support EUMF, TOU pricing and DSB and focus customer attention on the value and need for energy audits, using energy efficient end uses and modifying behaviour to minimise energy costs.

These measures can all deliver energy saving with Dynamic TOU pricing and DSB also assisting with system security. However, in order to implement these measures and assist customers to deliver the savings, significant investment is needed. Metering "Smartness" is an important factor in the drive to deliver the savings. However, it is only one factor, with "smart" controls and "smart" end uses also very important. These controls may be included in the meter or implemented separately by direct broadcast communication with end uses. The level of customer participation in energy saving in response to motivations is largely unknown but is a critical factor. Energy saving metering and controls infrastructure costs have a significant fixed part and a customer numbers, dependent variable part. Consequently it is important for economic viability that large numbers of customers participate.

All these energy saving measures are driven through the provision of high quality information to customers. This information comprises end use energy costs, CO_2 generation and electricity price and environmental benefits of demand shifting. A start should be made to provide customers with initial information of this type to start the education process.

7 Recommendations

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

- Studies should be carried out to quantify the specific value of the different feedback methods described and analysed in the Task XI reports. 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 saving CO_2.

- Study should be carried out, possibly within the IEA DSM Agreement, into how to motivate customers to attend energy saving interviews and participate in energy saving measures and behaviour changes. It may be possible to include the saving of other resources such as water in the same interview. Modelling of disaggregated end use and feedback should be carried out at the same time to help achieve cost effectiveness. Models should be developed or existing ones enhanced to quickly convert information collected during face to face customer interviews into disaggregated energy end uses and energy saving advice.

- Studies should be carried out to evaluate the potential and acceptability of different end use, demand management and customer participation methodologies with no customer override and single rate metering.

- Evaluation of the possibilities for lighting management should be carried out, taking into consideration the limitations imposed by energy efficient lights. No studies have been identified which have analysed the possibility or acceptability of reducing lighting levels for a few hours a few times per year. These studies should be carried out together with assessments of the financial incentives needed to obtain customer participation, particularly with no override options allowed.

- Evaluate the potential for using micro CHP and fuel cells to respond to demand change signals and reduce the demand to be met by scheduled generation.

- Estimate the required financial and motivating incentives needed to obtain customer participation in obtrusive demand side measures for relatively few hours per year.

- Evaluate combined Tariff, Dynamic and Real Time, TOU pricing in a single household and applied to different elements of the demand with different notice times and controls.

- Develop cost effective modelling and measurement mechanisms and processes for aggregating smaller customer demand and validating demand “available” and “turn down”.

- Quantify the impact of smaller customer, dynamic profiles on “profile” settlements systems and evaluate in more detail, the routes proposed for dealing with it.

- Develop technical and business architectures for smaller customer DSB within the IEA DSM Agreement. This includes business models to define how to market packages of measures and roll out DSB enabled end uses of energy and their management. Evaluate the use of ESCOs to fulfil this role.

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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
- co-operation 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 18 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
India	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 17 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 - *Completed*
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 - *Completed*
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
To be determined

Task 13 Demand Response Resources - *Completed*
Ross Malme, RETX, United States

Task 14 White Certificates – *Completed*
Antonio Capozza, CESI, Italy

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

Task 16 Competitive Energy Services
Jan W. Bleyl, Graz Energy Agency, Austria

Task 17 Integration of Demand Side Management, Distributed Generation, Renewable Energy Sources and Energy Storages
Seppo Kärkkäinen, VTT, Finland

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Also, visit the IEA DSM website: http://www.ieadsm.org