# Micro Demand Response and Energy Saving Products: Requirements and Options for Effective Delivery

**Prepared by Linda Hull**
**EA Technology**
**Operating Agent for Task XIX**

**March 2010**

**International Energy Agency Demand-Side Management Programme**

**Task XIX: Micro Demand Response & Energy Saving Products**

## Participants

VTT Technical Research Centre of Finland, Finland

ADEME, France

Public Power Corporation, Greece

Bureau of Energy Efficiency, India

NL Agency, Netherlands

Red Eléctrica de España, Spain

Department of Energy and Climate Change, UK



EA Technology Limited, Capenhurst Technology Park, Capenhurst, Chester, CH1 6ES; Tel: 0151 339 4181 Fax: 0151 347 2404
http://www.eatechnology.com
Registered in England number 2566313

# Executive Summary

## Background

Interest in the potential for Demand Side Management (DSM) to create more reliable and more sustainable energy systems has increased significantly over recent years, largely driven by International commitments to reduce greenhouse gas emissions. Greater participation from the demand side is seen as an important mechanism for addressing the issues of improving overall system balance, reducing the reliance on inefficient fossil fuel generation, particularly at peak times and increasing the utilisation of renewable energy sources with variable output.

Households and small and medium enterprises (SMEs) consume up to around 50% of electricity in developed countries. Therefore, encouraging these sectors to modify their energy consumption has the potential to make a significant impact on overall energy use. However, the participation of households and SMEs, which individually consume relatively small amounts of energy, requires that several thousand of 'micro loads' are influenced and co-ordinated to ensure that the desired outcome is achieved. Approaching consumers in order to integrate their energy use in this way is complex one. Ensuring that consumers can take advantage of all available opportunities is an important component of ensuring the potential value of modifying consumer behaviour is maximised.

Therefore, a project was established to define demand response and energy saving products and to determine how they can be delivered into the residential and/or SME markets on a commercial basis, using energy saving service providers and/or demand aggregator businesses. The project is entitled "Micro Demand Response and Energy Saving" and forms Task XIX of the International Energy Agency Implementing Agreement on Demand Side Management. Seven countries agreed to participate in Task XIX, namely Finland, France, Greece, India, the Netherlands, Spain and the United Kingdom.

## Objectives

The overall objective of Task XIX is to evaluate the business case for micro demand response and energy saving products from the perspective of energy saving service providers and / or demand aggregators.

Within the scope of this project energy saving and demand response products are defined as those intended to change the way energy is used whilst also achieving a commercial outcome for the business provider. Demand response products are those that target the delivery of short term changes in the pattern of electricity consumption for residential and Small to Medium Enterprise (SME) consumers through the application of end-use monitoring and feedback, time of use pricing and remote / automatic switching of end-user loads. Whilst the opportunities for effecting energy savings are wide and varied, the scope of Task XIX is limited to the opportunities available through the application of end-use monitoring and feedback.

Task XIX focuses on products targeted at residential and Small to Medium Enterprise (SME) consumers. In the case of SME consumers, Task XIX considers individual sites with a maximum demand of up to 100kW, regardless of the overall size of the business.

## Approach

This assignment has been conducted by the participants of Task XIX, comprising the Operating Agent and the nominated Task Experts from the participating countries. This has included the use of data collection questionnaires used by the Task Experts to collate country specific information on the structure of the electricity markets and on the consumption of electricity by households and SMEs within their country. The data provided by the Task Experts has been collated and analysed by the Operating Agent. This has been supplemented by desk research and attendance at selected seminars and conferences by the Operating Agent.

## Results

### Overview of electricity system and trading arrangements

The review of the arrangements in place that govern the way that electricity is traded and the roles and activities of the market players highlights, not unsurprisingly, that there are a number of significant differences between the participating countries. These differences lead to different drivers for demand response and energy saving products across the participating countries, and, more importantly, result in different barriers to the development of new products and services.

### Demand response requirements

Whilst the specific requirements of potential purchasers of demand response and / or energy saving products will vary, a set of generic requirements has been identified in terms of the amount of aggregated response required, the preferred profile shape, the notification period provided to customers and the duration over which the demand response should be delivered.

### Review of case studies and pilots

A high level review of a selection of DSM pilots and case studies highlights that the level of energy savings and demand response delivered varies widely across the trials reviewed. Whilst the results are wide ranging, the high level review would suggest that EUMF could deliver energy savings of up to 15% and that demand response products using time of use pricing, remote and/or automatic switching should be able to deliver peak load reductions of 10 to 15% where heating and cooling loads are prevalent. Without heating and cooling loads, the peak load reductions are likely to be less.

### End use demand changes

The analysis of energy consumption within the participating countries highlights that, in some instances, there is a general lack of data on how energy is consumed by smaller consumers. This includes both information on energy end uses (particularly for small non-domestic consumers) and on the time of use of the different energy end use categories.

The analysis of the available energy consumption data of households and small and medium enterprises demonstrates that there is, unsurprisingly, considerable variation in the end-uses of energy within the participating countries. Categorisation of the energy end uses according to their suitability for energy saving and demand response highlights that, due to the variation between the countries, new products will need to be tailored specifically to meet individual circumstances.

### Delivery Mechanisms

A range of different delivery mechanisms that can be used for energy saving and demand response products has been identified. This includes consideration of different approaches to aggregating small consumers and identification of a range of different products that could be used to motivate the consumers to modify their energy consumption. As identified in the review of the electricity markets, the different characteristics of the participating countries imply that there is unlikely to be a 'one-size fits all' solution. Rather, specific business models will need to be tailored according to individual circumstances.

### Technical Architecture

Technology is an enabling mechanism that ensures that energy saving and demand response products can perform as required. Each product requires a tailored solution, each with its own specific functionality requirements. These requirements are identified in terms of a series of Technical Architecture Components. The minimum requirements for each product considered have been identified, together with a more advanced solution. Whether or not the more advanced solution is commercially viable depends upon whether the additional benefits outweigh any additional costs involved.

## Conclusions

This report provides a basis for the next phase of the project which aims to evaluate the business case for energy saving and demand response products from the perspective of the aggregator. It is unlikely that a 'one size fits all solution' exists due to the inherent differences between the participating countries. As such, a range of business options will be considered in order to attempt to identify the combination of end use application, aggregation approach and product type likely to offer the best prospects in terms of ensuring a commercially viable business solution.

# Glossary

| | |
|---|---|
| A/C | Air conditioning |
| AMI | Automatic Metering Infrastructure |
| AMR | Automatic Meter Reading |
| CCS | Carbon Capture and Storage |
| CFL | Compact Fluorescent Lamp |
| CoP | Coefficient of Performance |
| CPP | Critical Peak Pricing |
| DER | Distributed Energy Resource |
| DNO | Distribution Network Operator |
| DSM | Demand Side Management |
| ESCO | Energy Service Company |
| EUMF | End Use Monitoring and Feedback |
| ES | Spain |
| FI | Finland |
| FR | France |
| GB | Great Britain |
| GPO | General Purpose Outlet |
| GR | Greece |
| ICT | Information and Communication Technology |
| IN | India |
| LV | Low Voltage |
| NL | Netherlands |
| microCHP | Micro Combined Heat and Power |
| MV | Medium Voltage |
| SME | Small and Medium Enterprise |
| TAC | Technical Architecture Component |
| TSO | Transmission System Operator |
| TOU | Time of Use |
| VDU | Visual Display Unit |
| UK | United Kingdom |

# Contents

# 1 Introduction

Interest in the potential for demand side management (DSM) to create more reliable and more sustainable energy systems has increased significantly over recent years, largely driven by International commitments to reduce greenhouse gas emissions.

Greater participation from the demand side is seen as an important mechanism for addressing the issues of improving overall system balance, reducing the reliance on inefficient fossil fuel generation, particularly at peak times, and increasing the utilisation of renewable energy sources with variable output. Households and small and medium enterprises (SMEs) consume up to around 50% of electricity in developed countries. Therefore, encouraging these sectors to modify their energy consumption has the potential to make a significant impact on overall energy use. The provision of information is increasingly seen as a crucial element in motivating consumers to use energy more wisely. Without information on how much energy is consumed by time of day and by end-use application, it becomes difficult for end users to make informed choices about how to reduce energy consumption or about when energy use should be avoided (for example at times of peak demand). Influencing demand at the time of peaks, for example through the use of time of use pricing, can have a large benefit in terms of reducing system capacity requirements.

However, the participation of households and SMEs, which individually consume relatively small amounts of energy, requires that several thousand of ‘micro loads’ are influenced and co-ordinated to ensure that the desired outcome is achieved. Approaching consumers in order to integrate their energy use in this way is complex. Ensuring that consumers can take advantage of all available opportunities is an important component of ensuring the potential value of modifying consumer behaviour is maximised.

Therefore, a project was established to define demand response and energy saving products and to determine how they can be delivered into the residential and/or SME markets on a commercial basis, using energy saving service providers and/or demand aggregator businesses. The project is entitled “Micro Demand Response and Energy Saving” and forms Task XIX of the International Energy Agency Implementing Agreement on Demand Side Management.

This report is the first output of Task XIX, and focuses on the requirements and options for the effective delivery of micro demand response and energy saving products.

# 2 Demand Response and Energy Saving – Definitions

The overall objective of Task XIX is to evaluate the business case for micro demand response and energy saving products from the perspective of energy saving service providers and / or demand aggregators.

Within the scope of this project, energy saving and demand response products are defined as those intended to change the way electricity is used whilst also achieving a commercial outcome for the business provider.

Task XIX includes consideration of the delivery mechanisms required to facilitate the implementation of demand response or energy saving products: There are four types of mechanisms:

- Control mechanisms that direct energy users to change their behaviour
- Funding mechanisms that provide funding for other mechanisms
- Support mechanisms that provide support for behavioural change by end users and energy businesses
- Market mechanisms that enable the use of market forces to encourage behavioural changes

Figure 2.1 provides an overview of energy saving and demand response delivery mechanisms and products that fall within the scope of Task XIX. Further descriptions of demand response and energy saving products are provided in the following Sections.

### Demand Response

Demand response products are those that target the delivery of **short term** changes in the pattern of electricity consumption for residential and Small to Medium Enterprise (SME) consumers through the application of:

- end-use monitoring and feedback;
- time of use pricing; or
- remote / automatic switching of end-user loads.

The ensuing short term changes in the pattern of electricity consumption (i.e. the demand response) of the residential and SME consumers can be utilised for a variety of purposes, which will generally fall into one of the two categories summarised below:

- The provision of balancing services; or
- The provision of energy services.

Within both of these categories, the change in demand is utilised to assist with managing the balance between the demand for and generation of electricity. Balancing services are predominately concerned with the provision of services to Transmission System Operators to assist with maintaining the quality and security of supply,. However these equally apply to Distribution System Operators to assist with managing the operation of local distribution networks. Energy services describe the delivery of energy products within the overall electricity market. Section 4 provides further information on the categories of demand response products considered within Task XIX.

Demand response has several important implications in terms of the overall efficiency of electricity supply. For example, reserve generation plant is generally regarded to be less efficient and produce more $CO_2$ emissions, than base load plant. There is also the added energy penalty in starting them up and holding them in a state of readiness. Thus, using demand response to reduce the need for reserve generation could lead to energy savings by optimising the overall efficiency with which the electricity system is managed. Similar arguments also apply to sustained load shifting actions. The impact of demand response on energy savings and $CO_2$ emissions depends on a number of factors including the generation mix and the efficiency of the generation plant. Demand response has the potential to replace a substantial amount of low efficiency high emission reserve, peak power generation capacity and expensive network investments, in systems that have high proportion of generation from non-controllable sources. This could include wind power, solar power, non-controllable CHP, nuclear and non-controllable hydro plant. Conversely, the impact of demand response on CO2 emissions would be very much lower where the use of biogas fired CCGT plant is prevalent.

### Energy Saving

Whilst the opportunities for effecting energy savings are wide and varied, the scope of Task XIX is limited to the opportunities available through the application of end-use monitoring and feedback.

End-use monitoring and feedback (EUMF) provides consumers with information about their individual end-uses of energy, its cost and environmental impact. Feedback of energy end use information is regarded as being an important tool to motivate consumers to modify their behaviour and hence reduce energy consumption and achieve energy cost savings. Significant changes in energy consumption (both in terms of the amount of energy used and the pattern of energy consumption) can be fed back to consumers so they can monitor the impact of their efforts. EUMF can therefore encompass a number of approaches to improve the provision of information to consumers including;

- **Direct feedback**, whereby immediate information is available to the end-user on their current level of consumption, for example via direct displays, pay-as-you-go meters or cost plugs fitted directly to individual appliances.
- **Indirect feedback,** whereby energy consumption is first processed before being sent to the end-user, for example information on historical consumption is provided in conjunction with frequent and accurate billing; and
- **Other,** whereby general, or targeted information, to motivate behavioural change is provided to end users. This could be via face to face energy audits, general advertising campaigns and energy saving leaflets or community actions groups.

In addition to the provision of information, specific incentives can be used to influence end-use behaviour. These could either reward energy efficiency savings or penalise high energy usage, and may be provided in conjunction with End Use Monitoring and Feedback. Such approaches are described in more detail in Section 7.

It is possible for direct feedback to be enhanced through the use of automated controls. For example, to automatically switch off lighting or appliances when no longer required. Alternatively, automatic controls could be used to implement short term changes in the pattern of energy consumption. In this case, such products would then be primarily considered to fall into the category of demand response. EUMF could also play an important role in verifying that automated responses function correctly.

An important factor in the provision of EUMF is the issue of who is going to provide this information. A range of possible options are considered in Section 7.

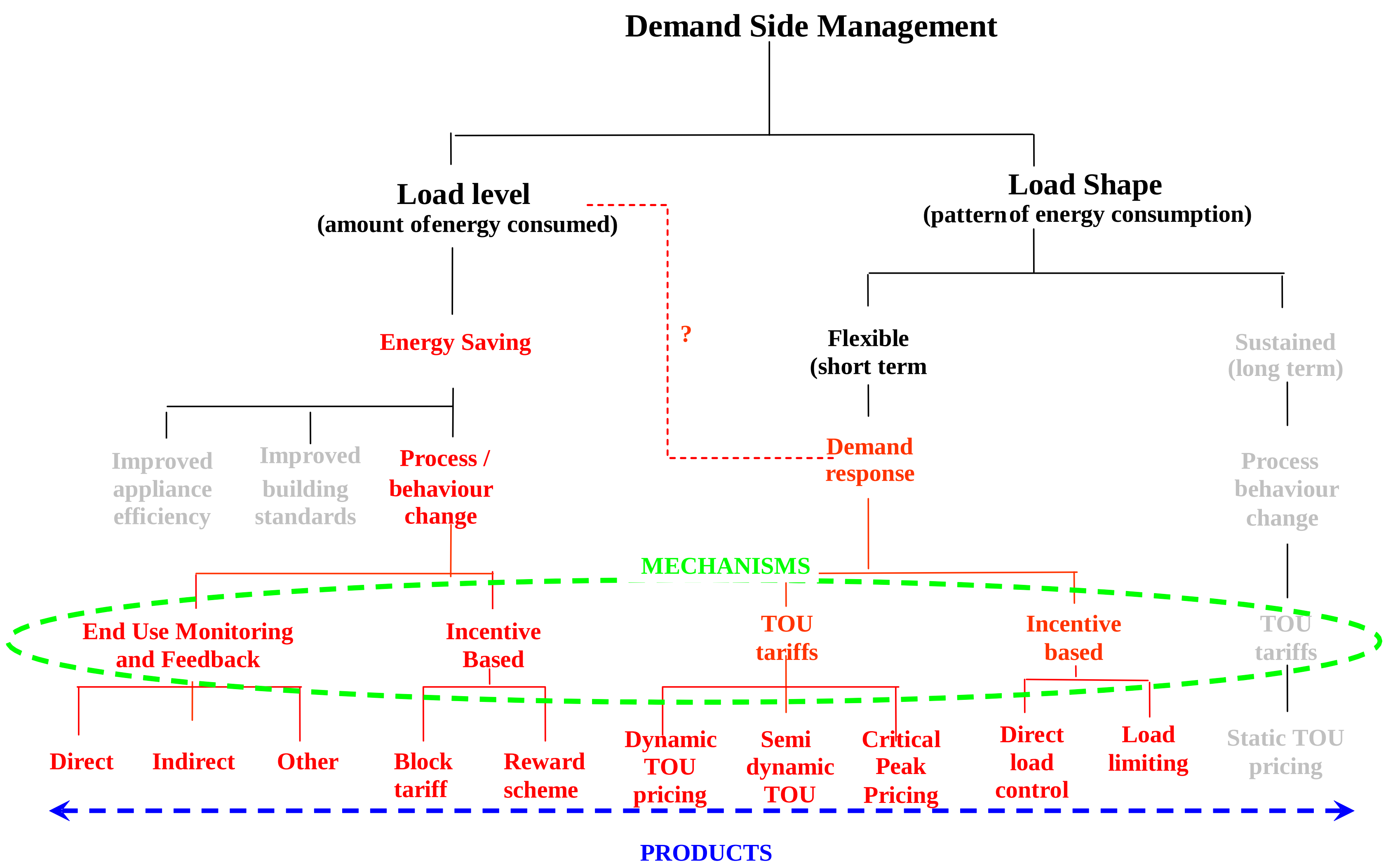



**Figure 2.1 Micro Demand Response and Energy Saving Products**

Task XIX focuses on products targeted at residential and Small to Medium Enterprise (SME) consumers. EU Recommendation 2003/361/EC provides a definition of SMEs, as summarised in Table 2.1 below. However, the focus of Task XIX is on the management of micro loads. Therefore, for the purposes of this project it was considered appropriate that the definition of SMEs be related to the size of individual premises (in terms of electricity consumption) rather than the size of the business in terms of capital investment, turnover or number of employees. Thus, the scope of Task XIX is limited to individual sites with a maximum demand of up to 100kW, regardless of the overall size of the business. For example, individual high street outlets with a maximum demand of less that 100kW are included within the scope of the project even if they form part of a chain that would otherwise exclude them from being considered an SME.

**Table 2.1 EU Recommendation 2003/361/EC Definition of SMEs**

| Enterprise Category | Headcount | Turnover | Or | Balance sheet total |
|---|---|---|---|---|
| medium-sized | <250 | ≤ 50 million Euros | | ≤ 43 million Euros |
| small | <50 | ≤ 10 million Euros | | ≤ 10 million Euros |
| micro | <10 | ≤ 2 million Euros | | ≤ 2 million Euros |

# 3 Incentives and Barriers

The general rules in place that govern the way that electricity is traded and the overall structure of the electricity market have an important impact on the potential for the demand side to participate directly in the electricity market. With the potential benefits of demand response and energy saving products accruing throughout the energy supply chain, it is important to understand the roles of the market players and how they interact with each other. Therefore, a survey was conducted to obtain an overview of the electricity market in each of the participating countries. The results of the survey are summarised in Appendix 1 of this report.

The following Sections draw upon the results of the survey to highlight specific incentives and barriers to the development of new demand response and energy saving products in each of the participating countries. Section 3.1 describes how unbundling could present a barrier to the development of new products, whilst Sections 3.2 to 3.5 describe the key issues for the Generation, Transmission, Distribution, and Retail sectors respectively, whilst Section 3.6 focuses on future issues that are likely to affect the incentives and barriers to the implementation of new demand response and energy saving products. The assessment of the barriers/opportunities is a qualitative assessment intended to indicate the extent to which barrier/opportunities impact on the potential for new demand response and energy saving products. In each case, the opportunities and barriers are summarised in tabular form as follows:

| | Barriers | | Opportunities |
|---|---|---|---|
| ⮟⮟ | Significant barrier(s) | ✪✪ | Significant opportunities |
| ⮟ | Moderate barrier(s) | ✪ | Moderate opportunities |
| ⮟ (light) | Minor barrier(s) | ✪ (light) | Minor opportunities |

## 3.1 Unbundling

The potential benefits of demand response and energy saving products accrue throughout the energy supply chain, including;

- end-user benefits, e.g. through reduced energy costs;
- Supplier benefits, e.g. through optimised energy purchasing;
- distribution company benefits, e.g. through optimised use of the distribution network;
- transmission company benefits, through avoided use of expensive and/or inefficient generation plant to maintain the quality and security of supply; and
- societal benefits, through reduced emissions of $CO_2$.

Since 2004[1] there has been a requirement on vertically or horizontally integrated electricity companies in the European Union to unbundle their transmission and distribution activities, which, at a minimum, requires them to produce separate internal accounts for these activities in order to avoid discrimination, cross-subsidisation and the distortion of competition. In many cases, electricity organisations have gone much further than these requirements and the activities have been separated into different business functions, often with different ownership structures.

Whether or not there is full business separation between key players in an electricity market has a significant impact on the potential implementation of demand response and energy

[1] Directive 2003/54/EC, which entered into force in 2003. Member States were required to bring the requirements under the directive into force by 1 July 2004, but were able to postpone the implementation of unbundling of the distribution and transmission activities until 1 July 2007.

saving products. In particular, full business separation can make it difficult to justify the business case for demand response and energy saving products; the potential benefits are distributed amongst a number of different organisations (i.e. the value chain is broken), rather than to a single organisation. In such a situation, the role of a demand aggregator, or energy saving service provider, could become pivotal in gaining access to benefits throughout the value chain.

A 2005 study of Smart Metering [2] provides an overview of how potential benefits are distributed throughout the electricity supply chain. The results, which are shown in Figure 3.1, show how Northern American utilities, who had already undertaken AMR[3] pilot projects, perceive the benefits of AMR to be distributed when fully integrated into their businesses.

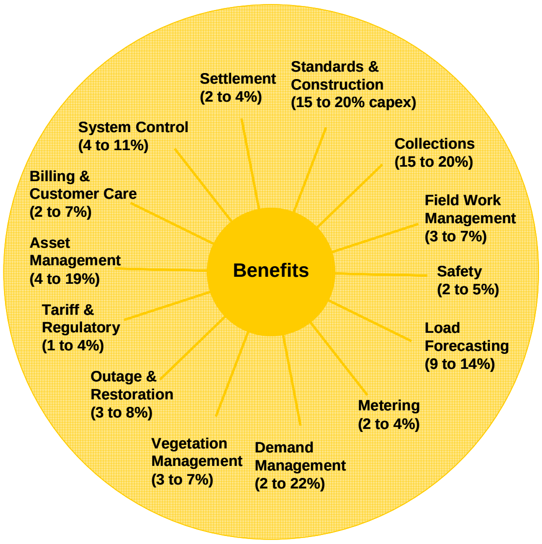



**Figure 3.1 Potential benefits of Smart Metering**

The data presented in Figure 3.1 indicates that of those utilities surveyed, many of the benefits of AMR are not directly associated with improvement in customer billing and payment collection traditionally associated with the introduction of the technology. Other benefits include (for example):

- asset management savings ranging between 4 and 19 percent, achieved through, for example, enhanced data on transformer loads;
- savings in standards and construction of between 15 and 20 percent on capital expenditure, achieved through the management of peak demands; and
- Savings of three to eight percent on outage restoration, because utilities can be automatically updated of power outages rather than waiting to receive reports from customers affected.

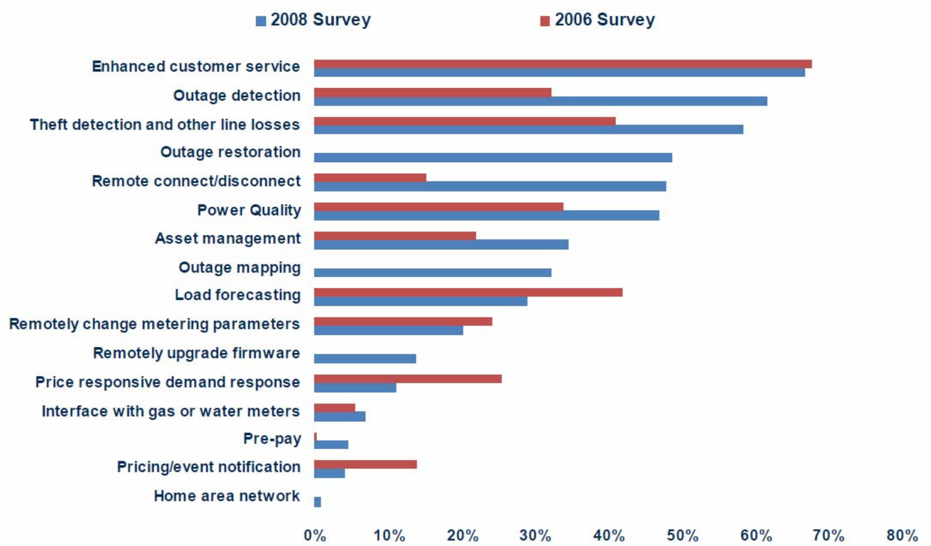
It is even claimed that information on momentary outages in the meters enable instances of trees rubbing on lines and causing drop outs (temporary loss of supply) to be identified, resulting in savings of three to seven percent for vegetation management.

Similar findings have been reported by the Federal Energy Regulatory Commission in the USA, which is required to publish an annual report to assess electricity demand response

2 Smart Metering: The holy grail of demand side energy management?, Capgemini, 2005

3 AMR typically refers to automated meter reading, but in the study is also taken to include other Smart Meter features such as load control.

resources. As part of this commitment, the FERC has conducted surveys to assess the way that advanced metering is used by utilities beyond interval meter reading collection. The results for 2006 and 2008 are shown in Figure 3.2[4]. In the 2008 study, the results indicate that advanced metering was used for outage detection by 62 percent of respondents, for outage restoration by 49 percent of respondent and for outage mapping by 32 percent of respondents. These results help to demonstrate the network benefits associated with advanced metering.




Source: Federal Energy Regulatory Commission, 'Assessment of Demand Response & Advanced Metering', December 2008, available at http://www.ferc.gov/legal/staff-reports/12-08-demand-response.pdf

**Figure 3.2 2006 and 2008 FERC Survey of reported uses of advanced metering**

It is worth noting that the results considered in the CapGemini and FERC studies considered only the benefit to the utility companies, and do not include the potential benefits to customers, e.g. through the provision of immediate and historic consumption information. In addition, the benefits of Smart Metering in terms of improving the electricity market have not been considered, e.g. facilitation of competition can contribute towards improvements in the functioning of the retail markets.

Whilst a fully unbundled market should not be a barrier to the development of demand response and energy saving products, it can never-the-less pose some significant challenges. For example, it is important to consider both who pays for implementation costs as well as who benefits. Consider the case where the provision of generation capacity, the operation and maintenance of networks and the supply of electricity to end-users is undertaken by separate entities. In this situation it becomes more complex to ensure that the costs of implementation are borne by those who also realise the benefits than where implementation is undertaken by a vertically integrated utility. Where full legal separation has occurred, as in Finland, India, the Netherlands, Spain and the UK, distribution network operators have significant restrictions placed on them regarding the way they are able to interact with energy Suppliers. Such restrictions are required to prevent distribution network operators offering favourable terms to a particular energy Supplier (e.g. where they are both owned by the same parent company), which could impact on competition between Suppliers. However, such restrictions also make it difficult for a distribution company and a supply company to work closely together in terms of the development of new demand response and energy saving products.

4 Assessment of Demand Response and Advanced Metering, Staff Report, December 2008, FERC

Although France also has full legal separation between its regulated and non-regulated activities, the publicly owned utility EDF is a major player in the generation and retail sectors, as well as the operator of the majority of the distribution network. As such unbundling is unlikely to present a significant barrier in this case. Similarly, unbundling is unlikely to pose a significant barrier in Greece, where the publicly owned PPC is still a major presence in all sectors of the electricity market.

The following table therefore highlights the extent to which the status of unbundling impacts on the barriers to the development of new demand response and energy saving products in the participating countries.

**Table 3.1 Impact of unbundling on barriers to development of new products.**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Barriers | ✓✓ | | | ✓✓ | ✓✓ | ✓✓ | ✓✓ |

## 3.2 Generation Sector

Adjusting the output of generators is the traditional means by which Transmission System Operators (TSOs) ensure that the balance between the demand for and supply of generation is met. However, demand response and energy saving products represent an alternative to the dominant position of generation. For example, demand response products that deliver instantaneous reductions in demand can provide an alternative to the response provided by generators to keep the system frequency within the prescribed limits. Similarly, programmes that deliver long term energy savings can be used as an alternative to investing in new generating capacity to meet peak load requirements. Thus, existing generators with significant market power can represent a potential barrier to the development of new demand response products, depending upon the extent to which they are able to influence the price and/or amount of electricity supplied. Of particular importance is the market power of existing generators at the time of the peak. Countering this market power is an important incentive for the demand side to increase demand response at the time of the peak. However, this could also present an opportunity for new generation to enter the market. Where it is difficult for new generators to come into the market, for example due to difficulty with planning consents, the incentive for demand side products is further strengthened.

Generation mix also has a significant impact on the incentives and barriers for demand side and energy saving products. Of particular importance is the proportion of generation capacity that can be dispatched at the request of the System Operator; such that low levels of generation flexibility provides a specific incentive for the development of demand response products. Factors affecting generation flexibility include the proportion of capacity that is provided by variable renewable sources (e.g. where the output varies according to prevailing wind or tidal conditions) and the proportion of inflexible generation that cannot readily fluctuate output (i.e. base load nuclear and inflexible CHP)

For example, the output of wind turbines varies according to the prevailing wind speeds. This has the potential to create difficulties for system operators who are required to maintain a balance between supply and demand at all times. The variation of the output from wind turbines could be managed using conventional generation plant operating at part load conditions, which is likely to impact on the overall efficiency, and hence cost, of operation. The impact of a high proportion of wind power is already impacting on system operation in Spain. The effects are particularly apparent during the night when the output from wind turbines can represent a significant proportion of the electricity produced. At such times, the amount of conventional generation operating is low, and as such, there is minimal flexibility available to accommodate any unexpected fluctuations in wind output that can occur. Moving additional demand from the peak into this 'valley' period represents a specific incentive for the development of products targeting households and small business. In addition to reducing the system peak, the use of additional conventional generation during the off-peak period improves system flexibility as well as reducing the steepness of the demand curve during the early morning. This offers significant operational benefits to the system operator.

Inflexible generation is a specific issue in Finland where CHP (mainly for district heating and for the pulp/wood/paper industry) forms a large part of the power generation sector. Such plant is largely unable to modulate its output, and as such represents one of the major drivers for demand response in Finland. This is in direct contrast to the situation in the Netherlands, which too has a significant proportion of generation from CHP. However, CHP in the Netherlands (mainly serving the horticultural industry, particularly those commercial greenhouses) is regarded as being highly flexible, and is considered to offer a suitable resource for spinning reserve. Thus, here, the flexibility of the generation mix provides little incentive for new demand response products to be developed.

Generation capacity margin is another important factor affecting the incentives for the development of products to both introduce demand side flexibility as well as reduce overall demand. Generation capacity margin is characterised in terms of the amount by which installed generation capacity exceeds the peak demand. This is often used to provide an indicator of the security of supply, particularly in terms of future planning of generation capacity requirements. A low margin may also indicate a higher dependence on imports. Generally, the higher the margin, the higher the security of supply and the lower the incentive for new demand response and energy saving products.

The actual margin required to ensure future system security is a function of several factors including the characteristics of the particular power system, the accuracy of forecasts of demand and availability of generating plant. For example, consider the event during 2006/07 when only 86.8GW of the estimated 100.7GW of demand in India could be met. At this time, the total installed generating capacity in India was 132GW, representing a plant margin of around 30 percent - comparable to that in other countries which have not experienced similar shortages. However, installed capacity figures generally reflect the 'nameplate' rating of generators, and the actual output could be lower, for example due to poor quality coal as is the case for the power plants in India. Thus, the plant margin in India does represent a significant opportunity for the development of new products, particularly those targeted at reducing demand at the time of the peak. Thus consideration of actual or forecast generating capacity margin in isolation (as presented in Appendix 1) does not necessarily provide a reliable indicator of whether demands for electricity can be met[5]. However, it does provide an indication of whether it is reasonable to expect that demand for electricity can be met by installed generation capacity.

[5] The data presented in Appendix A does not include available import capacity or expected generation availability, both of which would typically form part of any assessment of plant margin.

Table 3.2 below summarises the extent to which the structure of the generation sector presents barriers and incentives to the development of new demand response and energy saving products. The barriers are qualified in terms of the extent to which the market dominance of the existing generators could represent a barrier to the entry of new service providers. Thus, significant barriers could exist in France, Greece, the Netherlands and Spain where the market is dominated by a small number of generating companies.

The incentives are represented in terms of the extent to which the generation mix and generation margin create an incentive for new demand response and/or energy saving products to be developed. The inflexibility of CHP is regarded as a significant incentive for the development of new demand response products in Finland, while the variability of the output from wind turbines is a significant incentive for the development of new products in Spain. Similarly, plant margin in India represents a significant opportunity for the development of new products, particularly those targeted at reducing demand at the time of the peak. The relatively large proportion of nuclear generation in France represents a reasonably moderate incentive for the development of demand response products in order to reduce the reliance on conventional generation resources to help keep the system in balance.

**Table 3.2 Current Generation Sector Characteristics: Barriers and Incentives for demand response and energy saving products**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Barriers | | ⮟⮟ | ⮟⮟ | | ⮟⮟ | ⮟⮟ | |
| Incentives | ✪✪ | ✪ | | ✪✪ | | ✪✪ | |

## 3.3 Transmission Sector

Transmission is a regulated, monopoly activity that comprises the following activities:
- The day to day operation of the network to ensure supply and demand are kept in balance at all times;
- The maintenance of the existing network assets; and
- Planning for, and delivery of, new network assets.

In European countries, these activities are generally undertaken by a single entity, known as the Transmission System Operator or TSO[6], and this is generally the case for the countries participating in this Task. The main exception is India, where the electricity system is managed as five interconnected regional zones. Each zone has its own regional dispatch centre (operated by the State Transmission Utility, STU) which is responsible for maintaining system frequency between 48.5Hz and 50.5 Hz within the zone. The Central Transmission Utility (CTU), also known as the Power Grid Corporation, is responsible for operating, maintaining and developing India's inter-state transmission system, and for the operation of the five regional power grids.

The characteristics of the transmission sector represent another area of the electricity market that has a significant impact on the incentives and barriers to the development of new demand response and energy saving products. Of particular relevance are the following issues, which are discussed further in the following sections:

[6] In North America, netwok operation and system operation are generally conducted by different entities.

- The prevalence of network constraints
- The level of interconnectivity with neighbouring countries
- The ease of entry for new service providers
- Economic incentives on the System Operator to reduce operating costs

## Network constraints

Network constraints restrict the flow of power along the transmission network, and the management of such constraints is an inevitable part of operating a large interconnected network. The existence of significant constraints provides a specific incentive for the development of both demand response and energy saving products. Where constraints are of limited duration and/or occur infrequently, demand response provides an alternative to using expensive generation plant that is located in a favourable part of the network. Where constraints extend for several hours and/or occur frequently, energy saving could provide a viable alternative to network reinforcement. All of the participating countries have indicated that, to some extent, network constraints impact on the operation of the transmission system. Transmission constraints affect all the participating countries to some degree. For example, transmission constraints across Continental Europe and across the UK-France interconnector have had a significant impact on the availability, and hence the price, of electricity in the UK.

## Interconnectivity

Interconnectivity reflects the ability of a country to utilise available generation capacity from neighbouring countries. Therefore, a country with limited interconnection with its neighbours will have a greater incentive to develop demand response / energy saving products than a country which is better connected. The European grid is divided into five synchronous regions and five relevant organisations[7], as listed below and shown in Figure 3.3:

- NORDEL,
- BALTSO,
- UKTSOA
- ATSOI and
- UCTE.

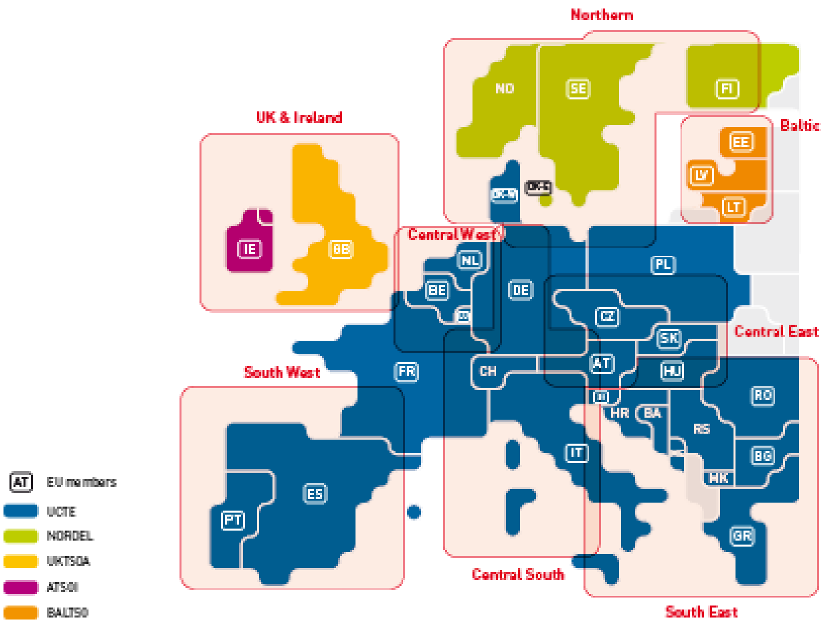



**Figure 3.3 Organisation of the Transmission System in Europe**

7 As of July 2009, the work of ATSOI, BALTSO, ETSO, NORDEL, UCTE and UKTSOA has been fully integrated into ENTSO-E, which provides a new framework aimed at facilitating coordination between the different areas.

As indicated in Figure 3.3, the UK has limited interconnectivity with its neighbours. Electricity interconnections exist between Northern Ireland and Southern Ireland, Northern Ireland and Scotland, and between England and France. However the capacity is generally scare compared to the extent to which market participants would like to arbitrage price differences between national markets. Therefore, explicit auctions are presently used on these interconnectors to allocate capacity. There are plans underway to build a further two interconnectors; a 500MW connector between Ireland and Wales, and a 1GW connector between the UK and the Netherlands.

Similarly, Spain which is located at the south-western extremity of the UCTE region is likely to be affected by transmission constraints to a much larger extent that, say, the Netherlands, which has a much more central location.

### Ease of Entry for New Service Providers

Whilst System Operators may be willing to deal directly with large end users able to provide demand response services, this is unlikely to be case for households and small businesses where several thousand small loads need to be aggregated. Therefore, the ability of new demand side service providers to offer aggregated demand side resources as an alternative to conventional generation is also important. The ease with which new service providers can enter the market is difficult to assess. The existence of service providers utilising the resources of large customers, as is the case in Finland, the Netherlands, and the UK, may indicate that no major barriers to entry exist, and certainly indicates the willingness of the TSO to utilise demand side resources. However, the lack of existing demand side providers does not necessarily imply the presence of barriers, rather that the opportunities may not yet have been fully tested.

### Economic Incentives

The economic incentives placed on the System Operator to reduce its costs could also represent a potential barrier to the development of new demand response and energy saving products. Whilst it is the role of the regulator to promote economic efficiency, specific incentives could provide additional motivation to encourage the development of new products and services. This could include demand response products to assist with the day to day operation and management of the network as well as energy saving products to defer or avoid network reinforcement. For example, the economic regulation of the activities undertaken by the TSO in the UK (National Grid) does include specific incentives to encourage the TSO to reduce operating costs. As with any regulated industry, the expenditure that National Grid requires to carry out its responsibilities are agreed in advance by the Regulator. Under the incentive scheme, if National Grid is able to meet all its obligations, but at a lower cost, it is able to receive an incentive payment. Conversely, if higher costs are incurred then the National Grid faces a penalty. A cap and collar scheme is in place which limits the bounds of these incentives and penalties. Whilst it is not possible to quantify the impact of such incentives on the development of demand response in the UK, it is apparent that the absence of specific incentives could present a barrier due to a lack of motivation on the part of the TSO or other third parties to explore alternatives to the services provided by conventional generation. Countries with some form of incentive in place to encourage the TSO to reduce its operating costs include Finland, India, the Netherlands, Spain and the UK. Thus the incentive for the TSOs in these countries to seek services from new providers is likely to be greater than for the TSOs in France and Greece where no specific incentives exist.

### Summary

Table 3.3 below provides a comparison of the impact of the characteristics of the transmission sector in the participating countries on the incentives and barriers to the development of new demand response and energy saving products. The incentives indicate the extent to which network constraints and limited interconnectivity could impact on the development on new products. With transmission constraints affecting all the participating countries to some degree, it has been assumed that there is at least a moderate incentive in all the participating countries to develop new demand response and energy saving products. However, the incentives are assumed to be slightly greater in Spain and UK due to the impact of location on interconnectivity.

In terms of barriers, the current lack of existing providers in India and Spain could represent a moderate barrier for new service providers to enter the market, whilst the lack of specific economic incentives for the TSO to reduce costs is perceived as a significant barrier to the development of new products and services in France and Greece.

**Table 3.3 Transmission Sector Characteristics:**
**Incentives and barriers for demand response and energy saving products**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Incentives | ✪ | ✪ | ✪ | ✪ | ✪ | ✪✪ | ✪✪ |
| Barriers | | ⮟⮟ | ⮟⮟ | ⮟ | | ⮟ | |

## 3.4 Distribution Sector

Distribution networks operators (DNOs) are responsible for transporting electricity from the Transmission system to the end-users via the distribution network. As such, the DNOs are responsible for maintaining and repairing the distribution network infrastructure.

Unlike transmission systems, distribution networks are generally passively managed, i.e. DNOs do not explicitly use balancing services to manage the system in real time. However, the introduction of distributed generation is placing increasing pressure on distribution network operators, particularly in terms of managing the power flows on networks primarily designed to transport electricity from the high voltage transmission system to end-users. Therefore, as active network management becomes commonplace, the potential role of the demand side will become progressively more important as DNOs increasingly need to manage the balance of supply and demand across their networks.

Whilst not widespread, DNOs already have much experience of active network management, including the following examples shown here:

- **Finland:** As in other countries, only the central parts of the distribution networks are covered by network automations and the far ends of the network are managed by mobile crews communicating with the control centre. Exceptions are some DNOs that have implemented network automation extensions to MV/LV transformers and the LV (400V) networks using remotely readable meters as part of this concept. In terms of demand side flexibility, some power line carrier control systems are in place, but these are now rarely used and will be removed when Smart Metering is rolled out. However, some of the small DNOs did use the system during the national power shortage in January 2006.

- **India:** Most distribution companies face power shortages during peak load. Some companies have initiated energy saving devices at the consumer to reduce peak loads, such as replacement of incandescent bulbs with CFLs, use of star label appliances, provision of subsidies for domestic customers with solar energy, and penalties for large customers with low power factors.
- **Netherlands:** Although DNOS do not currently actively manage their networks, the first steps towards more active network management are being taken. These include:
  - a) Smart Metering;
  - b) informing end-users about the possibility of generating their own energy by means of solar power systems;
  - c) grids capable of handling two-way power flows to accommodate the rise of decentralised generation
- **UK:** There is a general view in the UK that networks will have to become more actively managed to fulfil national renewable energy goals. As such, DNOs have commissioned projects such as dynamic circuit ratings and voltage control schemes. In the near future, communication and control advances that enable generation constraints to be lifted will be considered.

One example of an actively managed network can be found in the Orkney Islands, located off the northern tip of Scotland, which is now a significant exporter of energy from renewable devices. New generators quickly used up the theoretical transfer capacity of the subsea cables, therefore subsequent generators have been equipped with controllers and communications, so that they can fit into the ‘gaps’ created by the intermittency of existing generation using a ‘last-on, first-off’ algorithm. In this case, the reinforcement upgrade would have been in the region of £30M, with the active scheme costing around £200k.

The demand side represents a potential resource for DNOs wishing to seek an alternative to network investment, particularly in terms of the management of peak loads. In terms of avoided capital costs, demand response has the potential to offer a viable solution for deferring network investment rather than avoiding it altogether. This could be particularly attractive where a large investment is planned on the basis of uncertain load growth projections.

For example, consider the case of a DNO requiring a new 30 MVA primary substation costing £4M. However, growth predictions are uncertain and if the current network demand could be reduced by 2MVA, the investment in the new substation could be delayed for a few years at least, allowing future load trends to be more firmly established. A delay of 4 years would realise a fund of £890,000, assuming a discount rate of 6.5%, which could be spent on a dynamic demand programme.

Thus, the presence of network constraints represents an incentive for the development of new products and services using demand side resources as a mechanism to defer or avoid network investment. Constraints are an ubiquitous feature of any network, although, as shown by Table 3.4, the impact of these constraints affects the operation of networks in the participating countries to a varying extent.

**Table 3.4 Distribution Network Constraints**

| Country | Details of distribution network constraints |
|---|---|
| Finland | In rural networks, distribution network constraints do impact on the demand side (It is recognised that limiting demand peaks can defer or avoid network reinforcement and improve restoration times after faults). In urban networks, the capacity of the distribution network does not constrain demand under normal situations. The existing rural and sub-urban distribution networks in general have enough capacity to enable loading of the batteries of full penetration of electric cars, if some load control is applied. |
| France | No significant impact. |
| Greece | No significant impact. |
| India | Managing supply to customers during peak demand hours has a significant impact on the operation of the distribution network, as does high distribution losses |
| Netherlands | No information available, but levels of network disturbances could indicate that networks are becoming more constrained. |
| Spain | No significant impact |
| UK | Some constraints beginning to occur on the networks, often as a result of increased distributed generation. Active network solutions are likely to be used in these circumstances. |

However, care is recommended in interpreting these results, as it is not possible to ensure that the scale of the responses provided by the participating countries is comparable. For example, in Finland, long distances, together with a strict attitude towards power quality requirements, contribute to the need to take into account the network constraints. As a result, an indication that there is "no significant impact" due to distribution constraints may not fully reflect the integrity of the distribution network.

As with the Transmission System, the impact of economic regulation represents a major barrier to the development of new demand products and services for the distribution sector.

The Distribution System represents a natural monopoly, and therefore requires regulation to protect consumers, avoid abuse of powers and ensure that all parties are treated fairly. This includes the requirement to encourage economic efficiency. The framework in place to encourage economic efficiency can have a significant impact on the incentives and barriers for demand side products targeted at providing services to DNOs. For example, if the revenue a DNO is permitted to earn is linked to the number of units of electricity distributed along its network, there is no incentive for it to actively seek to reduce the number of units distributed. Any reduction in the number of units distributed, for example, through the implementation of energy saving measures for end-users would result in a loss of revenue. Likewise, the disparity between the way operating cost and capital expenditure is treated has a significant impact. Whilst operating costs are recovered in the year that they were incurred, capital expenditure is smoothed over a number of years. As such, network operators recover capital expenditure through a depreciation component and earn a return on their asset base. Any costs incurred on demand side measures are likely to be considered as operating expenditure. Thus, the use of demand side resources to avoid or defer capital investment would result in an increase in operating expenditure and a reduction in future income due to reduced depreciation and return on the asset base. This has now been recognised by the UK energy regulator, Ofgem, as a barrier to the development of demand side services by distribution network operators. This is being addressed as part of the current distribution price control review[8].

[8] Distribution Price Control Review 5 (DPCR5) is the next price control applicable to electricity distribution network operators, and is expected to commence on 1 April 2010.

Table 3.5 below provides a comparison of the impact of the characteristics of the distribution sector in the participating countries on the incentives and barriers to the development of new demand response and energy saving products where:

- The extent to which network constraints and the need for active network management represent the incentives for new products to develop; and
- The absence of specific economic incentives for network operators to consider alternatives to network investment represents the main barrier to new products.

**Table 3.5 Distribution Sector Characteristics: Incentives and barriers for demand response and energy saving products**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Incentives | ✪ | ✪ | ✪ | ✪✪ | ✪ | ✪ | ✪ |
| Barriers | ⩔ | ⩔ | ⩔⩔ | ⩔⩔ | ⩔ | ⩔ | ⩔ |

## 3.5 Retail Sector

Energy Suppliers are in a unique position in terms of their relationship with the end-user, and therefore have the potential to play a key role in terms of aggregating large numbers of customers for the delivery of demand response and energy saving products. Options include:

- utilising the demand side response capability of their own consumers as part of their overall energy purchasing portfolio in order to minimise energy purchasing costs, and / or minimise energy imbalance costs;
- trading the demand response capabilities of end-users (which could include consumers of other Suppliers) to other third parties, such as TSOs or DNOs, i.e. acting as a third party aggregator; and
- provision of energy saving products to end-users as a mechanism to meet any energy saving obligations.

The importance of the relationship between the energy Supplier and its customers should not be underestimated. In particular, the development of new demand response products by a third party has the potential to impact on this Supplier-customer relationship. For example, consider the case where the third party demand aggregator is part of a larger organisation with its own supply business. In this scenario, the implementation of load management actions by a third party aggregator could be perceived as a malicious attempt to sour the relationship between a Supplier and its customers.

Issues affecting the incentives and barriers to the development of new demand response and energy saving products include market dominance of the existing Suppliers, the energy settlement process and the impact of any energy saving obligations. These are discussed in more detail in the following sections.

### Market dominance

Market dominance of existing Suppliers represents a significant barrier to the development of new demand response and energy saving products. Energy Suppliers have the potential to make it difficult for new service providers to enter the market. For example, consider the case of Voltalis in France, which is a new demand aggregation business that installs electricity management devices in homes and businesses and then manages their energy use. The company claims to reduce electricity consumption by 5% to 10% by cutting the power to certain appliances at peak times. The business model assumes the grid operator pays Voltalis for help in maintaining supply and demand equilibrium. However, a ruling by France's energy regulator determined that Voltalis was required to compensate the energy utilities for the loss of revenue due to the reduced energy consumption. The ruling has caused much furore in France, and it has even been suggested that the decision demonstrates that the country's electricity utilities wield too much influence over regulators[9].

## Settlement Process

The situation regarding Voltalis in France highlights the potential complexity of the relationship between demand aggregators, the customers and their energy Supplier. In particular, the actions of demand aggregators have a direct impact on the imbalance of energy Suppliers if their customers use less energy than expected (during a particular trading interval) due to demand response actions. In the UK, where the provision of balancing services by the demand side is well established, this issue has not yet proved to be a barrier to the implementation of demand response products. Whilst there is a mechanism for the metered position of balance responsible parties[10] to be adjusted to account for the provision of balancing services to National Grid, no such provision exists for demand side providers, which are generally classified as non BM units. However, even though such demand response actions leave Energy Suppliers 'long', they generally do so at a time when the market is 'short'. Thus any Supplier 'imbalance' arising through demand response actions actually helps counter the overall market imbalance position, which is reflected in the calculation of imbalance charges. It is believed that this benefit is sufficient to prevent the lack of a contractual agreement between demand side aggregators and Suppliers presenting a significant barrier to demand response in the UK. Whether the situation will remain unchanged, if demand response becomes widespread, is a significant unknown.

The settlement process by which the energy consumption pattern of customers without interval meters is determined has the potential to represent a significant barrier to the development of demand response products. As discussed in an earlier IEA project[11], the use of profiles makes it difficult for energy Suppliers to capture the value of any changes to the demand profile of their consumers. Whilst the roll out of Smart Meters enables time of use energy profiles to be collected for small consumers, the interval data is not necessarily used for settlement purposes. In many cases, households with Smart Meters are still settled on the basis of a deemed consumption profile rather than their actual energy consumption. The main exception to this is in Finland where it has now been decided that, once the roll out of Smart Metering has been completed by the end of 2013, 80% of hourly metered consumers must have their electricity meter read daily, thus facilitating settlement based on actual consumption patterns.

## Energy saving targets

Targets to reduce energy consumption and greenhouse gas emissions create a positive driver that could encourage the adoption of the micro demand response and energy saving products that fall within the scope of this project. For example, the European Union has agreed a climate change package to deliver a 20% cut in emissions, a 20% improvement in energy efficiency and increasing the share of renewables in energy use to 20% by 2020. Individual countries within the European Union have different implementation plans to ensure that both their specific obligations are met and that the overall commitment is achieved. The following table highlights whether any specific energy saving obligations have been placed on Energy Suppliers.

---

9 Article presented in French Business Magazine, Challenges, July 2009, "Les fournisseurs d'électricité trop représentés à la CRE ? ", available at http://www.challenges.fr/

10 The 'units of trade', which could comprise a generation unit, demand directly connected to the transmission system or demand provided by a Supplier within a specific region (referred to as a Grid Supply Point).

11 "Time of Use Pricing and Energy Use for Demand Management Delivery", Task XI of the IEA DSM Implementing Agreement

**Table 3.6 Overview of energy saving targets placed on Suppliers**

| Country | Energy Saving Target | Details | Funding | Penalty |
|---|---|---|---|---|
| Finland | ✗ | On a voluntary basis only, where companies receive state aid in return for agreeing specific targets. | State | Return of any state aid received. |
| France | ✓ | White certificate system | | 2c€/kWh |
| Greece | ✗ | No energy saving target or other obligation has been placed on Suppliers to date as EU Directive 2006/32 has not yet been transferred to national legislative framework. | | |
| India | ✗ | No specific energy saving target placed on Suppliers. However, the Bureau of Energy Efficiency has a target to avoid 10,000MW of generation capacity over the period 2007 to 2012 through various end user initiatives. | Government of India | |
| Netherlands | ✓ | Targeted mainly at buildings, and aims to make 500,000 buildings 30% more efficient over 2008-2011, increasing to 2.4 million buildings by 2020. | | None |
| UK | ✓ | Scheme is called the Carbon Emissions Reduction Target (CERT), the current phase of which runs from 2008 to 2011. The scheme is directly targeted at domestic customers, and at least 40% of the target must be been achieved via 'priority' customers – low income / elderly. | Levy paid by end-users | Not defined, but regulator has power to impose a penalty or secure compliance. |

Table 3.7 provides an overview of the key characteristics of the retail sector in each of the participating countries. The incentives indicate the extent to which the existence of energy saving targets specifically create an environment for new demand side products, particularly energy saving products. As such, the presence of mandatory targets represents significant opportunities in France, India and the UK, whilst the incentives in Finland are considered to be moderate in comparison due to the voluntary aspect. The Netherlands also has specific energy saving targets, but directed at buildings. Whilst much activity is likely to focus on improving the thermal performance of buildings this will also create opportunities for demand side products to improve the operation of these buildings.

Table 3.7 also indicates the extent to which market dominance and settlement process represents a potential barrier. The use of profiles represents a barrier for demand response products in all but Finland, which has now committed to the use of interval data for settlement, by 2013. Market dominance of the existing energy Suppliers is seen as a significant barrier in France and Greece to the development of new products by new service providers.

**Table 3.7 Retail Sector Characteristics:**
**Opportunity for demand response and energy saving products**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Incentives | ✪ | ✪✪ | | ✪✪ | ✪ | | ✪✪ |
| Barriers | | ⮟⮟ | ⮟⮟ | ⮟ | ⮟ | ⮟ | ⮟ |

## 3.6 Metering

Smart metering is recognised as a key enabling technology for the implementation of demand response and energy saving products. In April 2008, the European Parliament approved an agreement reached by the EU Institutions on a package of legislation to liberalise EU energy markets. The package includes Electricity and Gas Directives which require the EU Member States to "ensure the implementation of intelligent metering systems."[12] The Electricity Directive foresees full deployment by 2022 at the latest, with 80% of consumers equipped with Smart Metering systems by 2020. This will ensure that all households in the EU will be fitted with Smart Meters by 2022.

Thus, whilst Smart Metering is set to become the 'norm' across Europe, it is never-the-less important to consider the current metering arrangements in place. In particular, many European countries have yet to decide the timescales over which Smart Meters will be deployed. The same also applies to India, which has not yet committed to the roll-out of Smart Meters to households and small business users. Therefore, it could be many years before Smart Meters become a reality.

In general, in most countries it is the responsibility of DNOs to provide meters to consumers. The UK is one of the exceptions to this general rule. Here, it is the responsibility of energy Suppliers to provide meters to consumers, except where the consumer provides their own meter with the Suppliers' agreement. The provision of meters (referred to as 'metering services') differs between half-hourly meter points (generally non-domestic sites) and non-half-hourly meter points (generally domestic sites). The 14 regional distribution network operators (DNOs) are the main providers of meters for non-hourly metered consumers within their geographic region. In terms of half-hourly metered consumers, there are a range of providers, including DNOs operating "out of area", and independent third parties. The DNOs have a license obligation to provide metering services for all meter points, if requested by the relevant Supplier. The UK is also the only country to have implemented competition in metering, which was introduced in 2001/02.

The following Table summarises the extent to which the roll-out of Smart Metering is expected to facilitate the implementation of new demand response and energy saving products, reflecting the status of Smart Meter roll-out and the timescales to full roll-out. Thus, the incentives are significant in Finland where Smart Meters have already been rolled out to 1 million of the 3.1 million customers, and there is a commitment to extend the rollout to 80% of households by the end of 2013 and to use the data for settlement. Elsewhere, where roll-outs of Smart Meters are more limited or where there are no specific timetables in place for their roll-out, the incentives are less.

**Table 3.8 Metering Characteristics:**
**Opportunity for demand response and energy saving products**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Incentives | ✪✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ |

12 http://pr.euractiv.com

## 3.7 Future considerations

Energy sectors rarely remain static, and generally undergo a process of gradual, continual change. Therefore, whilst Sections 3.1 to 3.6 focuses on the current status of the electricity markets in the participating countries, this Section aims to highlight the main issues that are likely to have an impact on the potential opportunities for demand response and energy saving products in future years: In particular, this Section focuses on future changes in generation mix and the emergence of new energy-end use applications.

### Future generation mix

The future mix of generation plant is likely to be a major driver for the development of new demand response and energy saving products over the coming years. Specifically, the EU commitment to reduce greenhouse gas emissions by 20% and to ensure that 20% of energy comes from renewable sources by 2020 are considered to be major drivers for change. Thus future generation mix could comprise:

- Higher proportion of electricity generated from renewable sources, particularly wind which is classed as a variable generation;
- Higher proportion of nuclear generation and super critical steam plant (with carbon capture and storage), which is less flexible that traditional steam plant; and
- Increasing proportion of distributed generation.

Each of these issues creates specific opportunities for new demand response and energy saving products to emerge to reflect the increased requirement for flexible demand and the need to reduce overall demand for energy.

Overall, the European Union has agreed to increase the share of renewables in energy use to 20% by 2020[13]. The extent to which this and any other related commitments impact on the participating countries is summarised in Table 3.9.

**Table 3.9 Renewables Targets in the Participating Countries**

| Country | % generation to be met by renewable sources | Date when target should be achieved | Current level of renewables |
|---|---|---|---|
| Finland | 38 % of all energy consumption<br><br>31.5 % of electricity generation | 2020<br><br>2010 | 28.5 % of all energy consumption (2005)<br><br>25 % of electricity generation (2006) |
| France | 21% (of consumption) | 2010 | 13% (2007) |
| Greece | 18% (of generation) | 2020 | ~9% |
| India | 25GW | 2012 | -15GW (target for February 2009) |
| Netherlands | No specific targets | | |
| Spain | n/a | | |
| UK | 32% (of generation) | 2020 | 4.4% (2007) |

n/a no information available/provided

There has been increasing debate over the future role of nuclear generation, and it seems likely that the future will see a major expansion in nuclear capacity. The following table shows the new nuclear capacity currently under construction in each of the participating countries.

13 Citizen's Summary, EU Climate and Energy Package, http://ec.europa.eu

**Table 3.10 New Nuclear Capacity Under Construction (as at December 2008)**

| | In operation | | Under construction | |
|---|---|---|---|---|
| | Number | Net capacity (MWe) | Number | Net capacity (MWe) |
| Finland | 4 | 2,696 | 1 | 1,600 |
| France | 59 | 63,260 | 1 | 1,600 |
| India | 17 | 3,782 | 6 | 2,910 |
| Netherlands | 1 | 482 | - | - |
| Spain | 8 | 7,450 | - | - |
| United Kingdom | 19 | 10,097 | - | - |

Source: Nuclear Power Reactors in the World, 2009 Edition, IAEA Power Reactor Information Service

In addition to the plant currently under construction shown in Table 3.10, there are further plans to increase nuclear capacity. For example, a new generation of nuclear power stations in the UK has been given formal backing by the government, with the first expected to be 'on-line' by 2017[14]. Conversely, the Spanish Government has declared itself opposed to building new nuclear power plants, although it has recently indicated an intention to extend the operating life of its oldest nuclear reactor for another ten years[15].

Carbon capture and storage (CCS) is an, as yet, untried approach to mitigating the contribution of fossil fuel emissions to global warming, based on capturing carbon dioxide (CO2) from large point sources such as fossil fuel power plants and injecting it into deep geologic formations for permanent storage. It is considered to be a key carbon abatement technology by the IEA, as reflected its recent publication on this subject[16]. The use of CCS is expected to compromise the flexibility of fossil fired generation, although a number of options to improve plant flexibility are under consideration. For example, turning off the CCS process temporarily would improve plant flexibility (and possibly capacity) but would also lead to increased CO2 emissions. Alternatively, it may be possible to provide further improvements in fossil-fired plant flexibility through the use of solvent storage to allow flexibility in determining when the energy penalty for the capture process is applied to the power plant output.[17].

Most electricity is generated in large power stations which deliver economies of scale, safety and reliability. However, new technologies are now becoming available to generate electricity near to where it is used, including roof mounted PV panels and micro CHP. Such technologies have the potential to improve energy efficiency and reduce emissions. A move towards the use of more distributed generation creates a strong driver for products that deliver enhanced demand flexibility both to ensure local generation matches local output and to assist distribution network operators with the move towards active network management.

Energy storage represents an alternative to the use of demand flexibility to assist with maintaining the balance between supply and demand, particularly where generation has a variable output or limited capability to adjust output to meet fluctuations in demand. Pumped hydro storage is currently the only large scale energy storage technique that is widely used in power systems throughout the world. Most of the world's large pumped hydro schemes were commissioned in the 1970s and 1980s and the technology is well developed. Electricity companies use pumped hydro as an economic method of utilising off peak energy by pumping water to a high reservoir during times of low energy demand. The stored energy is

14 New nuclear plants get go-ahead, news items released via web-site http://news.bbc.co.uk/
15 Spain facing key decision on use of nuclear power, news item released via web-site http://www.expatica.com
16 CO2 Capture and Storage – A Key Carbon Abatement Option, IEA Publication
17 Potential for Synergy Between Renewables and Carbon Capture and Storage, Chalmers and Jon Gibbins, Energy Technology for Sustainable Development Group, Mechanical Engineering Department, Imperial College, London

then released during periods of peak demand by discharging the high level reservoir to a lower level reservoir via turbine coupled generators. In addition, other hydro power reservoirs (i.e. those not classified as pumped storage) do provide some facility for energy storage, although typically on a seasonal basis. In this case, the storage capability is heavily dependent upon prevailing weather conditions to replenish and/or maintain the water reserves.

Table 3.11 provides an overview of the current installed storage capability in the participating countries, together with the status of any plans to increase future storage capacity.

**Table 3.11 Installed Storage Capability**

| Country | Storage Capability | Future plans for additional capacity |
|---|---|---|
| Finland | None | The total hydro reservoir capacity is approx. 5.5TWh, and there is no pumped storage.<br>No specific plans in place, but discussions are ongoing regarding the development of a new hydro power reservoir. |
| France | 4.4GW (Hydro) | No specific plans |
| Greece | .7GW (Hydro) | No specific plans to increase storage plans |
| India | n/a(i) | |
| Netherlands | None(ii) | |
| Spain | 3494 GWh (Hydro) | No specific plans |
| UK | 2.7GW (Hydro) | Scottish and Southern Energy have recently drawn up plans to build two pumped storage plants, each with a capacity of 600MW. It is anticipated that the planning application will be submitted in 2011. . In addition, there are a few demonstration projects currently underway exploring the use of electro-chemical storage, for applications such as standby capacity for substations and integration of renewables. |

(i) Few Hydro Power Stations have pumped storage capability. The exact capacity is not known at the time of writing.
(ii) There is no hydro storage capability in the Netherlands, but there is significant flexibility in the gas market due to large gas storage facilities, as such flexibility in the electricity market can be facilitated with relative ease.

## New end-use applications

Decarbonisation of the electricity sector could lead to significant reductions in emissions of greenhouse gases through the substitution of fossil fuels. The electrification of transport is seen as particularly important with transport accounting for some 20% of all the world's CO2 emissions[18]. Switching from petroleum-based fuels to decarbonised electric power offers a viable opportunity to make dramatic emission reductions from light duty vehicles (private cars and small commercial vehicles).

The use of heat also offers the potential to reduce the $CO_2$ emissions associated with heating, another major contributor to $CO_2$ emissions. This applies both with current generation mix as well as for a decarbonised electricity sector. Heat pumps extract low temperature heat from the air, ground or from water to provide useful heat. Heat pumps (particularly ground source heat pumps) are sometimes referred to as renewable energy sources; although they do require energy input (work) to upgrade the 'free' heat. This energy input is usually provided via an electrically driven compressor. The efficiency of a ground source heat pump is measured in terms of its coefficient of performance (CoP), which defines the amount of heat produced compared to the amount of electricity consumed. A typical CoP for a ground source heat pump is around 3.2[19] without allowing for any energy used in the heat distribution system.

18 World Coal Institute, Climate Policy Paper 6, Section 6 Electrification of Transport
19 Energy Savings Trust

Any increase in the use of such new end-use applications could lead to significant growth in the use of electricity, which could outweigh other electricity savings achieved with ‘existing’ end-uses. This impacts on both generation capacity and network capacity, leading to further ‘strains’ on existing resources. Whilst this will provide additional drivers for solutions to manage the balance between supply and demand, they could also be part of the solution. For example, the charging regime for plug-in electric vehicles could be optimised to avoided system peak and maximise the use of available generation capacity. In addition, it is theoretically possible for the batteries of electric vehicles to provide distributed storage of excess generation capacity, for example when the output from wind generation is high. However, the payments made for such use of the batteries would need to compensate for any reduction in overall life due to the increased battery cycling.

Widespread adoption of heat pumps could have a significant impact on electricity demand during peak hours. Optimising the use of heat pumps to minimise demand during peak hours would require the integration of fabric storage or thermal storage to allow the heat pump to be switched off for a period of time without loss of comfort. Alternatively bivalent operation would allow an alternative fuel source, such as gas, to be used[20] at times of peak electricity demand.

### Summary of future considerations

- As summarised in Table 3.12, future considerations are likely to result in increased incentives for new demand response and energy saving products. However, the impact is likely to be greatest where challenging targets for the use of renewable generation have been set (particularly in France, Greece, India and the UK).

**Table 3.12 Future Considerations:**
**Opportunity for demand response and energy saving products**

| | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|
| Incentives | ✪ | ✪✪ | ✪✪ | ✪✪ | ✪ | ✪ | ✪✪ |

## 3.8 Summary

The review of the market arrangements that govern the way that electricity is traded within the participating countries highlights, not unsurprisingly, that there are a number of significant differences between the participating countries. As summarised in Table 3.13, these differences give rise to different drivers for demand response and energy saving products and, perhaps more importantly, different barriers to the development of new products and services. This suggests that no one product or service will be applicable, but rather that new products or services will need to be tailored specifically to individual needs. Although this review of incentives and barriers is high level, it does provide a useful basis for identifying the factors that could influence the successful implementation of demand response and energy saving products. A more detailed understanding of the specific national rules and legislations may be required in order to fully understand the potential interaction between major stakeholders. Such understanding could be facilitated by use of a market map. This provides a schematic picture of the most relevant stakeholders within a particular market, and also shows the main interactions between those stakeholders. An example of such a market map is provided in Appendix 2, which provides an overview of a specific market chain, the relevant service providers and its enabling environment.

20 Example of a bivalent system available at http://www.unitedenergy.ca/brochures/kool-fire_2.pdf

**Table 3.13 Summary of extent to which incentives and barriers could impact on the opportunities for new demand response and energy saving products**

| | | FI | FR | GR | IN | NL | ES | UK |
|---|---|---|---|---|---|---|---|---|
| Unbundling | Barriers | ⮟⮟ | | | ⮟⮟ | ⮟⮟ | ⮟⮟ | ⮟⮟ |
| Generation Sector | Barriers | | ⮟⮟ | ⮟⮟ | | ⮟⮟ | ⮟⮟ | |
| | Incentives | ✪✪ | ✪ | | ✪✪ | | ✪✪ | |
| Transmission Sector | Incentives | ✪ | ✪ | ✪ | ✪ | ✪ | ✪✪ | ✪✪ |
| | Barriers | | ⮟⮟ | ⮟⮟ | ⮟ | | ⮟ | |
| Distribution Sector | Incentives | ✩ | ✩ | ✩ | ✪✪ | ✩ | ✩ | ✩ |
| | Barriers | ⮟ | ⮟ | ⮟⮟ | ⮟⮟ | ⮟ | ⮟ | ⮟ |
| Retail Sector | Incentives | ✪ | ✪✪ | | ✪✪ | ✪ | | ✪✪ |
| | Barriers | | ⮟⮟ | ⮟⮟ | ⮟ | ⮟ | ⮟ | ⮟ |
| Metering | Incentives | ✪✪ | ✪ | ✩ | ✩ | ✪ | ✪ | ✪ |
| Future considerations | Incentives | ✪ | ✪✪ | ✪✪ | ✪✪ | ✪ | ✪ | ✪✪ |

# 4 Demand Response Requirements

Historically, many demand response products would have been defined with generators in mind, and so will often have notification times, durations and sizes specifically suited to the characteristics of generators. However, demand side products may be able to offer alternative characteristics that would still be attractive. Therefore, this section reviews the range of demand response products that could be provided by end-use consumers either through changes to their pattern of consumption or through the application of on-site technologies such as micro-generation or energy storage. In particular, this Section identifies some specific requirements for a range of demand response products.

Whilst much terminology exists to describe the various types of demand response programmes according to the specific issue being addressed, no standard set of definitions has emerged to date. Therefore, this Section considers the requirements for the following range of demand response products:

- **Response services** to help maintain the system frequency within the specified limits. This can include both dynamic services, that automatically regulate in response to second by second changes in frequency and non-dynamic services that are triggered if the frequency deviates from the nominal value by a pre-determined amount.
- **Reserve services** that provide additional power through a reduction in demand (or through the use of on-site generation or storage facilities) to deal with unforeseen changes in demand or generation.
- **Constraint management services** whereby changing the demand profile of end-users (either through avoided or deferred use of electricity) allows for avoided network constraints, both in the short term (to improve day to day operation of the network) and over the longer term (for avoided or deferred network reinforcement).
- **Imbalance energy trading** whereby demand side providers participate directly in a balancing market (where one exists), offering to reduce (or indeed increase) demand to assist with correcting any energy imbalances between electricity supply and demand close to real time once all energy trades have been completed.
- **Within day energy trading** whereby the demand profile of end-users is adjusted within 24 hours of the time of delivery in order to optimise within day trading.
- **Day ahead energy trading** as above, but where the aim is to optimise trading at the day ahead stage.
- **Long-term energy trading** as previous, but where the aim is to adapt the profile of end-users over the longer term in order to optimise energy trades over the longer term (for example smoothing of the load profile may enable a greater proportion of energy consumption to be purchased under longer term contracts, as the risk to exposure by peaks in demands is reduced).
- **Valley filling** as above, but where the aim is specifically to adjust the profile to address any valleys in the overall load profile, which could become important where there is a need to ensure demand for electricity during off peak period is sufficiently high to offset the output from non-dispatchable generation (such as wind and/or base load nuclear)
- **Peak lopping** as previously, but where the aim is specifically to reduce the overall peak demand on the system, either through short term demand reduction during peak periods or via long term changes to the demand profile.

The requirements of the potential 'buyers' of demand side response are considered in terms of the following parameters:

- The amount (MW) of aggregated demand response typically required;
- The preferred profile (or shape) of any demand response delivery;
- The notification provided to each customer before demand response is required to be delivered; and
- The duration over which the demand response should be typically provided.

As highlighted in Section 3 of this report, there are many differences between the structure of the electricity markets in the participating countries. Therefore this Section focuses on the generic requirements; any specific differences relating to individual countries are highlighted where relevant.

The parameter that is probably of most importance from the perspective of the end-user (i.e. the provider) is the notification period, and as such this is considered first.

## 4.1 Notification period

The notification period refers to the length of time that is provided to end-users that they are required to deliver their demand response in advance of its actual delivery. It does not refer to any advance negotiations between the provider and the buyer in terms of the contractual issues concerning the provision of demand response.

The following schematic, therefore, provides an overview of the notification period generally associated with the different demand response categories.

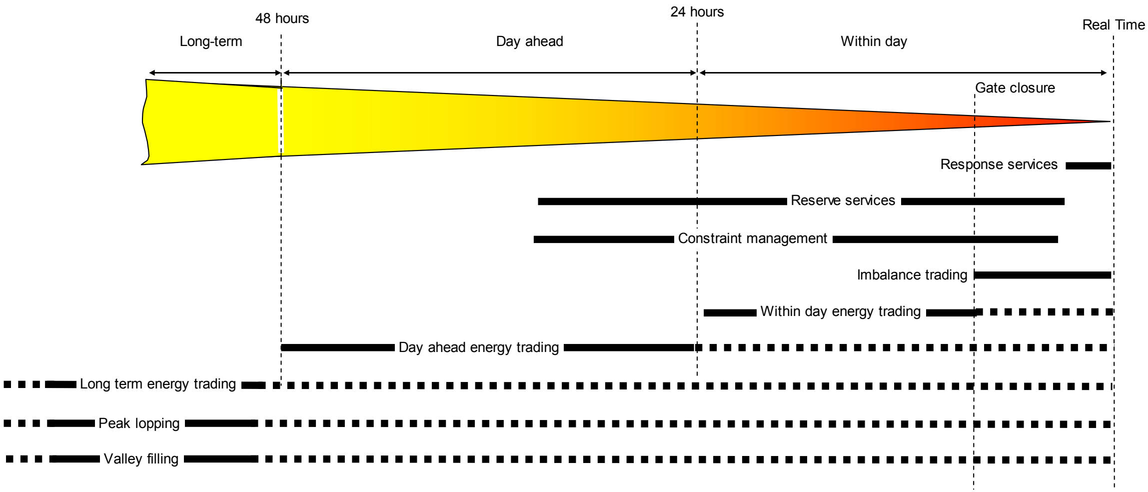



**Figure 4.1 Demand response products notification periods**

The information presented in Figure 4.1 demonstrates how the notification period varies according to the general purpose of the product. Response services, by definition, are required close to real time (for non-dynamic services) or in real time (for dynamic services). Likewise, participation in a balancing market requires that decisions on adjustments to demand are made after gate closure, ranging from 15mins to 1 hour ahead of real time for the participating countries. Consequently, demand response products within these categories allow for little or no opportunity to notify users in advance that demand response actions are to be instigated. Thus, end-uses suitable for aggregating to provide these services need to be able to be turned off instantaneously and automatically.

Demand response products for reserve services, constraint management and to facilitate optimised within day energy trading, all provide for notification periods to the end-user ranging from a few minutes to several hours ahead of real time.

Whilst the timing of network constraints can often be predicted in advance, operational decisions to reschedule generation plant and/or to instigate demand response actions are often made much closer to real time. Likewise, shortages of capacity can often be predicted several days or months in advance, for example when they arise due to scheduled maintenance. However, it seems reasonable to suggest that operational decisions on whether to actually dispatch demand reductions for these eventualities would be made much closer to the time of delivery, and typically on the day or at the day ahead stage.

Whilst the notification for demand response actions linked to optimised energy trading can be provided within the appropriate timescale (i.e. within day, day ahead or longer term), it is possible that decisions do not need to be taken up until gate closure. This latter case, which is particularly relevant where demand response comprises the aggregated load of a large number of customers, allows the aggregator flexibility in how the demand response is actually delivered. For example, a demand aggregator committed to providing 10MW of demand reduction over 1 hour may have flexibility in how the level of demand reduction is delivered, assuming it has a significantly diverse portfolio of demand side providers to enable it to do so. For example, the required level of demand response could be provided by:

- 1,000 customers each providing 10kW of response for 1 hour; or
- 10,000 customer each providing 1kW of response for 1 hour; or
- 1,000 customers each providing 10kW of response for ½ hour, followed by a further 1,000 customers providing 10kW of response for ½ hour.

Delaying decisions up to the time of delivery may offer certain advantages in terms of avoiding or minimising energy imbalance penalties. For example, an unexpected shut down of a large industrial customer may reduce (or even remove) the need for other planned demand response activities. Thus only minimal further demand response would be required to avoid imbalance charges, provided that imbalances are determined on the aggregated demand of all the customers.

Similar arguments to those discussed in the preceding paragraph also apply to demand response activities designed to smooth the demand profile (i.e. reduce peak demands and / or fill valleys). Therefore, it is apparent that there is the potential for significant variability in the notification period given to end-users within individual categories depending upon how the product is managed and delivered. The main exception to this is for response services where little or no notification is the norm.

## 4.2 Shape

The shape of demand response can be determined in terms of the ramp rates at the start and end of delivery, where the ramp rate is defined as the rate of change of load (usually expressed in MW per minute, as indicated in Figure 4.2.

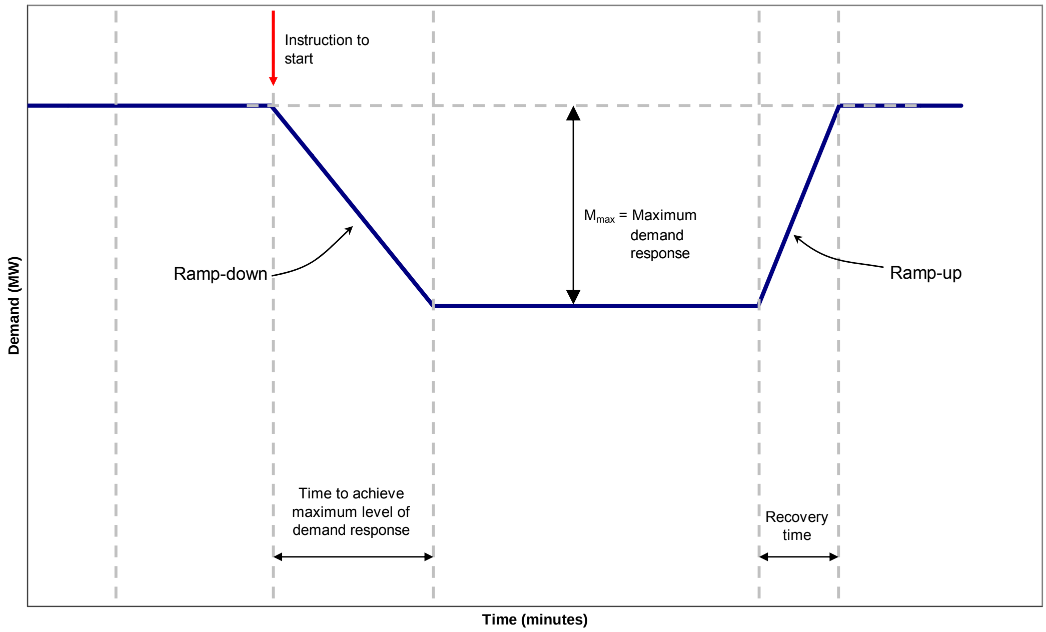



**Figure 4.2 Ramp rates for demand response**

Ramp-up / down rates are most relevant for services used to maintain the quality and security of supply, particularly response and reserve services, which by definition are used to maintain a close balance between the supply of and demand for generation. In the case of demand response services used to facilitate wholesale electricity trading (e.g. within day or day ahead trading), the shape will be of less importance. Trades are based on the average level of demand over the relevant trading interval, thus the metered unit for such trades is the amount of energy response (MWh) delivered.

Some examples where specific ramp-down rates have been defined are shown below.
- **Regulating Power Market, Finland.** Participants must be able to implement a power change of 15MW in 15min (i.e. a ramp rate of 1MW/min). However, it is important to note that the limit has been reduced to 5MW for a trial of aggregated small distributed resources.
- **Fast Reserve, UK**. Participants must be able to deliver their reserve at a rate greater than 25MW/minute.
- **Frequency Control by Demand Management, UK**. Participants must deliver a minimum of 3MW within 2seconds on instructions.

From the perspective of end-users, ramp-rates such as those highlighted above effectively imply that loads must be able to be shut down instantaneously to be able to participate in such schemes.

There seems to be little documented information on the appropriate ramp-up rates for demand response, which is somewhat surprising as large loads coming back on line in an uncontrolled manner do have the potential to cause further network disturbances. In some cases, demand side providers may not even be required to come back 'on-line' at the end of their demand response delivery. For example, Task VIII[21] showed that large industrial consumers providing frequency response services often undertake planned maintenance during the ‘down-time’, which may on occasion extend beyond the 30 minute delivery window.

## 4.3 Duration

The length of time that demand response is required is generally dictated by the duration of the settlement periods, i.e. the intervals over which energy trades are settled. As shown in Table 4.1, the trading intervals in the participating countries vary from 15 minutes to 1 hour. In addition, energy is often traded in larger blocks to create standard products for trading, i.e. energy is often traded over a number of trading intervals. In the Elspot market in Finland, bids are required to cover a minimum of 3 consecutive hours, and blocks can also be further linked into larger blocks.

**Table 4.1 Trading Intervals**

| Country | Trading Interval |
|---|---|
| Finland | 1 hour |
| France | ½ hour |
| Greece | 1 hour |
| India | ¼ hour |
| Netherlands | ¼ hour |
| Spain | ¼ hour |
| UK | ½ hour |

In most cases, the shorter the time interval then the easier it will be for end-users to participate in demand reduction schemes, as the impact on ‘service provision’ will be minimised. This will apply particularly to end-uses that are interrupted mid-cycle (such as heating and air-conditioning loads) as well as end-uses that are rescheduled (e.g. delayed start to a dishwashing cycle). Therefore, this Task will initially focus on the consideration of micro demand response services with the shortest duration.

## 4.4 Amount

The amount or size of demand response required by market participants will of necessity be large, generally of the order of several MWs. This is especially true of products offered as an alternative to the use of conventional generation plant which typically have capacities of several hundred MWs. Thus it is unlikely that aggregated demands of less than 1MW are likely to be technically or commercially viable. The only exception to this may be for demand response products targeted at providing network support services for distribution network operators.

The following table provides an overview of the required minimum size of demand response products that currently exist in the participating countries.

[21] Task VIII of the IEA DSM Implementing Agreement, Subtask 3 Report, The consumer potential for DSB: National Reports for Finland, Greece, Netherlands, Norway, Spain, Sweden and the UK, June 2002

**Table 4.2. Minimum size requirements of selected demand response products**

| Country | Category | Product | Minimum MW |
|---|---|---|---|
| Finland | Response/Reserve | Regulating Market | 15MW in 15 min<br>(5MW in experimental trial) |
| | Energy trading | Elbas | 1MWh |
| | | Elspot | 0.1MWh |
| France | Imbalance trading | Distributed demand response | 10MW |
| India | Energy trading | Power exchange trades | 0.25 MWh<br>(1MW over 15 mins) |
| Netherlands | Energy trading | APX spot market | 0.1MW |
| UK | Response Services | Firm frequency response | 10MW |
| | | Frequency control by demand management | 3MW |
| UK | Reserve Services | Short-term operating reserve | 3MW |
| | | Demand management | 25MW |

The issue of 'firmness' is probably of greater importance than the absolute level of demand response required. This is particularly the case when response is provided by a large number of very small loads and where the pattern of consumption is difficult to predict. End-uses that cannot be readily predicted in advance do not need to be excluded from demand response programmes and can often provide a useful service as demonstrated by the commercial frequency response service offered by arc furnaces to the UK System Operator. Arc furnaces are capable of instantaneous shut down with no adverse effect on the plant making them ideal candidates for offering frequency response services. However, individual arc furnaces have very high, but irregular, patterns of electricity usage, fluctuating from zero demand to over 50MW within a half-hour. This makes them, as individual plant, unsuitable for frequency response. However, the net load of several arc furnaces, when aggregated together, can provide a predictable load as shown below. Thus, in this case, the demand is aggregated to establish a minimum demand response requirement that can be attained for at least 90% of the time.

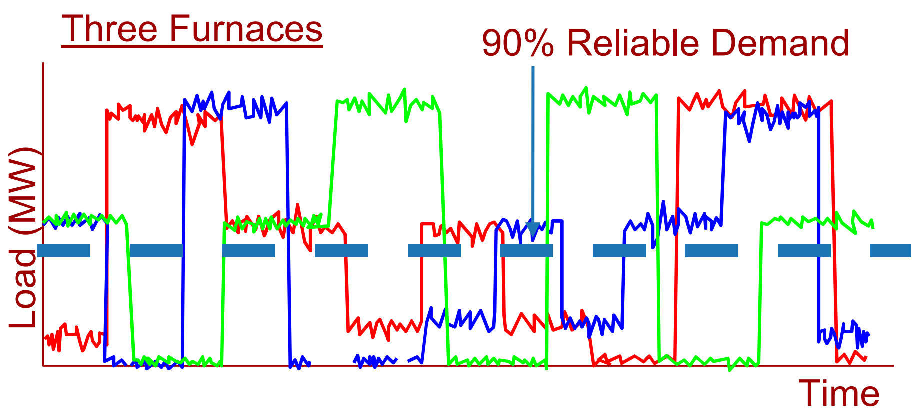



**Figure 4.3 Aggregating loads to provide a 'firm' level of demand response**

Thus, the level of demand response provided by a group of customers can be expressed as follows:

$$DR_{total} = DR_{customer} \cdot N_{customers} \cdot F$$

Where

$DR_{total} =$ total aggregated demand response, MW

$DR_{customer} =$ maximum level of demand response per customer, MW/customer

$N_{customers} =$ total number of customers

$F =$ firmness factor

The ‘firmness’ factor thus reflects the level of variability associated with a particular end-use, such that the more predictable the load the higher the ‘firmness’ factor, up to a maximum of unity for loads that can be predicted reliably. Such a ‘firmness’ factor could also be used to reflect diversity across a group of customers.

## 4.5 Summary

The following table provides a summary of the main characteristics of the different categories of demand response products in terms of the notification period, duration and shape requirements. The exact requirements will depend upon the purpose of the product, which will inevitably vary on a case by case basis. Therefore, the following table is intended to provide an indication of the range of possibilities that exist for each product category. In each case, no specific details are provided for the amount of demand response required. It is likely that specific requirements can often be ‘negotiated’ between the participants, such that the value of any product is likely to be proportional to the amount of demand response that can be offered.

**Table 4.3 Characteristics of demand response product categories**

| | | | | Energy Trading | | | | |
|---|---|---|---|---|---|---|---|---|
| | **Response services** | **Reserve services** | **Constraint mngt** | **Imbalance trading** | **Within day** | **Day ahead** | **Long-term** | **Valley filling / Peak lopping** |
| **Notific-ation** | minutes to seconds | hours to minutes | hours to minutes | gate closure to real time | in line with energy trading schedule | | | years to months |
| **Duration** | minutes | few hours | few hours | trading interval | single / multiple trading intervals | | | hours |
| **Shape** | ramp up/down rates important | | MWh only | MWh only | MWh only | | | MWh only |
| **Size** | ← several MWs → | | | | | | | |

# 5 Review of Case Studies and Pilots

This section provides an overview of the findings from a selection of DSM pilots and case studies conducted over the last 10 to 15 years or so that have encouraged end-users to change the amount of electricity they consume and the way that it is consumed. The pilots and case studies presented here are not intended to be an exhaustive selection, nor are they intended to highlight typical results that might be expected from the application of various approaches to demand response and end-use monitoring and feedback. Rather, the case studies and pilots presented provide an insight into the range of results that are possible.

Section 5.1 focuses on trials of various approaches to motivate consumers to reduce energy consumption through End Use Monitoring and Feedback, whilst Section 5.2 focuses on trials specifically designed to motivate consumers change the way they consume energy through various demand response mechanisms.

## 5.1 End Use Monitoring and Feedback

Within the context of this study, End Use Monitoring and Feedback (EUMF) relates to any means of providing information to end-users on the energy they consume in order that they can make changes to the way they consume energy. This could include making behavioural changes such as:

- turning off lights and appliances in unoccupied room;
- adjusting thermostat settings; or
- making informed decisions about when to operate certain appliances (such as washing machines, tumble dryers and dishwashers).

Table 5.1 provides an overview of reported electricity savings from a selection of trials involving various approaches to end-use monitoring and feedback.

The reported savings of the trials highlighted in Table 5.1 range between 0% and 25%. The wide variation demonstrates the difficulty of determining a benchmark saving that could be expected for a particular approach to End Use Monitoring and Feedback. For example, both the Northern Ireland Key Pad Trial and the Birk Tecknik og Miljo trial in Sweden, involved the deployment of prepayment meters with visual displays. However, there was is a marked difference in the level of energy savings reports. The level of savings reported in the Northern Ireland trial have been reported to range from 4 to 11% compared to reported savings of 20% in the Swedish Trial. Trials involving real time displays but without pre-payment metering show a similarly wide range in the extent of energy savings reported. For example, the savings achieved during the Hydro One trial were 6.5% compared to 16% for the WarmPlan trial.

As noted by Darby[22], who has conducted an in-depth review of the effectiveness of feedback of energy consumption, it is important that the results of each study are considered in context. Thus it is not wise to draw out specific conclusions about the effectiveness of a feedback approach without also considering factors such as the overall package of measures evaluated, the selection criteria used to select the households for the trial, the size of the trial and the length of the trial. The Darby study, which included a review of a much larger selection of trials than has been cited here, suggested that savings in the region of 5%

[22] The Effectiveness of Feedback on Energy Consumption, A Review for Defra of the literature on Smart Metering, billing and direct displays, Sarah Darby, April 2006

to 15% have been achieved with direct feedback, reducing to around 0% to 10% where feedback is indirect.

**Table 5.1 Summary of Reported Energy Savings of Studies Involving End Use Monitoring and Feedback**

| Study | Country | Date | Sample Size | Electricity Savings | Feedback Type |
|---|---|---|---|---|---|
| Energy Demand Research Project[23] | UK | On-going | 8,500 | None reported for 6 months Mar to Aug 08 | Clip-on visual displays |
| Green Streets[24] | UK | 2008 | 64 | 20% | Community action |
| WarmPlan[25] | UK | 2007 | 130 | 16% | Smart meter with direct display |
| Pilot Systems[26] | UK | 2005 | 73 | 0% to 25% | Smart meter trial for SMEs |
| Hydro One[22] | Canada | 2006 | 500 | 6.5% | Real time display |
| NIE Key Pad Trial[22] | UK | 2002/3 | - | 4% to 11% | Pay-as-you-go meter with accessible key pad |
| Birka Tecknik og Miljo[27] | Sweden | 1998 | 288 | 20% | Prepayment meter with display |
| Eco Team Program[28] | Netherlands | 1995 | 83 | 8% | Own meter read and comparison with peers in 'Eco Team' |
| Niagara Mohawk (LICAP)[29] | Canada | 1998 | 704 | 3% to 23% | Energy savings advice and energy services |
| LINKKI[30] | Finland | 1996 | 105 | 17% to 21% | Indirect energy feedback |

It is interesting to note that the results shown above would suggest that achieving energy savings that can be sustained over the longer term is not dependent upon the use of advanced metering and displays, as demonstrated by the EcoTeam Trial. This trial involved a relatively small sample of households who were grouped together in 'ecoteams'. The householders were asked to manually read their meters and compare their energy savings with others within their 'ecoteam'. As a result, the energy consumption some two years after the completion of the trial was on average eight percent less than it had been before the trial, even though only modest improvements were reported shortly after participation.

The results of these trials demonstrate the range of potential savings that can be realised through the application of direct feedback of energy consumption information. Without such information, it is difficult for householders and SMEs to identify where potential savings could be made or evaluate the impact of any changes implemented. Whilst the level of savings will depend on a variety of factors, particularly the willingness of the end-users to actively engage in any energy saving program.

23 Energy Demand Research Project, Review of progress for period April 2008 – August 2008, March 2009 Ref: 29/09

24 Green Streets, Final Report to British Gas, Institute of Public Policy Research, March 2009

25 Warm Plan Smart Meters Monitoring Report (Phases 3 to 5), Ofgem, June 2008

26 Presentation by Nigel Orchard at Synergy 2007 Conference

27 European Smart Metering Alliance Case Studies, available at http://www.esma-home.eu/smartMetering/caseStudies.asp

28 Effectiveness of the EcoTeam Program in the Netherlands: A Long Term View, Harland and Staats, available at http://www.globalactionplan.nl/

29 Low Income Customer Assistance Program Impacts on Energy Usage, Report by Applied Public Policy Institute for Study and Evaluation for Niagara Mowhawk, February 2002

30 IEA DSM Task XI: Time of Use Pricing and Energy Use for Demand Management Delivery Subtask1 Report: Smaller Customer Energy Saving by End Use Monitoring and Feedback.

Whilst the results from the application of end-use monitoring and feedback are wide ranging, it would seem reasonable to suggest that it could be expected deliver savings of up to 15%, depending upon the approach taken.

## 5.2 Demand Response

This Section looks at the impact of different incentives to motivate end users to change their pattern of electricity consumption, and in particular to reduce peak demand. Included are details of short term trials and products offered on an ongoing commercial basis.

**Table 5.2 Summary of reported peak load reductions achieved through various approaches to demand response**

| Study | Country | Date | Sample Size | Peak Load Reduction* | Approach |
|---|---|---|---|---|---|
| Tempo Tariff[31] | France | On-going | 350,000 (residential)** | 1kW | TOU (Dynamic / traffic light) |
| PG&E Smart Meter Trial[32] | USA | 2006 | 2,011 (residential & commercial) | 16.6% | TOU tariff (critical peak pricing) |
| California Statewide Pricing Pilot [33, 34] | USA | 2004 | 2,500 (residential, commercial & industrial) | 4% to 34% (residential) | TOU tariff (critical peak pricing) |
| | | 2003 | | 6% to 10% (commercial and industrial) | |
| Dynamic pricing trial[35] | Finland | 1993 | 130 (residential, commercial, agriculture) | 2% to 31% | TOU tariff (dynamic/ traffic light system) |
| ETHOS[31] | UK | 1996 | 100 (residential) | 25% | TOU tariff (dynamic) |
| Winter peak reduction scheme[31] | Ireland | 2003 | 186 (large industrial) | 430kW (80MW total) | Incentive (direct load control) |
| New York ISO DR programmes[31] | USA | 2001 | 2,000 (commercial and industrial) | 877kW (1,754MW) | Various |

(*) Expressed in terms of the average peak load reduction per customer
(**) Also available to small commercial and business customers

The data presented in Table 5.2 demonstrates that demand response products can have a significant impact on peak electricity consumption. Again, care is needed when considering the results from the various case studies. The ETHOS study, which formed part of the European Commission Esprit programme involving a number of European electricity utilities, evaluated whether multimedia energy management systems could be used to achieve demand management outcomes. Parts of the rural distribution network were peaking during the night period because of storage space and water heating loads. Therefore, part of the trial involved optimising the charging period of storage appliances in response to the broadcast of cost information. The combination of a dynamic tariff/cost structure and the energy management systems enabled the local distribution network operator to influence when energy was used to charge storage appliances and also had the ability to prevent

31 IEA DSM Case Studies available at http://www.ieadsm.org/CaseStudies.aspx
32 http://apps1.eere.energy.gov/state_energy_program/project_brief_detail.cfm/pb_id=1081
33 California's Statewide Pricing Pilot: Commercial & Industrial Analysis Update, George, Faruqui & Winfield, June 2006
34 California Statewide Pricing Pilot, Overview and Results 2003-2004, Presentation obtained from http://sites.energetics.com/
35 IEA DSM Task XI: Time of Use Pricing and Energy Use for Demand Management Delivery Subtask 2 report,April 2005

charging completely in any specified period. However, various software and hardware issues meant that the local network operator was only able to make one attempt to modify the shape of the distribution network demand profile. Nevertheless, this attempt was successful in reducing the night time peak by as much as 25%.

Tempo is often cited as being the most sophisticated tariff for mass market customers. It enables smoothing of both the annual and daily electricity load curves in order to reduce marginal generation and network costs. The Tempo tariff comprises six rates of electricity pricing based upon the actual weather on particular days and on hours of use. Under this option, each day of the year is colour coded blue, white or red which correspond to low, medium and high electricity prices. The colour of each day is determined by EDF (the dominant generator and Supplier in France) based on the forecast of electricity demand for that day, which is largely dependent on the prevailing weather conditions. RTE, the French Transmission System Operator, also has the ability to determine the day colour if there is significant congestion on the electricity network. In addition to a colour, each day also has normal and off-peak periods, with 10pm until 6am being the off-peak period. The number of days per year of each colour is fixed; there are 300 blue days, 43 white days and 22 red days. On red days, the price is very high to encourage lower electricity usage - the normal rate on red days is over 10 times that of the off-peak rate on blue days. Red days are usually the coldest days in winter. In 2005, the prices for the different days are shown in

**Table 5.3 Tempo Tariff for 2005 (euro cents / kWh)**

| | Blue Days | White Days | Red Days |
|---|---|---|---|
| Off-peak | 2.99 | 6.51 | 12.42 |
| Normal | 3.81 | 7.79 | 35.46 |

Customers are informed each night about the colour for the next day. Customers can adjust their electricity consumption manually by switching off appliances, adjusting thermostat settings, etc. Some customers who have the necessary communications and load control equipment are able to select load control programmes which enable automatic connection and disconnection of separate water-heating and space-heating circuits. Compared with blue days, the Tempo tariff has led to a reduction in electricity consumption of 10% on white days and 40% on red days, on average 1 kW per customer. The tempo tariff has been taken up by around 480,000 consumers, mainly high use households (330,000), such as very large houses, and those with electric heating and full time occupation and for small business customers (150,000).

The California Statewide Pricing Pilot is often cited in literature reviews of demand response and time of use pricing. The aim of the pilot was to test if customers would shift or reduce load in response to time varying price signals. A variety of Time of Use and Critical Peak Price options were evaluated, and the results demonstrated that large price differentials were required to obtain reductions in the 10 to 15% range. In this case, climate is seen as an important factor in the ability of end-users to offer demand response, with the prevalence of air-conditioning both contributing to peak demand as well as presenting an end-use whose operation can be readily modified in response to price signals. The pilot evaluated three forms of Time of Use Pricing as listed below:

- Seasonal TOU tariff - on-peak and off-peak rates fixed according to the season
- Fixed Critical Peak Pricing (CPP-F) - the seasonal TOU tariff with an additional ‘critical peak’ price that can be dispatched during the peak-period for up to 15 times each year, with day ahead notice.
- Variable Critical Peak (CPP-V) – the seasonal TOU tariff with a Critical Peak rate that can be dispatched during the peak-period for 2-5 hours, with 4 hour advance notice.

For residential customers, the average price for customers on the CPP-F tariff ranged from 9.4 cents/kWh during the off-peak period to 61 cents/kWh during the critical peak price period, compared to an average price of 13.3 cents/kWh for the control group. For CPP-V customers, prices ranged from 8 cents/kWh during off-peak period (7,260 hours) to 73 cents/kWh during the critical peak price period which applied for up to 75 hours per year, although the timing of these was fixed in advance. At the end of the trial, analysis of the results showed that peak load reduction was 4% for customers on the seasonal time of day tariff compared to the control group, increasing to12.5% for customers on the CPP-F tariff and 34.5% for those with the CPP-V tariff. The results showed that residential customers were more price responsive that the commercial customers, who reduced peak demand on critical peak days between 6% and 10%.

Another trial investigating the impact of dynamic pricing on different types of customers was that conducted in Finland in 1993. For 90 to 180 hours per year the price was 5 to 10 times higher than the normal base rate. During the rest of the year, the price was reduced slightly so that the annual bill would be the same if the customer made no change to their electricity consumption. Customers were provided with 'traffic light' displays with a green light indicating normal price, a yellow light indicating that a possible high price period would occur the next day, and a red light indicating that the high price was in operation. Communication with customers was via PLC technology and telephone lines. The results of this trial highlight that the ability of customers to respond depends very much on their end-uses of electricity. As would be expected, households with electric heating showed the largest level of peak response (in both absolute and percentage terms), with peak demand by almost a third during the morning and evening peaks. The commercial and industrial consumers demonstrated the lowest level of demand response during the trial, with peak demand reductions ranging from two to eight percent for this category.

The Winter Peak Demand Reduction Scheme was implemented during 2003/04 to combat network constraints and peak generation shortages. Customers joining the program were required to commit to reduce their consumption between 5 and 7 pm every business day from November to February. This reduction was achieved through reducing energy use or utilising on-site generation.

A total of 106MW of committed load reduction was offered by these customers, representing a significant proportion of their base load consumption of 410MW. Contributors were generally large energy users, including cement and paper industries, manufacturers of agricultural products, commercial premises and refrigeration/ meat industry. In 2003/04, the peak load reduction achieved was an average of 82.5MW in November, 83.0MW in December, 84.4MW in January and 81.3MW in February. This was 1.85% of the winter peak load of 4,320MW.

The New York Independent System Operator (NYISO) operates three demand response programmes:

- EDRP (Energy Demand Reduction Program);
- ICAP-SCR ( Installed Capacity Special Case Resources); and
- DADRP (Day-Ahead Demand Response Program).

EDRP and ICAP-SCR are controlled by NYISO and are intended to provide system operators with additional resources that can be deployed in the event of energy shortages to maintain the reliability of the system. DADRP, is controlled by customers and allows energy users to bid their load reductions, or "negawatts", into the day-ahead energy market. Customer either participate via a third party (e.g. electricity Supplier or demand aggregator) or directly.

In February 2005, there was a total of 1,754 MW load reduction capacity registered in the NYISO demand response programmes, when total demand was 31,000MW. This represents about 2,000 customers enrolled through 44 Curtailment Service Providers. This implies that participating customers are able to offer a demand response of almost 900kW on average. Although, such large customers do not fall within the scope of this project, the results provide an indication of the level of savings that the SME customers may be able to achieve.

The results listed in Table 5.2 highlight that TOU pricing can deliver demand reductions. However, the majority of the demand reduction has been delivered via modification to heating and / or air conditioning loads, particularly where domestic customers are concerned. Very little is known about modifying other end-uses. One study[36] conducted in 1989 investigated the impact of static time of use tariffs on the demand of residential customers. The trial, which involved 500 customers in the UK, demonstrated that customers without electric storage heating were able to reduce their demand at the time of the peak by around 20%. Changes to timing of washing machine usage being the most common behaviour change noted by participants in the trial, with changes to operation of tumble dryers, immersion heaters, ovens, dishwashing and direct space heating also mentioned. The trial also noted that many of the participants in the trial did not understand their tariff, highlighting the importance of communicating with customers to ensure they understand their tariff and educating them on the potential benefits of modest behaviour changes.

## 5.3 Summary

The data presented in this Section highlight the range of results that have been achieved through the application of various approaches to influence the amount and the pattern of electricity consumption. The trials and pilots highlighted in Section 5.1 indicate that energy savings through EUMF can range from zero up to 25%. It is important to note that the level of savings will depend on a variety of factors, particularly the willingness of the end-users to actively engage in any energy saving program. Many of the trials involve relatively small sample sizes, and therefore the results may not reflect those that would apply under a mass roll out. Perhaps, significantly, the largest trial of the effectiveness of visual displays, the Energy Demand Reduction Project, has not reported any savings to date. However, the results quoted are from the early stages of the trial which is due to run for a period of two years. Therefore, whilst the results from the application of end-use monitoring and feedback are wide ranging, it would seem reasonable to suggest that it could be expected deliver savings of up to 15%, depending upon the approach taken.

The selection of trials and case studies considered in Section 5.2 demonstrate that the application of time of use pricing can deliver peak load reductions of up to 30%. However, it is difficult to determine a benchmark load reduction that could be expected for new services and products based solely on these results. Therefore, these results should be considered alongside a ‘bottom-up’ analysis, as considered in Section 6, to determine the potential impact of specific end-uses on peak demand.

Clearly, the price differential applied has a significant impact on the level of response, with the California Statewide Pricing Pilot reporting that large price differentials were required to obtain peak demand reductions in the 10 to 15% range. Also important, is the end-uses available for demand reduction. Heating and air-conditioning loads often contribute to peak demand, and make ideal candidates for demand reduction programmes as they are large loads that can be easily controlled, often with minimum impact on end-users. However, the high level analysis of the results presented in Section 5.2 would suggest that peak loads reductions of 10% to 15% should be achievable where heating and cooling loads are prevalent. Without heating and cooling loads, the peak load reductions are likely to be less.

36 Domestic Customer response to a multi-rate tariff, SV Allera and AA Cook, 7th Int Conf. on Metering Apparatus and Tariffs for Electricity Supply, Glasgow, IEE, November 1992

# 6 End Use Demand Changes

Electricity is used by domestic and small commercial consumers in a variety of ways. By understanding these ways, the '*end uses of electricity*', a clearer picture evolves of the potential for demand response and energy saving programmes to change demand. A survey was therefore conducted to obtain an overview of consumption patterns by small consumers in the participating countries. The results of the survey are summarised in Appendix 3 of this report.

In order to fully evaluate the potential impact of demand response and energy saving programmes, it is necessary to understand both the quantity of energy used by specific end use applications and the time that the energy is used. Whilst data on the consumption of electricity by broad sectors (i.e. industrial, commercial and residential) is generally available, information on the time and nature of consumption is less well understood. Within the commercial sector, very little data is available on the different consumption patterns experienced within the sub-sectors.

The ways in which energy is consumed are gaining an increased level of importance as different participants, from Government, to utilities, to end consumers, try to gain a clearer picture of how energy is used and the implications of its usage. A greater ability to scrutinise the data relating to consumption will allow for a more detailed analysis of the opportunities for demand response.

## 6.1 End Uses and End Use Monitoring and Feedback

All end uses can be targeted for EUMF and greater visibility of how much electricity is used by different appliances and/or processes can enable individual consumers to take a greater control of their consumption and target areas of potential waste appropriately. The approaches taken to providing the feedback may vary, depending on the consumer and end use. It is therefore essential that the provision of EUMF is targeted to the needs of the consumer.

Provision of EUMF for residential consumers should focus on meaningful information that the consumer can act on. This is a broad group and heterogeneous in nature, so flexibility in how information is provided to enable choice is important. Some consumers, for example, will be keen to understand how the data is made up and the trends within it. However, it would be inappropriate to assume that all residential consumers would want data in this degree of detail and could result in the information being ignored.

The comparisons between end uses that residential consumers might make also need to be considered, especially in relation to those uses that are associated with comfort or convenience. Information on an individual lighting appliance left on in an empty room may be considered trivial by the consumer when compared to an end use that is perceived as essential (such as a washing machine) and consumes more electricity when in use. It may therefore be more appropriate to aggregate small loads, such as lighting, consumer electronics and ICT, within a property to create the required visibility to prompt behaviour change.

Within the commercial sector, there is a significant amount of variation in the end uses between different sub-sectors and even between different organisations in the same sub-sector. Large commercial organisations tend to employ facilities and/or energy managers with responsibility for monitoring and reducing energy consumption. These individuals are well placed to recommend the appropriate interventions to reduce unnecessary consumption.

Smaller businesses are unlikely to be able to justify this expense but the information that they require is not necessarily the same as residential consumers. They are potentially better placed than residential consumers to identify what information they need and choice is again important.

Commercial consumers are more financially motivated than residential consumers and therefore will consider measures to address end uses like lighting and ICT where there is a clear benefit to the organisation.

## 6.2 End Uses and Demand Response

In contrast to EUMF, some end uses are significantly more suited to delivering demand response products than others. The end uses need to be considered when developing demand response programmes as some are more suited to some schemes than others.

End Uses can be separated into categories to help understand their suitability for demand response programmes. Some reports have described loads as discretionary or non-discretionary. In designing DSM programmes, these terms can be seen as being relatively subjective as different individuals will value these end uses differently. For a family with a sick child, for example, using the washing machine is a necessity, rather than a choice.

For the purposes of this report, end uses have been categorised according to their technical suitability for interruption. These definitions are provided in Table 6.1. The end uses suggested for each category are based on technologies that are commonly available to the consumer. As technology develops, some end uses may shift between these categories. Wet appliances, for example, may be developed with in-built logic that allows the load to be interrupted with no impact to the cycle or the products within the appliance.

The approaches that can be adopted will vary across the participating countries, dependent on the end uses observed in those countries. Tariff interventions are possible with all end uses, although the degree of response will vary depending on how price sensitive consumers are within the country.

The remainder of this section therefore assesses end uses within the participating countries against the criteria outlined in Table 6.1 to identify the interventions that are most likely to be appropriate.

**Table 6.1 Definitions of Terms used to analyse End Uses**

| | | |
|---|---|---|
| Interruptible | Definition | • Loads can be interrupted with minimal or no notice.<br>• Consumers are more interested in a level of service.<br>• Less time sensitive as to when this service or process occurs. |
| | Residential customers | • Types of end uses are space heating, water heating and air conditioning.<br>• The inclusion of some form of thermal storage within the system may be required to facilitate this. |
| | Commercial customers | • Types of end uses are as for residential plus processes which can be interrupted with limited impact on the end product or service.<br>• Examples include milling of grain or aggregates. |
| | Mechanisms | • Tariff Interventions, Direct Load Control, Load Limiting and Generation &/or Storage Dispatch |
| Schedulable | Definition | • These loads are more problematic to interrupt.<br>• A more significant period of notice is required (anticipated to be in the region of 4 to 6 hours).<br>• They are usually relatively significant loads, especially within small consumers' sites. |
| | Residential customers | • Types of end uses are wet appliances and charging of Electric Vehicles, where applicable. |
| | Commercial customers | • Types of end uses are processes that are run for a period of time within one or more days each month which could be scheduled to different times such as batch processing (e.g. invoicing, data back-ups). |
| | Mechanisms | • Tariff Interventions, Direct Load Control, Load Limiting and Generation &/or Storage Dispatch |
| Hybrid | Definition | • These are loads that can be interrupted, but there is a limit to how often or for long they can be interrupted. Scheduling interruptions may increase the time that the loads can be interrupted for. |
| | Residential customers | • Types of end uses are cold appliances. These can be interrupted but, presently, only for a limited period without impacting on food quality. |
| | Commercial customers | • Types of end use are cold appliances and processes that fall within the description given in the definition. |
| | Mechanisms | • Tariff Interventions and Direct Load Control |
| Convenience | Definition | • These are loads that are associated with either the comfort or convenience of the consumer. Interruptions are unwelcome, unless chosen by the consumer. Consumers may change their behaviour in response to a price signal but are unlikely to be willing to accept direct interventions by other parties. |
| | Residential customers | • Types of end uses are lighting, cooking, computing and consumer appliances. |
| | Commercial customers | • Types of end uses are lighting, ICT and cooking, where appropriate. |
| | Mechanisms | • Tariff interventions only |

## 6.3 Residential End Uses

There are many demands for electricity within the residential sector, including heating; air conditioning; lighting; cold appliances for food refrigeration; wet appliances for laundry and dishwashing; consumer electronics (such as televisions, DVD/video players, set-top boxes, music players etc.); and increasingly Information Communication Technology appliances (such as computers, printers, routers, mobile telephones, etc.). In the participating countries, residential electricity consumption ranges between 2.7% and 34.5% of total electricity consumption. Figure 6.1 shows the variation in average end uses in the residential sector across the participating countries.

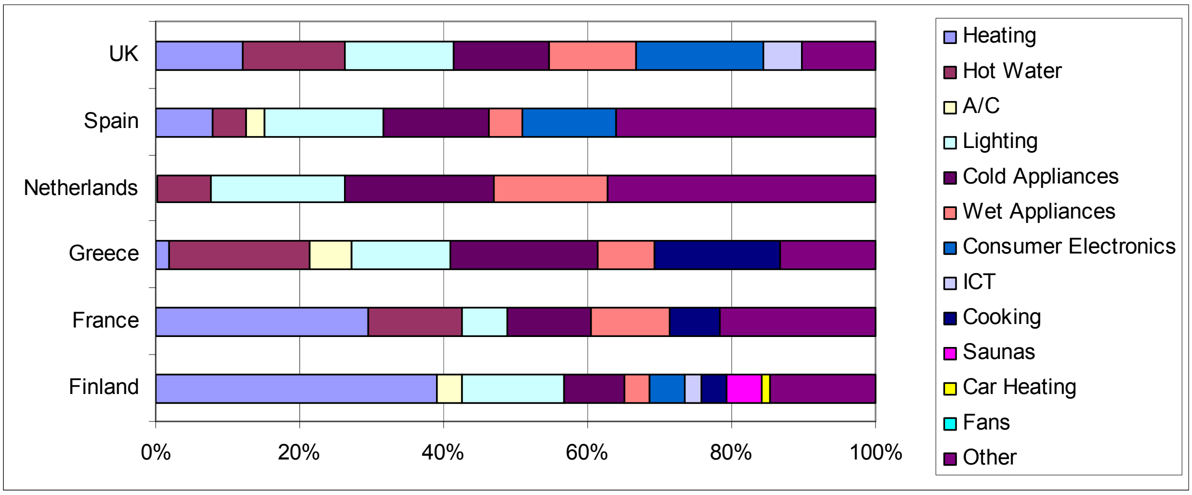



**Figure 6.1 Residential End Uses (2007[a, b,])**

a Data for Greece is based on an average for the years 2001 to 2005, Data for Finland is for 2006, Data for Spain is for 2008.

b No data available on electricity consumption by different appliances for India.

Whilst EUMF has the potential to impact on all end-uses of electricity by increasing customer awareness, not all will be suitable for demand response programmes. Figure 6.2 shows the proportion of residential consumption within each participating country against the terms defined in Table 6.1.

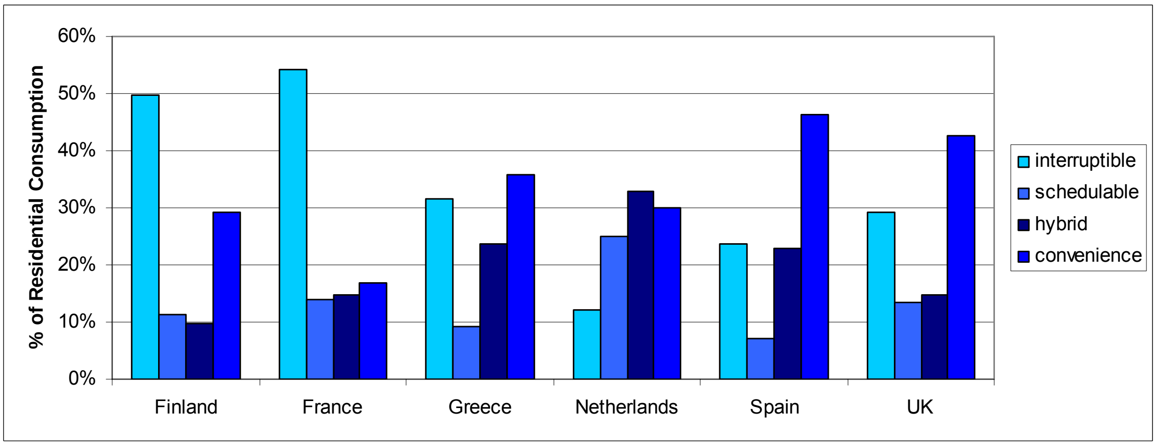



**Figure 6.2 Categorisation of Residential Consumption**

In countries where there is a significant proportion of consumption associated with interruptible or schedulable load, such as Finland and France, the full range of mechanisms discussed in Section 7 can be considered. As discussed above, tariff interventions are suitable for all categories of end use and therefore, on this basis, would be appropriate for the end uses observed in all of the participating countries.

Where a significant proportion of consumption is associated with comfort and convenience, there is an increased level of uncertainty as to the level or response that would be achievable. Of the participating countries, this is likely to be most problematic in Spain and the UK. The price sensitivity of consumers is likely to determine the amount of response achievable in these countries.

The time of use is important, particularly with the end uses that are considered to be interruptible or schedulable. If space heating is considered as an example, the type of heating system determines the degree to which it can be interrupted and whether or not it is already scheduled. In Finland and the UK, for example, over half of the properties with electric space heating have storage heating. These uses are usually charged over night to release heat as required. This charging could be interrupted but it is unlikely to be of significant value as it is already occurring at times of lower demand. By contrast, almost all of the properties in France with electric space heating use direct heating systems, i.e. electricity is consumed to create heat at the times that heat is required in the property. Consequently, there will be consumption across the peak. Being able to interrupt this load is likely to be of significantly more value, both financially and in terms of carbon impact, as it will reduce the need for peaking plant to be used.

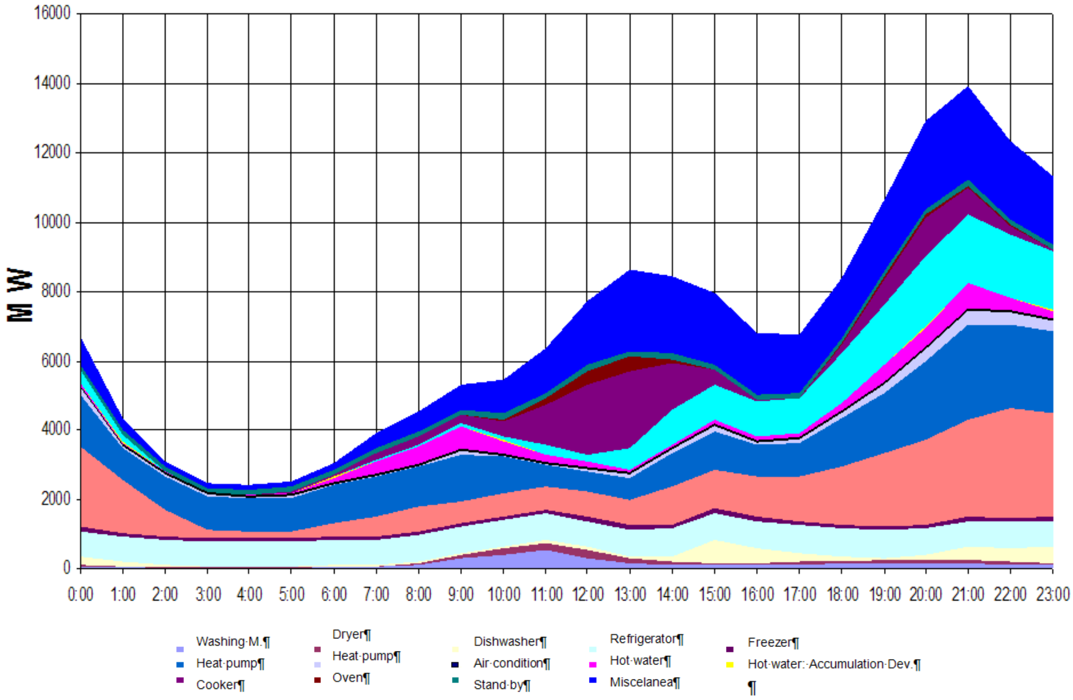



**Figure 6.3 Time of Use of Domestic End Uses (Spain, Cold winter)**

Spain, for example, has carried out some research to understand when different end uses occur as shown in Figure 6.3. This type of understanding of when the different types of end uses occur would be beneficial to those parties considering developing demand response programmes.

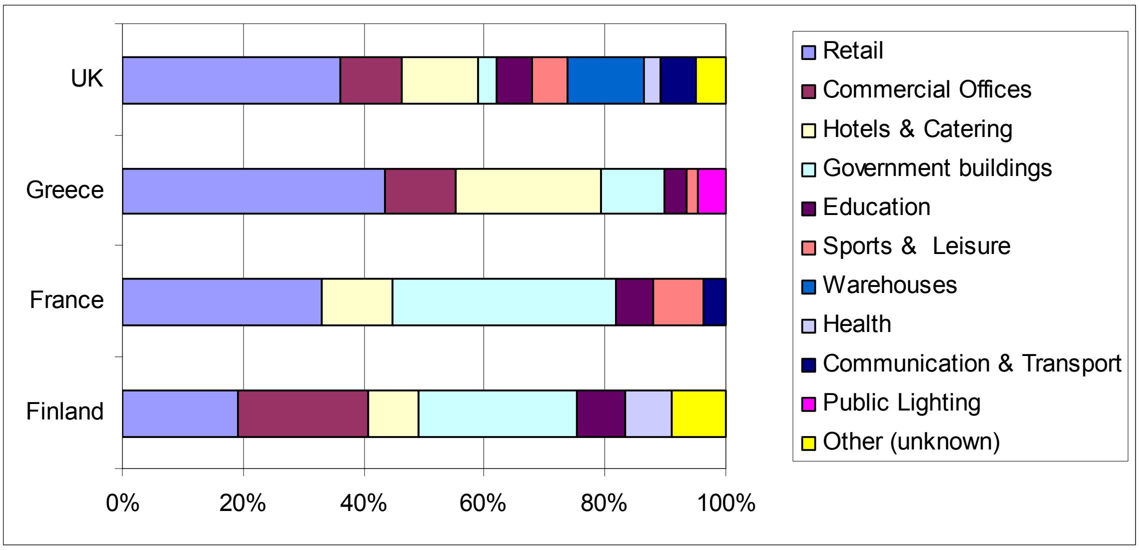
## 6.4 Commercial End Uses

This project is also looking at the opportunities for demand response and energy saving through EUMF with Small Commercial Consumers. For the purposes of this project, these consumers have been defined as "*individual sites with a maximum demand of up to 100kW*," as discussed in Section 2.

Unlike residential consumers where there is a degree of homogeneity, there are many different types of small commercial organisations each with differing patterns of electricity consumption. The types of organisations of particular interest to the participating countries are listed below:

- Small offices
- Small food retail
- Small hotels
- Schools
- Leisure centre
- Kindergartens
- Public lighting
- Small health providers
- Small light industrial
- Horticulture
- Warehouses

The difficulties experienced in collating data for these consumers were even greater than those for experienced with regard to residential consumers. Whilst data was not available specifically for customers with demands < 100kW, data on the consumption by overall sub-sector was generally available, as illustrated in Figure 6.4.




Retail sector in France also includes energy consumption by warehouses
Government buildings in France also includes energy consumption by commercial offices

**Figure 6.4 Breakdown of Consumption by Commercial Sectors**

End-use consumption by sub-sector was provided by France, Greece and the UK, as shown in Figure 6.5, Figure 6.6 and Figure 6.7.

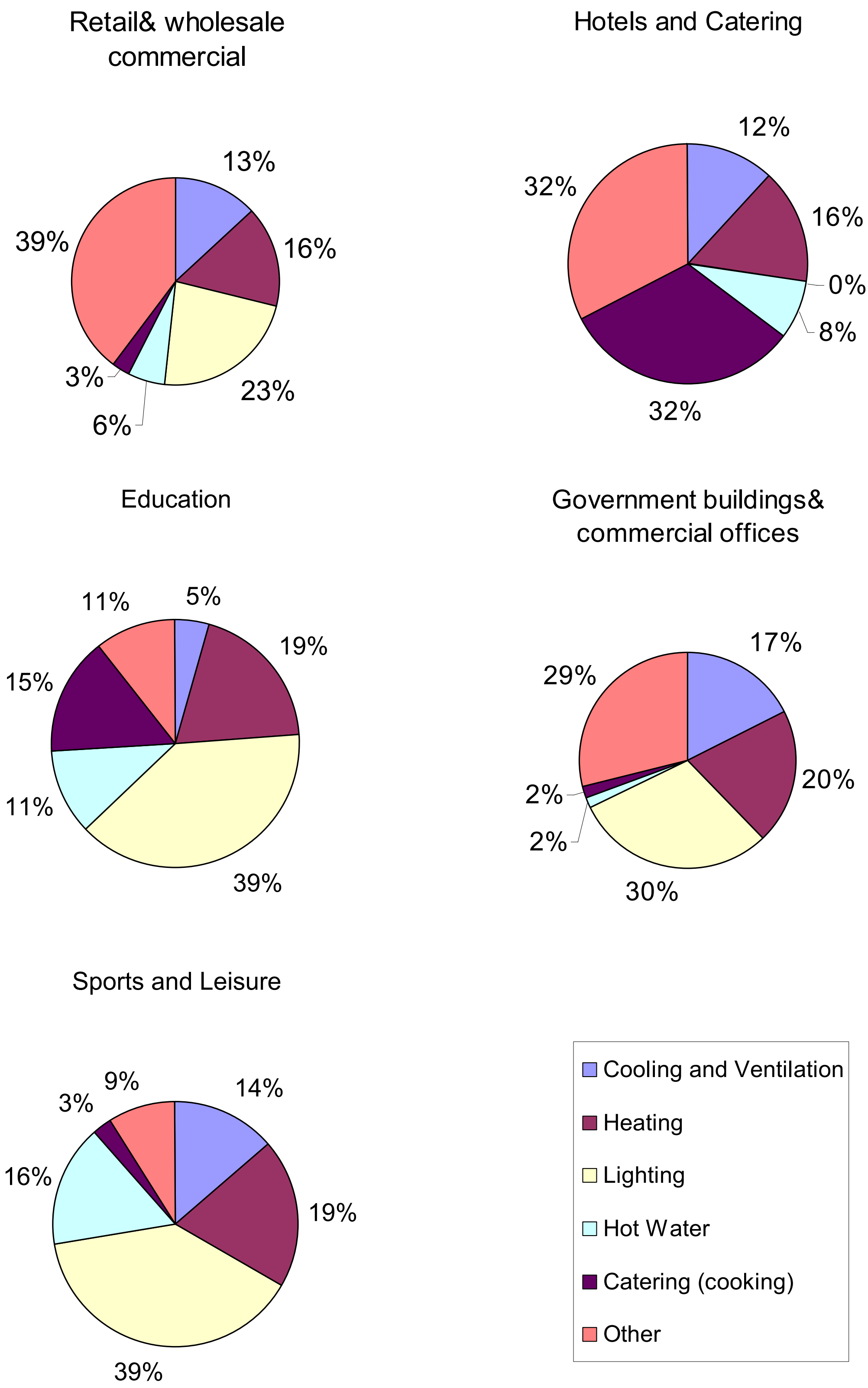



**Figure 6.5 Commercial Consumption by Sub-Sector & End Use in France**

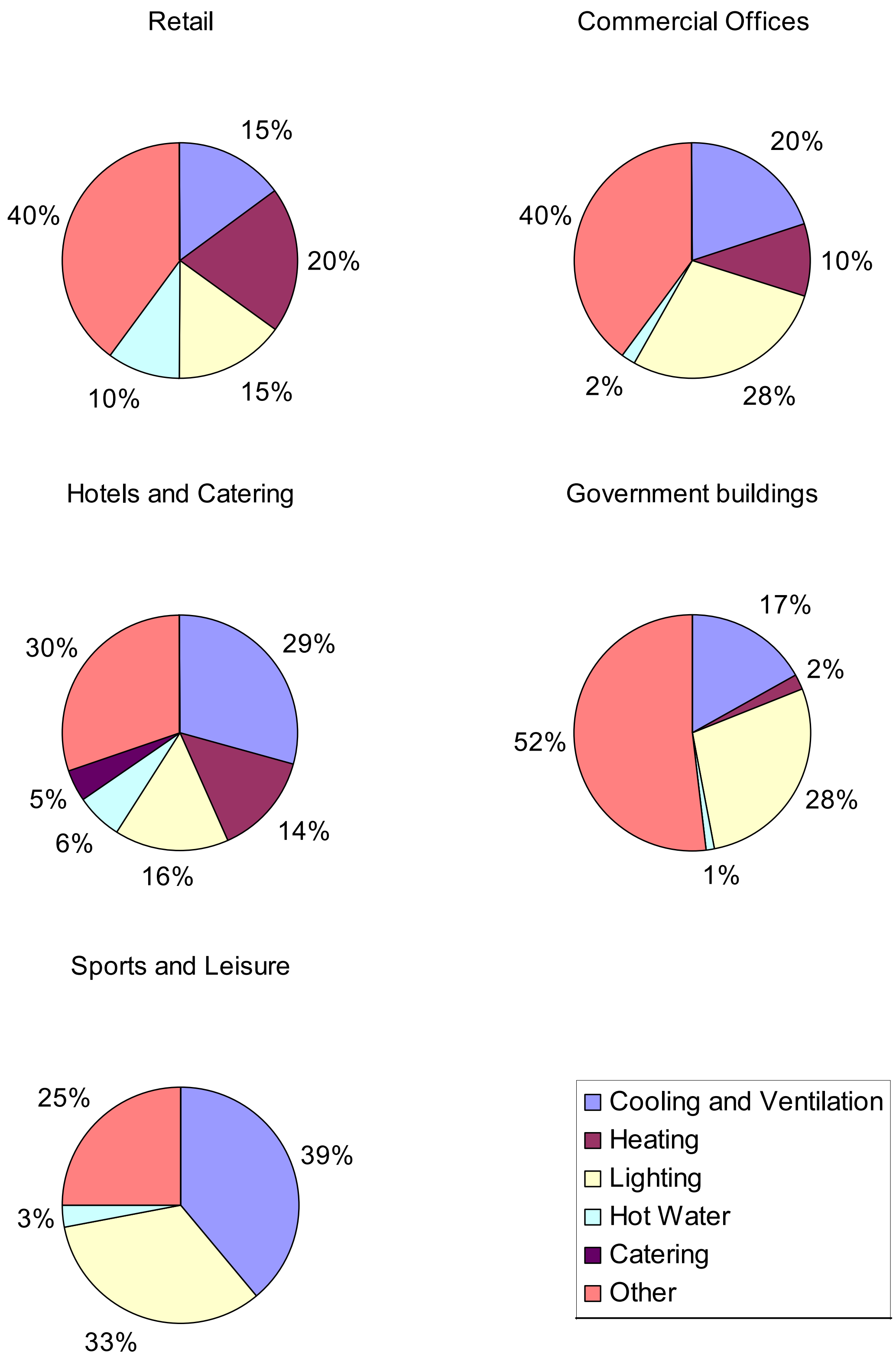



**Figure 6.6 Commercial Consumption by Sub-Sector & End Use in Greece**

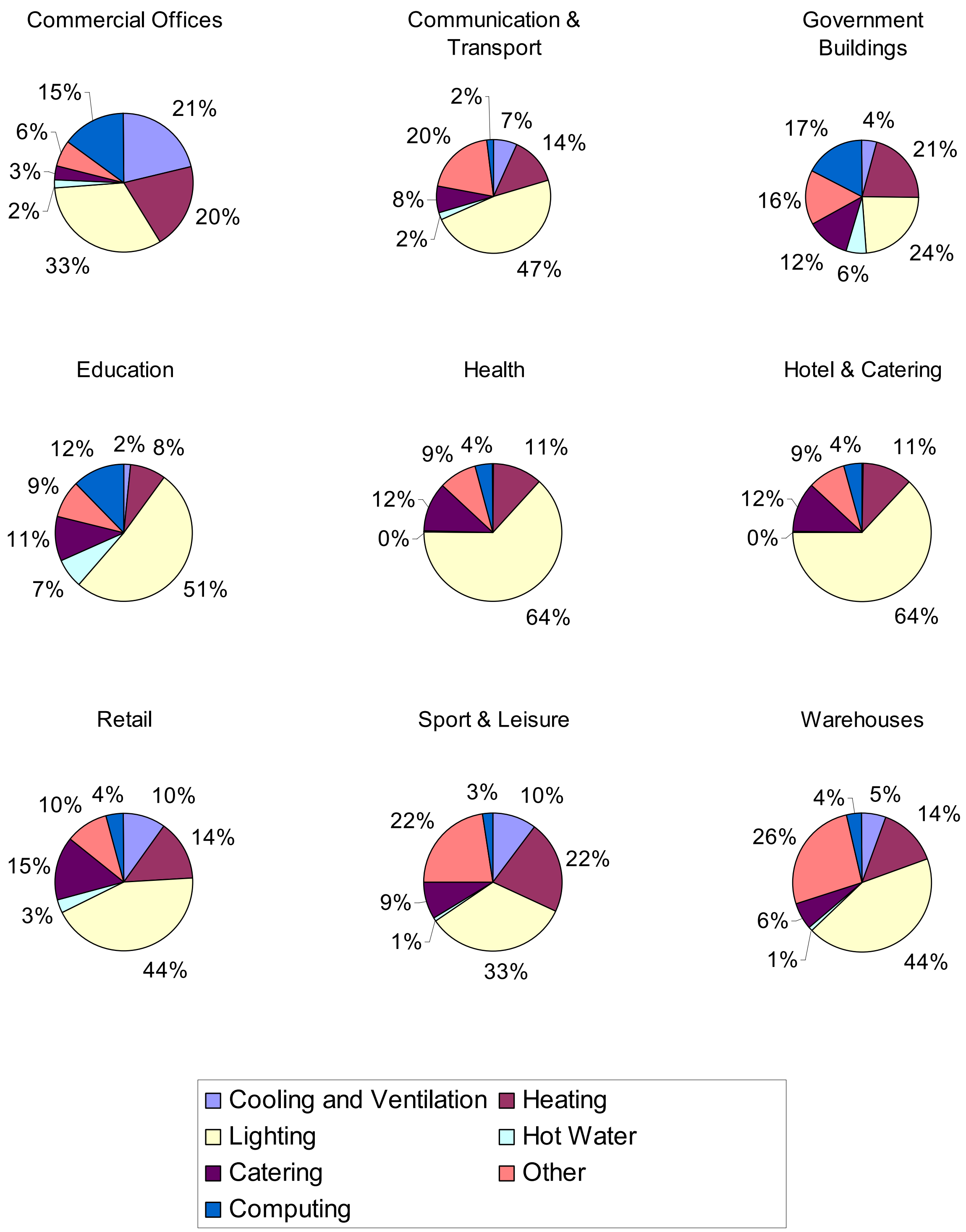



**Figure 6.7 Commercial Consumption by Sub-Sector & End Use in the United Kingdom**

As little information is available on the nature of the end uses within the Commercial sector, it is much more difficult to categorise these against the terms defined in Table 6.1. A very high level analysis, based on the data above, is shown in Figure 6.8 and suggests that all end uses in the Commercial sector are either interruptible or convenience. Common sense would suggest this is unlikely to be true and needs further investigation to understand how electricity is consumed in the different sub-sectors in order for this consumption to be categorised meaningfully.

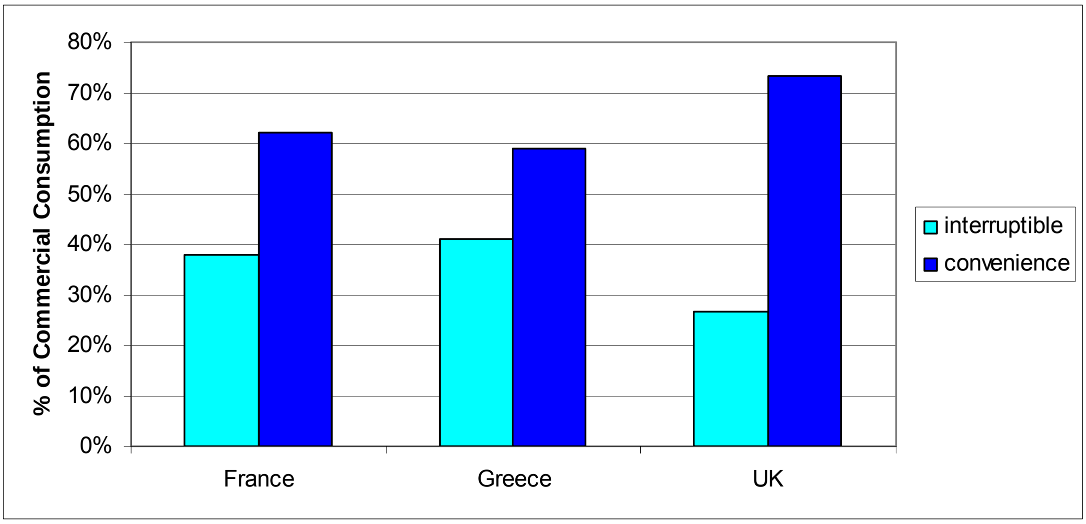



**Figure 6.8 Categorisation of Commercial Consumption**

As with Residential consumption, there is little information on when these end uses occur. This makes is difficult to identify the value associated with interrupting a load as it is unclear whether it occurs at the peak or in a period of low demand.

## 6.5 Summary

The mechanisms adopted to deliver demand response need to be based on the nature of the end use/s they are intended to change. Where there is a high level of end uses associated with convenience, tariff interventions are likely to be preferable. In contrast, end uses that can be interrupted or scheduled can be targeted with a much wider range of demand response mechanisms.

At present, relatively little is understood in the participating countries as to how electricity is used, particularly in the Commercial sector. This makes it problematic to understand the degree to which a load can be interrupted and therefore how effective different mechanisms will be in encouraging consumers to participate in demand response. Greater understanding of the end uses will help effective programmes to be developed that are suited to the consumption patterns of the targeted consumers.

There is also limited data available as to when different end uses occur within the day. The value of demand response at present is predominantly determined by its ability to reduce peak consumption. Programmes that are able to target consumption across this time are likely to deliver more value. Increased understanding of when electricity is consumed is therefore required to enable programme developers to target programmes to shift consumption from this period of the day.

# 7 Demand Response and Energy Saving Delivery Mechanisms

This section considers the delivery mechanisms that can be used as part of demand response and energy saving schemes with small consumers. It begins by examining the potential providers of energy saving and demand response schemes, before outlining the types of schemes that a provider may wish to establish with small consumers and how such schemes may operate in practice. The schemes considered are broken down into two main categories: energy saving and demand response schemes.

## 7.1 Providers of Energy Saving & Demand Response

Within most energy sectors, there are a range of participants with defined roles. The approach taken to market liberalisation will determine whether or not these participants are separate organisations (as discussed in Section 3.) This section considers the different potential providers and the likely interactions between them.

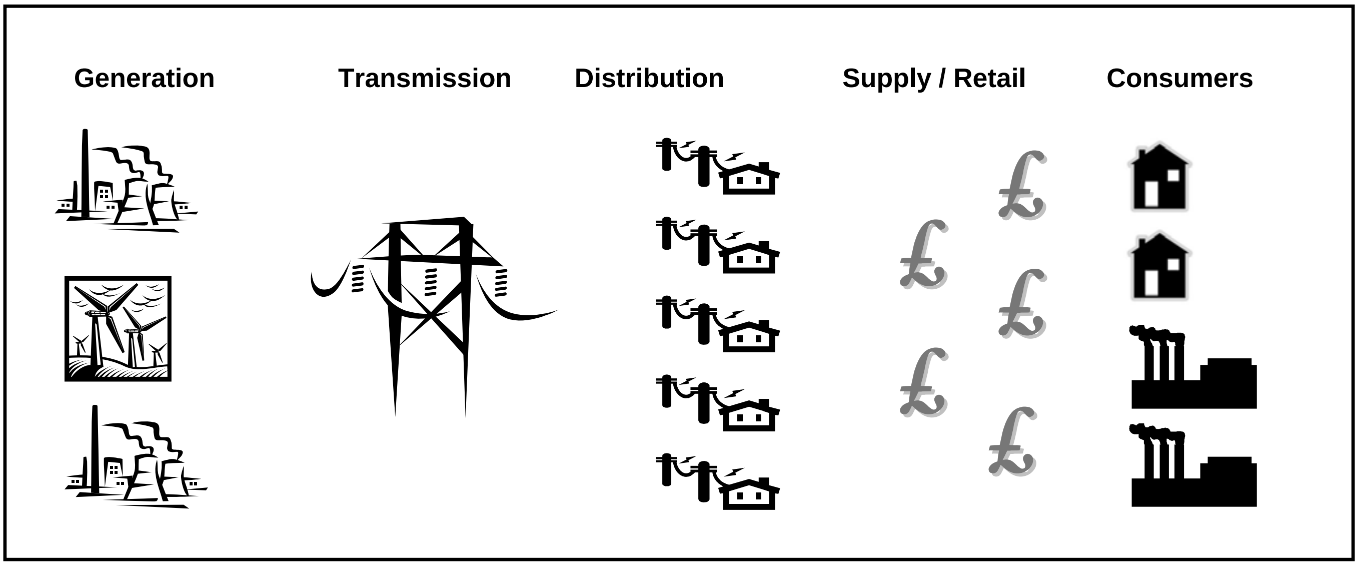



**Figure 7.1 Typical Energy Market Participants**

Most energy markets will contain participants with responsibility for the above roles. In addition, some countries also have seen the development of Energy Service Companies (also referred to as ESCOs) who interact between utilities and consumers, usually for a geographically defined Community. Aggregators are also used in some markets to combine the generation and / or load requirements of smaller players to enable them to access the market.

In most countries, the energy consumption of small consumers will need to be aggregated in order to be comparable to generation or demand side measures from larger consumers and therefore be of value to the market participants. Figure 7.2 outlines three examples of how these small loads could be aggregated.

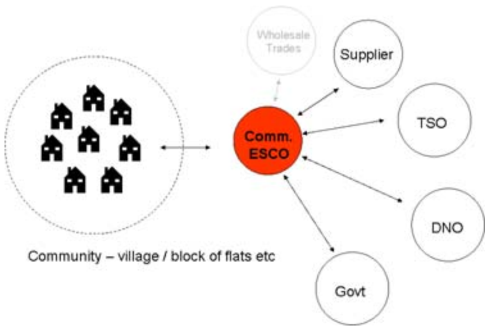
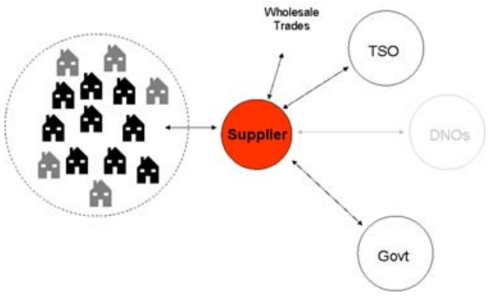
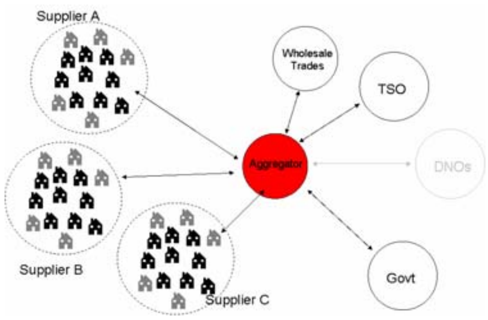
<table>
<tr>
<td>
</td>
<td>ESCO Model<br>The ESCO acts as an intermediary for all consumers within a geographically defined area, such as a village, block of flats etc.<br><br>The ESCO aggregates load on behalf of all engaged consumers within the Community.</td>
</tr>
<tr>
<td>
</td>
<td>Supplier-led Model<br>The Supplier acts as the sole point of contact between the consumers it supplies and other industry stakeholders.<br><br>The Supplier provides programmes as part of its offerings to its consumers. Consumers have the choice as to whether or not to participate.</td>
</tr>
<tr>
<td>
</td>
<td>Aggregator Model<br>An aggregator would operate programmes for consumers to participate in, irrespective of which Supplier provides their electricity.<br><br>The aggregator acts as a single point of contact for other stakeholders to procure services.</td>
</tr>
</table>


**Figure 7.2 Approaches to Aggregation**

In considering potential providers, there are some programmes that may be provided by a number of different participants, whilst others are likely to only be provided by those participants that are responsible for supplying energy to the end consumer. Table 7.1 provides a summary of the programmes discussed in greater detail in Sections 7.2 and 7.3 and participants that are most likely to provide each type of programme. Although the aggregator role, as illustrated in Figure 7.2, may be provided by new entrants, it may also be provided by existing participants. For example, existing Suppliers could act as demand aggregators for a group of customers that may not necessarily be its own supply customers. This could be particularly relevant for demand response products offered to the System Operator to assist with maintaining the quality and security of supply. Table 7.1 provides a summary of which products are most likely to be interest to different market stakeholders.

The likelihood of the stakeholders to deliver the various programmes is indicated as follows:

| | **Likelihood that stakeholder will deliver demand response and energy saving programmes** |
|---|---|
| ✓ | ↑ Most likely |
| ~ | |
| ✗ | ↓ Least Likely |

**Table 7.1 Summary of Providers of Demand Response & Energy Saving Programmes**

| | **Stakeholders** | | | | |
|---|---|---|---|---|---|
| **Products** | **Transmission** | **Distribution** | **Supply / Retail** | **ESCO** | **Aggregator** |
| EUMF | ✗ | ~ | ✓ | ✓ | ✓ |
| Block Tariffs | ✗ | ✗ | ✓ | ✓ | ~ |
| Rebate Tariffs | ✗ | ✗ | ✓ | ✓ | ~ |
| Time of Use Tariffs | ✗ | ✗ | ✓ | ✓ | ~ |
| Direct Load Control | ✓ | ✓ | ✓ | ✓ | ✓ |
| Load Limiting | ✓ | ✓ | ✓ | ✓ | ✓ |
| Generation / Storage Dispatch | ~ | ~ | ~ | ✓ | ✓ |

It should be noted that the participants will have different drivers for providing these programmes. Consequently, there may be times when some of the participants (or the programmes) are competing with each other. For other participants, their requirements from the programme may be in conflict with other stakeholders. The extent to which there is commonality will depend on the market structure and the participants' drivers.

## 7.2 Energy Saving Programmes

There are many different types of energy saving programmes that can be established by different stakeholders within the energy industry. This Task focuses on energy savings via EUMF. A number of different types of EUMF products are outlined below. Block Tariffs and Rebate Tariffs are also included in this section as the impact of this type of DSM programme is likely to be a reduction in consumption, rather than load shifting.

### 7.2.1 End Use Monitoring and Feedback Programmes

End Use Monitoring and Feedback is the provision of information to consumers as to their energy consumption, with the intention that the information creates a feedback loop with a resulting behavioural change. There are increasing degrees of complexity that can be developed and such programmes may be useful preparation for small consumers, enabling them to understand their consumption patterns and to make informed choices about demand response schemes. Table 7.2 provides an overview of different types of EUMF programmes, with examples of where these schemes have been applied.

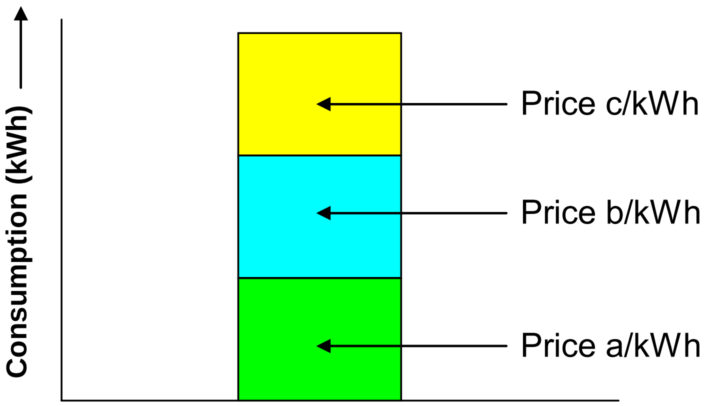
**Table 7.2 Overview of EUMF Programmes**

| EUMF Programme | Description | Example/s |
|---|---|---|
| Billing | Information on Utility bills provides some feedback on consumption patterns. For this to be an effective programme, consumers need to receive regular, accurate bills, with additional information as to how consumption compares with the previous period (or the equivalent period in the previous year). | |
| Websites | Provision of websites to support consumers to monitor and compare their consumption over time and in relation to their peers. May be a standalone service, with consumers entering the details from paper bills; part of the billing method; or support service for one of the other programmes below. | LINKKI (Finland) |
| Real Time Information Provision (e.g. Visual Display Units, Home Energy Manager) | Real-Time Provision of Consumption Information, enabling consumers to link consumption to appliances being used at any given time. This may be provided by a Visual Display Unit, with or without a 'Smart Meter', or fed from the meter to an alternative device (such as home computer, mobile phone, website, PDA, etc). | Energy Demand Research Project (UK); Birka Technik og Miljo (Sweden) |
| Disaggregated Demand Information | Provision of a breakdown of consumption by appliances / appliance type, enabling consumers to identify where they use energy within the property. May be incorporated into most other programmes. | Being developed by Green Energy Options[37] (UK) |
| Face-to-Face Energy Advice / Energy Audits | Face-to-face support, provided to enable the consumer to understand his consumption patterns and the interventions he can take to reduce his energy usage (e.g. installing more efficient heating devices; identifying inefficient appliances and understanding when energy is being 'wasted'). | Niagara Mohawk (LICAP) project (Canada) |
| Community Energy Saving Schemes | Community Members work together to drive down energy use in their community. Community Members are encouraged to support and challenge each other to reduce their energy use. May include an aspect of competition (i.e. between Community Members or between Neighbouring Communities). | British Gas (UK), 'Green Streets'; Eco Team Program, Netherlands |

[37] http://www.greenenergyoptions.co.uk/

### 7.2.2 Block Tariffs

An alternative energy saving programme is the use of Block Tariffs, whereby an increasing price is charged as the consumer uses more energy as illustrated in Figure 7.3. This type of programme can be developed based on cumulative (weekly, monthly or annual) or interval (hourly or daily) consumption. With this tariff, higher rates are charged once consumers exceed predetermined consumption levels, with block C attracting a significant premium.




Where a < b < c units/kWh

**Figure 7.3 Block Tariff Example**

This type of tariff requires an EUMF element to function well. Consumers need to have visibility of how much energy they have used and when to enable them to know when they are moving between price bands and to be able to respond to the pricing signals. Communication to the consumer is critical to create an understanding of how this type of tariff operates and the benefits it can offer. For schemes with a longer time period between feedback provision, the price differential is likely to need to be lower as the ability to act on the information will be reduced.

This tariff has the potential to be quite controversial, especially in countries where consumers are used to (and expect) an endless and relatively low-cost energy supply. There is likely to need to be a significant, demonstrable benefit to consumers before this type of tariff is likely to be chosen by the majority. For those able and willing to reduce their consumption, this type of tariff may offer a significant financial saving.

The introduction of such a tariff within a competitive electricity market does, however, pose significant challenges. If such tariffs were introduced voluntarily by Suppliers, then it is likely that they would only be selected by those customers with low energy consumption. There would be no incentive for high users to voluntarily accept such a tariff. However, requiring Energy Suppliers to introduce block tariffs for all consumers has the potential to create a disjoint between the cost to supply and the price which is not consistent with the development of competition. Additionally, such tariffs could create perverse incentives for Suppliers to increase energy sales, particularly at the higher rate due to the increased margin associated with the units sold at the highest price.

### 7.2.3 Rebate Tariffs

Rebate Tariffs incentivise consumers to reduce their consumption by providing a Rebate if the consumer reduces his consumption by an agreed amount over an agreed timescale. The Rebate may be a fixed amount or proportionate to the consumer's energy spend, and is additional to any financial saving accrued by the consumer. An alternative incentive could be offered if more attractive, such as discounted energy efficient appliances and / or microGeneration; or loyalty points which can be traded in for other benefits.

The challenge with this tariff is in ensuring that the initial momentum is maintained, as the first year (or two) is likely to see the consumer achieve the 'easy hits'. Whilst they may be able to sustain this saving, achieving greater savings may require substantial cost or inconvenience. It may be appropriate to offer different incentives to both encourage consumers to maintain the savings already achieved as well as promoting further savings.

## 7.3 Demand Response Programmes

Whilst energy saving programmes focus on reducing consumption, demand response programmes focus on consumers shifting consumption in response to a signal from an industry stakeholder. The programmes tend to divide into two distinct types: Time Of Use (TOU) Tariffs and Incentive Based Programmes. The distinction is predominantly based on which stakeholders are suited to deliver the programme. TOU Tariffs can only be delivered by the organisation that is responsible for the customer's supply (usually the Supplier, but may be an ESCO in some markets). In contrast, Incentive Based Programmes can be delivered by a wider range of stakeholders (including the TSO, DNO, Supplier, and / or ESCO, with or without the involvement of an aggregator). Within each type, there are a number of sub-types or variations which are considered below.

### 7.3.1 Time Of Use Tariffs

TOU Tariffs use price signals to encourage consumers to move their load from the peak or times of system stress to times when there is less concern or greater availability of electricity being generated from variable output resources (such as wind, tidal, PV, etc). With a flat tariff, the exposure to price risk is solely on the Supplier. These tariffs share that exposure, to varying degrees, with the consumer. Table 7.3 provides an overview of the types of TOU programmes that have been established, with examples as appropriate.

Whilst the technical requirement are considered in greater detail in Section 8, it should be noted that it is essential that the metering is able to capture the consumption in the different price periods as these options are all centred around price differentials across the day,. For the more complicated options, the need for interval metering and increased communication with the consumer is much greater.

**Table 7.3 Overview of TOU Programmes**

| TOU Programme | Description | Example/s |
|---|---|---|
| Static TOU | Multiple tariffs are made available to the customer at different times of the day. These times may be constant or published at regular intervals (i.e. biannually, seasonally) but apply every day, although non-working days may be treated slightly differently. Tariffs are structured to encourage consumers to move their loads where possible away from expensive periods.<br><br>This is probably the most common demand side management measure at present for small consumers. It is relatively simple for consumers to understand, with significant notice as to what prices apply when so consumers can plan their consumption accordingly.<br><br>There is limited flexibility associated with this programme as prices are notified significantly in advance of their application. | Various, 'Economy 7' (UK) |
| Dynamic or Real-Time Pricing | Pricing varies between settlement periods to reflect changes in the wholesale price for electricity. There may be some notice given but this is usually short, depending on how close gate closure is to delivery in the country concerned. Messages can be conveyed to the consumer through a variety of media, although the short lag time means that responses are more likely to occur if the price is received by a pre-programmed appliance (i.e. thermostat for heating or cooling).<br><br>The relative lack of notice may make small, and particularly more vulnerable, consumers subject to a significant increase in their energy costs if they are unable or unwilling to respond quickly to the price signal. | Tempo tariff (France) |
| Semi Dynamic Pricing | This is effectively a hybrid between Static TOU and Dynamic Pricing. Prices are made available to consumers 1 day to 1 week ahead of real-time to allow consumers to plan changes to their behaviour accordingly. Automated devices or appliances that can respond to changes across the day are still beneficial in enabling consumers to move their load to reflect price changes with minimal inconvenience or disruption. | |
| Critical Peak Pricing | Critical peak pricing (CPP) tariffs will specify a significantly higher price to be charged at times of critical system stress, as reflected in the wholesale prices. The price charged will either be pre-determined or determined according to the market conditions at the time. Their usage is normally limited within the contract to a specific number of days in a year. The critical peak period, in terms of its timing and duration, may be fixed or variable.<br><br>Some schemes use a Peak Time Rebate (PTR) as an alternative approach for small consumers. Instead of charging a higher rate during critical periods, these schemes offer consumers a Rebate if they avoid or minimise their consumption during these peak periods. | PG&E Smart Meter Trial (USA) |

### 7.3.2 Incentive Based Programmes

All demand response programmes are likely to require some element of incentive. For the TOU rates, these are directly charged to the consumer by the Supplier according to when consumption takes place. However, in the case of incentive based programmes, the incentive does not need to come directly from the Supplier. This creates opportunities for other ‘providers’ to liaise and interact with end-users. It has tended to be assumed that programmes of this nature would be delivered by an organisation with responsibility for maintaining system or network balancing but there is the possibility for third-parties to interact between the system operator and the end consumer to aggregate demand response and distribute the incentive to the consumer. Such parties could include Suppliers, ESCOs and aggregators.

#### Direct Load Control

In a Direct Load Control Programme, consumers would agree that the demand response deliverer can remotely control one or more of their appliances. This could be shutting them off with little or no notice to provide reserve for the System Operator, adjusting their operation to deliver frequency response or to advance/delay their operation to utilise non-dispatchable electricity on the system. (This may become increasingly important with the expected growth of variable output generation.) Example appliances that may be suitable for this type of programme are space heating, air conditioners, water heaters, refrigeration equipment, washing machines, dishwashers and tumble dryers.

This could be delivered through the use of direct control of the appliance (i.e. radio communications, teleswitching or similar); through limiting the power to a particular phase or circuit within the property; or through communications within a Smart Meter. The incentive to the consumer to take part may be in the form of specific tariffs associated to the appliance/s being remotely operated; use of interval metering to capture the different costs of the electricity dependent on when it was consumed by the appliance (assuming the load is moved to a cheaper period than that it which it should have been used); occasional payments for subscribing to the service (i.e. monthly, annually or one-off) or subsidised cost for purchasing the appliance with load control in-built.

A challenge presented by an increasing use of direct load control is its impact on load diversity. Load diversity reflects the statistical likelihood of consumers within a given area consuming their maximum demand at the same time. Typically, there is sufficient differentiation between consumers to allow for a smaller load to be planned for any one specific property which enables capacity within the networks to be ‘shared’. However, wide-scale control of large end-uses could impact on load diversity, such that network capacity limits are exceeded.

#### Load Limiting

With Load Limiting, consumers agree that the maximum load that their property can consume is limited at time of peak demand or system stress. Limits need to be carefully assessed to ensure that essential functions such as lighting, alarms, and health equipment are not jeopardised. Supply is then curtailed by a limiter which could be an add-on to a Smart Meter or a separate device on the supply to the property. Acceptance is likely to require some prior notification of limits being applied but this is otherwise a relatively simple intervention.

Consumers are reimbursed for the inconvenience through either a lower overall tariff or payments/credits when their supply is curtailed. The amount of energy made available would not be an easy calculation on an individual basis but could probably be statistically calculated within a Supplier's forecasting activities, based on the number of consumers with the device fitted and their usual consumption pattern for the relevant time of day.

A variation of this programme would allow the consumer to decide whether or not to curtail their consumption following a request from the demand response deliverer. This may not be applicable for all consumers as it would require some way of being able to see the curtailment which is easy if plant machinery is shut off but more difficult in a domestic setting where other factors could cause changes in consumption.

### Generation &/or Storage Dispatch

A number of small consumers have direct access to onsite generation (i.e. standby diesel generators, microCHP) and /or electrical energy storage (i.e. UPS systems, batteries). These consumers could be incentivised to participate in a programme whereby they dispatch their generation and/or storage outside of the periods they would usually deploy them. In exchange, the relevant party would provide an incentive to the consumer which would cover the costs incurred by the consumer in dispatching their generation or storage and any inconvenience incurred.

This is not a strict demand side management measure, in that it does not impact on how the consumer uses electricity. Furthermore, dispatching generation is typically seen as a supply side measure. That being said, the generation or storage plant is located on what is traditionally known as the demand side. There are arguments both for and against its inclusion as a delivery mechanism. For the purposes of this report, it is included as it is likely to require similar engagement between the relevant party/ies and the consumer.

# 8 Technical Architecture

This Section defines the technical architecture required to deliver the products/mechanisms described in Section 7.

Each of the defined Products will need a tailored solution and each solution will have its own functionality requirements. However, each solution can also have varying levels of sophistication whilst still performing the same function. To capture these differences and allow meaningful comparisons, the overall solutions are separated into a series of Technical Architecture Components (TACs), as shown in the following schematic.

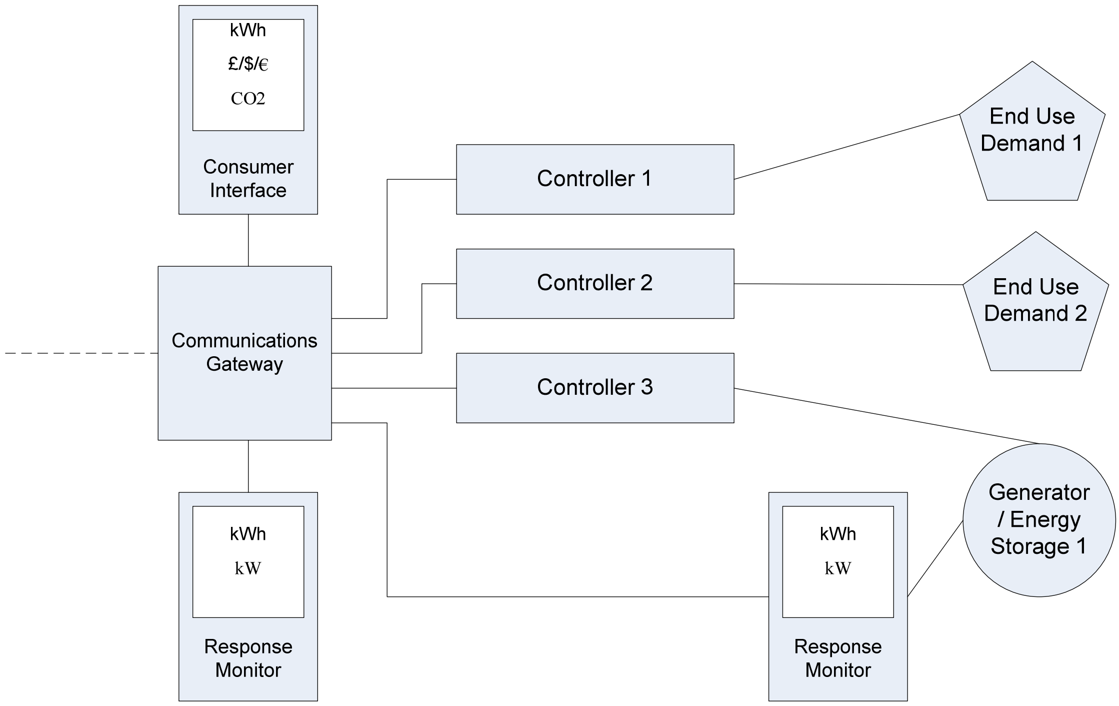



**Figure 8.1 Technical Architecture Components to deliver demand response and energy saving**

The Technical Architecture Components (TACs) each perform a specific function as described below:

- The **Controller** refers to the TAC responsible for interpreting instructions and modifying the End Use Demand accordingly.
- The **Consumer Interface** provides the consumer with information that will motivate the desired demand response.
- The **Response Monitor** (Meter) is responsible for recording consumer loads (energy usage and possibly demand) from which the energy savings and demand response can be assessed.
- The **Internal Communication** is the means by which communications are made within the consumer premises, between the communications gateway and other internal TACs.
- The **Communications Gateway** is the link between internal and external communication.
- The **External Communication** is the means by which communications are made to and from the consumer premises, including communication between external parties.

The TACs are further described in the following sections, together with the range of options available for implementation. In particular, the following sections focus on the varying levels of sophistication of the range of options in terms of cost, functionality and most importantly their technical potential to reduce demand.

## 8.1 Controller

The “Controller”, refers to the TAC responsible for modifying the end use demands. The type of control can be differentiated according to the following criteria:

- Trigger Mode – how the change in end use demand is triggered
- Demand Modification – how the end use demand is modified
- Location – where the controller is located in relation to the end use demand

The Controller can be as simple as a manually operated switch on a General Purpose Outlet (GPO). A more complex solution would incorporate an automatic central control system with in built logic that can be programmed to respond to a change (e.g. in price or system frequency) according to consumer preferences. Manual triggering is likely to be less expensive however the effectiveness at reducing demand is totally dependent on the consumer. The consumer needs to be notified of the need to initiate a demand response and must be motivated to react. Automatic controllers receive notification of a desired demand response and automatically adjust end use demands as required. Once set (according to consumer or third party preferences), these controllers are likely to be more effective at reducing demand, as they react without the need to continuously notify and motivate the consumer. Automatic controllers are more sophisticated and therefore more expensive solutions.

The simplest form of modification is to simply turn the end use demand on or off. Some loads (e.g. heating elements) can be modulated, that is, they can be reduced without switching it off completely. Some loads cannot be modulated either due to their normal mode of operation (e.g. domestic fridge/freezers) or due to consumer preferences. Clearly switching out a load completely would result in greater demand reduction than modulation or partial reduction. Controllers to modulate a load are more sophisticated and are therefore likely to attract a higher cost. That being said, they would only be used in the case where complete switching was not possible or preferred by the consumer.

Controllers can be in-built, standalone devices or a part of a central control system. The in-built devices can be retrofitted into the device or included by the manufacturer (e.g. future smart appliances). The standalone devices are typically hard wired in line with the mains supply (e.g. ripple relays) or devices that plug into a GPO and have a socket for attaching an end use demand. For single end use demands, it is likely to be less expensive to have the controller inbuilt or a standalone device in line with their supply. A central controller configuration may also be feasible if multiple end use demands require control within a single consumer premise. Central control systems may already exist in some SMEs. Existing central control systems typically allow for customer input however some modification may be required to interface with incoming demand response signals. Standalone controllers are most likely to be the least expensive solution for single end use demands. However, as the number of controlled end use demands increases, it is more likely that a Central Controller configuration may be more cost effective. It is worthwhile noting that in built Controllers may also become more common in the future. Provided open standards/protocols are developed for the demand response signals, these controllers could become more common and would increase effectiveness of demand response products.

The adoption of these controllers is largely dependent on the manufacturers themselves and the market development.

## 8.2 Consumer Interface

The Consumer Interface is responsible for informing the consumer and motivating them to modify their energy usage and/or demand. The different ways of interacting with the consumer can be described in terms of:

- Information - what information is provided to inform/motivate
- Notification - how the customer if provided with information/motivation
- Notification Frequency - how often the notification occurs
- Input – does the interface allow the consumer to modify their end use energy and/or demand directly

The interface can provide the consumer with information at standard intervals (historical or forecast) or in real-time. The simplest and least expensive method would be to provide this information historically at standard intervals (for example billing for EUMF). Providing information in real-time is obviously the most expensive method as it would require a Visual Display Unit (VDU) of some description (e.g. In Home Displays / Home Energy Monitors, PCs, Intelligent Thermostats, Meter Displays or Integrated Appliance Displays). As consumers may not always be within viewing range of the VDUs, a means of mobile notification may also improve the chances of the desired demand response (e.g. Mobile phone or pager for Real-time TOU tariffs). Although more expensive, providing real-time information would most likely result in the highest reductions in demand as consumers would be kept informed and would be able to see the immediate result of the actions (depending on the information provided by the VDU).

The type of information conveyed to a consumer can include energy usage, demand, savings (energy or cost), electricity price or reduction in carbon emissions. The more information provided, the more likely the consumer will be motivated to modify their demand. That being said, too much information may overcomplicate the message. Price information is likely to be the most effective at motivating consumers. The provision of price information does not have to be expensive (e.g. Billing for EUMF including Static TOU Tariffs). In some cases (e.g. Real-time TOU tariffs) the VDU may also require communication with external parties (e.g. Suppliers, ESCOs, aggregators). Although this would attract a higher cost it would most likely be more effective since it would allow the sending of cost reflective price signals.

More sophisticated interfaces may also allow for consumer input. Input could be used to trigger manual demand response or to set criteria for automatic demand response (such as price/ consumption thresholds). The input may also provide the ability to override automatic demand response that may be automatically triggered by third parties (Direct Load Control or Load Limiting) or by a controller acting on predefined consumer criterion. This consumer input would then be passed to the Controllers (which may or may not be housed within the same device). This kind of sophistication would add cost but would likely result in more effective reduction in demand. It is unlikely that consumers will be able (or willing) to monitor consumption continuously. Therefore, enabling specific criteria to be set through an interface would allow the controllers to respond automatically without the need for continuous consumer involvement.

It is worth noting that the consumer interface may be heavily influenced by ‘Smart Meter’ rollouts in various countries. ‘Smart Meters’ are discussed further in Section 8.6, however, in terms of the consumer interface there is a lot of discussion surrounding the inclusion of In-home Energy Monitors in various metering system specifications.

## 8.3 Internal Communications

Internal Communications refers to the communication links within the consumer premises. These links are typically between the Communication Gateway and the Controller. Internal Communications also includes links between the Controller and the end use demand. Depending on the type of information displayed, the Consumer Interface may also require communication links between itself and the Demand Monitor, Controller and the Communication Gateway. Any communication devices that communicate with other devices within the consumer premise are also part of the Internal Communications. This TAC is often referred to as the Home Area Network (HAN). The major considerations for internal communications are whether to have simplex or duplex communications and whether to use “wired” or “wireless” platforms.

Communication systems can be divided into “wired” or “wireless”. These categories refer only to the medium used for signal propagation and therefore the choice of one over the other has little influence on the effectiveness of demand reduction. Although less sophisticated, “wired” links between the Communication Gateway and the Controller for each EUD, is likely to be unnecessarily intrusive and expensive. The use of Power Line Carrier (PLC) technology may be one “wired” solution that may be less intrusive as it would make use of existing wiring. “Wireless” solutions are the least intrusive and are simple to extend. There are a number of “wireless” communications platforms available. The most suitable platforms for the HAN generally seem to be ZigBee, Zwave and Wifi. Some of the key considerations when choosing a platform include the communication range, susceptibility to noise and required power.

The other major consideration for this TAC is the use of simplex (one –way) or duplex (two way) communications. Duplex communications can be full or half duplex depending on whether communication is required to go in both directions simultaneously or not. For this TAC, simplex or duplex functionality will have the greatest influence on the effectiveness of products to reduce demand. Duplex is more sophisticated and more expensive, however it would be more effective for some products (e.g. Dynamic TOU). Depending on the configuration of TACs, two-way communication may be necessary for some products (e.g. between the Communication Gateway and the Response Monitor and/or Customer Interface for Dynamic TOU). Two way communication would close the loop and allow validation that the appropriate demand response has occurred. Validation is discussed further in the next section on External Communications.

Both PLC and “wireless” solutions would still require a Communication Gateway and a device capable of receiving (and possibly sending) the signal. This receiving device would need to be either retrofitted or built into the Consumer Interface, Controller or end use demand. PLC receiving devices can also respond to communications directly from third parties (e.g. ESCOs, Suppliers, aggregators, DNOs, TSOs). For this case, the PLC receiving device would be performing the Communications Gateway function. If required, the external signals for “wireless” solutions would be received via the Communication Gateway.

## 8.4 External Communications

The “External Communications” TAC refers to the communication between the consumer and an external third party. Any communications with an external third party would be handled by the Communications Gateway. The third party is largely dependent on the model adopted for demand aggregation (see Figure 7.2). This TAC also includes any communications between third parties or distributed data storage (concentrators) that may be required by the adopted model.

Each model has a different operational nature which influences the communication requirements and the preferred architecture. Some of these differences stem from the number of communication nodes (consumers) and the size of the geographic area covered. For example, the ESCO model is defined by a geographical area (block of flats or community) and is likely to have a relatively stable number of consumers. On the other hand a typical Supplier can experience significant consumer turnover which also directly affects their geographical coverage.

The actual physical environment can also affect the chosen architecture. Some “wireless” communications solutions are dependent on “Line of Sight” between communicating devices and signal “noise”. Therefore its use can be subject to the local terrain (mountains, vegetation etc.) and development (buildings, electricity towers etc.). Furthermore, some “wireless” solutions also have range limitations and might therefore be preferred in urban environments rather than rural, due to consumer density. Consumer density may also affect the “wired” solutions, for example, expensive fibre optic solutions may only be justified in high density areas where there is a need for high capacity and the cost per customer per km is lower.

Another major influence on the External Communications is the existing infrastructure. In most developed areas, there is already a number of existing public and private communication networks. The existing infrastructure could provide alternative options (e.g. leased sections or use of network charges) or it could limit options (e.g. limited physical space for ‘wired’ solutions or limited frequency spectrum for ‘Wireless’).

Given the potential for variability discussed above, it is difficult to determine which communication medium or platform would be preferred in terms of cost. That being said, it is possible to discuss some high level functionality.

The External Communications TAC is only required if there is a need for data to be transferred to or from a remote location. As with Internal Communications, an important consideration is the whether the remote communications are simplex or duplex. At a minimum, simplex communication will be required for any Product that requires external signals to be broadcast to consumers either at short notice or at non-standard intervals (e.g. Critical Peak Pricing or Semi-Dynamic TOU). Duplex communication will be required for Products where data is required for the external parties. Typical information of use to external parties includes meter data and demand response validation.

The meter data is useful for billing/settlement purposes but as explained below in Section 8.6 it does not have to be collected via remote communications. Meter data can also be used for validation of demand response and energy savings. Validation can be completed in real-time or by comparing historical time stamped meter data with a log of demand response signals. Validation would allow for greater analysis of the effectiveness of demand response programmes. Real-time validation would help to overcome the issues surrounding load diversity. Therefore, validation in real-time is likely to increase the reduction in demand by allowing the initiating external parties to adjust the demand response signals. The signals could be adjusted to drive the 'actual' demand response to meet the 'desired' demand response. This capability would be particularly quite useful for Dynamic TOU but not essential. Providing real time validation will increase the cost of the External Communications namely due to the increased capacity requirements.

## 8.5 Communication Gateway

The Communication Gateway is the link between the internal and external communication systems. Although the "Communication Gateway" can be considered part of the greater communications architecture, it is treated as a separate TAC. This is primarily because it must be compatible with two potentially independent communication systems that are likely to have different requirements. Furthermore, the Communications Gateway, whilst also situated at the customer premise, should be differentiated from the local communication devices required for Internal Communications.

For the purposes of this task, the communications gateway is described in terms of:

- Signal Flow – the direction/s that the communication singles flow
- Situation – where the gateway is located and if required, any TACs that are housed in the same device

The Communication Gateways functionality is largely dependent on the requirements for Internal and External Communication TACs and it need only be in place if both TACs are required. Similarly, simplex or duplex communication also depends on the Internal and External communications required to deliver the defined products. In this way, the gateway itself does not directly influence the reduction in demand and/or energy savings.

The "Communication Gateway" can be a standalone device (newly installed or existing) or can be incorporated into another TAC (e.g. Controller or Response Monitor). For single end use demands it may be less expensive to use Controllers with an in-built Communication Gateway. However, it may be more cost effective to have a central Communications Gateway (standalone device or in-built to a Central Controller or Response Monitor) if there are multiple end use demands within a single consumer premise that all require similar access to signals from external parties. The location of the Communications Gateway does not directly influence the reduction in demand and/or energy savings.

## 8.6 Response Monitor (Meter)

The "Response Monitor" is largely responsible for monitoring consumer demand and energy consumption. Pertinent to subtask 3, this TAC will provide a means of monitoring the effectiveness of the defined Products/Mechanisms, in terms of reductions in demand or energy savings. That being said, there are some demand response devices where the effectiveness can be assessed by monitoring system frequency as opposed to demand. In these cases stabilisation of network frequency is evidence of adequate response. In most other cases, this TAC is essentially an electricity meter, which can be categorised according to:

- Type – how the demand and/or consumption is recorded
- Data Transfer – how the data is collected
- Tariff – how the meter handles multiple tariffs

Accumulation meters are typically electromechanical devices that record energy consumption typically in kWh. The major limitation with these types of meters is that they only provide total energy consumption. Due to this limitation, these types of meters would not be suitable for many of the Time of Use (TOU) products. The advantage of this type of meter is that the majority of consumer premises will already have an accumulation meter in place which would reduce the cost of wide scale deployment basic DSM programmes.

Interval meters are typically electronic devices that record both (customer) demand and energy consumption information at set intervals (typically hourly or half hourly). Interval meters therefore provide a greater understanding of peak demand patterns and allow for various TOU products. The term “Smart Meter” is often used to describe an electronic meter with higher functionality than basic interval meters. Smart Meters are often seen as key to various advanced metering systems such as Automatic Meter Reading (AMR), Automatic Meter Management (AMM) or Automatic Metering Infrastructure (AMI). Subtle differences within these systems often result in inconsistent interpretations of a “Smart Meter”. A “Smart Meter” is most often defined as having all or most of the following attributes/functionalities:

- Interval Metering (hourly or half hourly)
- Auxiliary Supply (Battery Backup)
- On Board Memory (sufficient to retain information volumes required between reads)
- Remote Reading
- Secure Two-way communication (PLC, Mesh Radio, Fixed Radio, Broadband, GPRS, GSM)
- Remote Connect-Disconnect
- Load Control Switch
- Loss of Supply notification
- Import/Export capability

The Import/Export functionality is often included to allow for Distributed Energy Resources (DER) at a consumer premise. The rationale is that the energy output from local consumer generation and/or energy storage devices may sometimes exceed the local energy consumption. By including this functionality, the meter would be capable of recording any energy exported into the electricity grid. It is worth noting that this functionality commonly only records the Import/Export of energy at the metering point and does not give any indication of the local energy consumption/demand or the actual output of the DER. This information may not be of importance to programmes designed to reduce demand however it may be of use to energy saving programmes (as the actual energy savings could be masked/inflated by local DER). In order to capture the actual consumer demand and generation contributions, it is likely, that an additional meter would be needed to monitor the output from the Generator.

All of this additional functionality in a “Smart Meter” adds cost to this TAC and to other TACs (e.g. External Communications). It is difficult to assess how much additional demand reduction or energy savings would be gained from these additional functions without a comprehensive comparison of different existing programmes and trials. However, at a minimum, most of the TOU products could be delivered with an interval meter, with some of the functions performed by other TACs.

Some of the defined products are based on two or more tariffs designed to promote energy savings and/or demand response. Similarly, the energy exported by consumers may also require a separate “In-feed” tariff. Some accumulation meters are capable of recording consumption for multiple tariffs. However, the tariffs are typically fixed for certain time periods (such as Economy 7) and there is a physical restriction on the number of tariffs that can be built into the meter. Conversely, interval meters record the consumption against time and so theoretically, any number of tariff changes could be applied retrospectively. This makes interval meters particularly attractive for TOU schemes where the tariff is set according to market conditions that can fluctuate frequently and unpredictably.

Accumulation meters can only be read manually and require a meter reader to visit the installation and/or some form of estimation. This information from interval meters is typically stored within the meter's on-board memory. This information can be read locally by a hand held device or through manual inspection by the meter reader (if the meter has a visual display). Similarly, higher functionality interval meters (or Smart Meters) also have the ability to store information onboard. However, if the meter has remote communications, this data can be read remotely and/or stored remotely in a central archive. Remote reading does also require the appropriate External Communications to be in place.

Remote communications also allows for the transfer of Loss of Supply signals (with adequate auxiliary supply) and/or demand response validation to be sent to external parties. Furthermore, the inclusion duplex communications also allows for data to be transferred to the meter, for example, firmware upgrades, connect/disconnect signals, Supplier switching information and/or demand response signals.

If the interval meter does have remote communications capability, it would effectively also be performing the role of the Communication Gateway. Similarly, if the meter included a Load Control switch it would also be performing the Controller function. It is worth noting that this functionality can be performed by devices separate from the meter.

## 8.7 Summary

This section considers the minimum requirements for each of the TACs to deliver the Products listed in Section 7.

Within each TAC, there are numerous existing and emerging technologies capable of providing the required functionality. Many of these solutions/systems are commercially available and are often capable of performing the role of two or more of the TACs. There are obvious financial and operational benefits to be made by purchasing multi-purpose solutions/systems from a single manufacturer. Not all manufacturers provide multi-purpose solutions and in fact each TAC could be provided by a standalone solution/system. Separating the total architecture into components that reflect core functions (and location within the delivery chain) should aid with any future comparisons of a wider range of delivery solutions that include both standalone and combined systems. Figure 8.2 shows some of the possible configurations of available technologies in terms of TACs.

The minimum functionality is defined as the absolute simplest solution that allows the products to carry out their intended purpose. One important aspect of this is ensuring that the appropriate equipment is in place to allow the desired demand reduction and energy savings. Another consideration is ensuring that information can be sent or received by the consumers or the appropriate external third party (ESCO, aggregator, Supplier etc.). The timing and/or frequency required for information transfer is also considered. Table 8.1 describes the minimum required functionality for each TAC to deliver the various Products.

Where possible, this section has discussed how higher functionality would be able to increase the effectiveness of the product to deliver demand reductions and /or energy savings. These higher functionalities represent some of the more advanced options. It is important to note here, that the advanced option does not necessarily represent the optimum solution. This is particularly relevant where the additional benefits do not offset any additional consists incurred. The costs and benefits will be considered more fully when the business case is developed in the next stage of the project. The examples of advanced options are highlighted in red in Table 8.1.

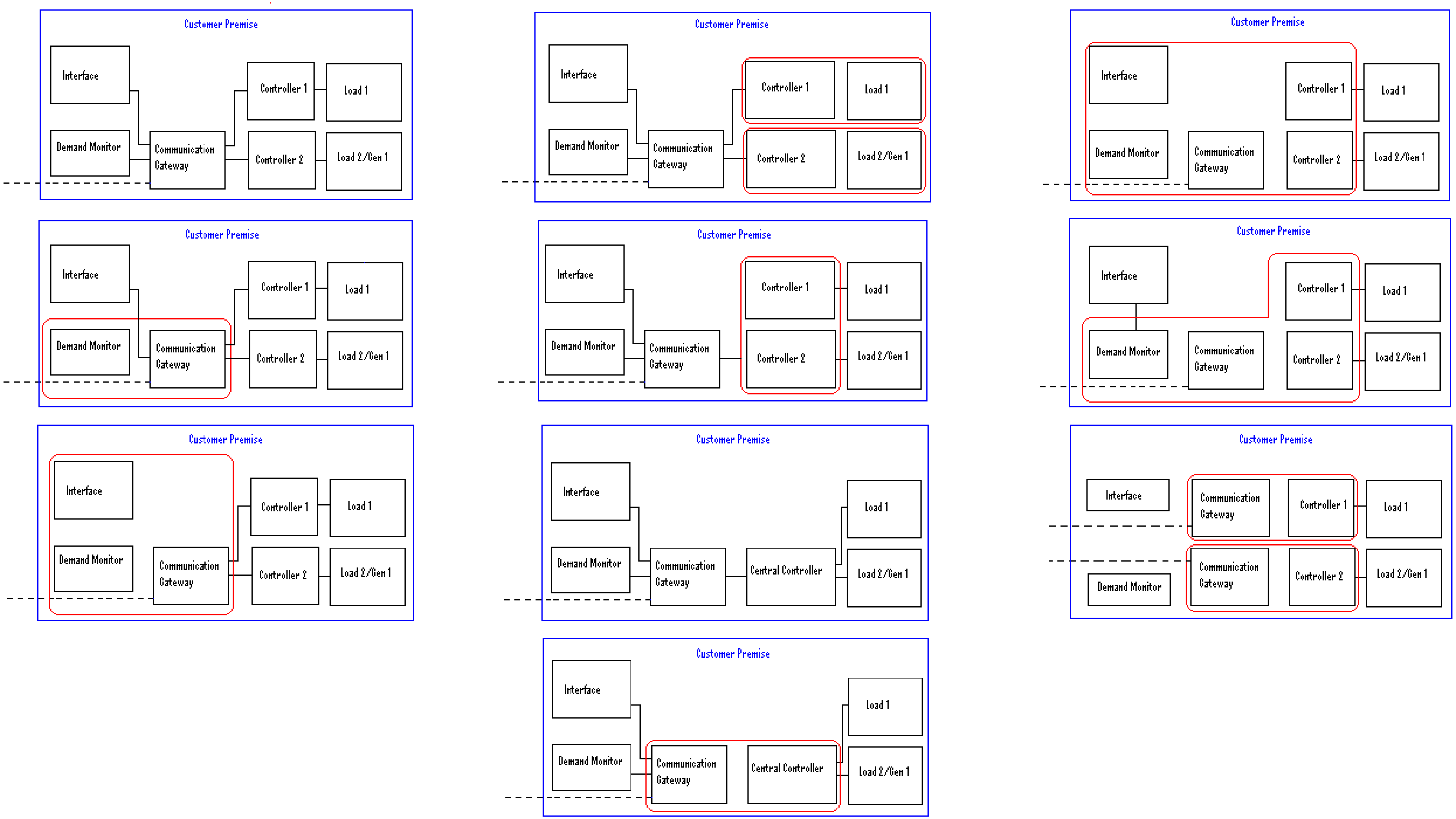



**Figure 8.2 Possible Configurations for TACs**

## Table 8.1 Minimum Requirements for Product Delivery (Advanced Options in Red)

| Programme Category | Product Group | Product | Controller | Consumer Interface | Internal Communications | Response Monitor | Communications Gateway | External Communications |
|---|---|---|---|---|---|---|---|---|
| Energy Saving | End Use Monitoring & Feedback (EUMF) | Billing | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Historical consumption<br>*Notification: Bills<br>*Notification Frequency: Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | None | None |
| | | Websites | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Historical consumption (possibly comparisons)<br>*Notification: Website Electronic Bills<br>*Notification Frequency: Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | *Signal Flow: Duplex (Two-way)<br>*Situation: Existing Gateway (Dial-up or ADSL Modem) | *Signal Flow: Duplex (Two-way)<br>*Connection: Existing ISP |
| | | Real Time Information Provision (e.g. Visual Display Units, Home Energy Manager) | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) [Central Home Energy Management System] | *Information: Historical consumption [Current consumption, Copmarative Savings (cost & emisisons), Tariff, Cumulative Bill to date)]<br>*Notification: Meter Display/VDU<br>*Notification Frequency: Real Time (Hourly, Half-hourly)<br>*Input: None | *None (Meter Display) [Wireless (VDU)] | *Type: Interval Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Tariffs can be applied retrospectively with time stamping (though product does not specify multiple tariffs) | None<br>[*Signal Flow: Duplex (Two-way)]<br>[*Situation: Central Home Energy Management System] | None<br>[*Signal Flow: Simplex (One-way)]<br>[*Connection: From Aggregator, ESCO or Supplier] |
| | | Disaggregated Demand Information | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Historical Breakdown of consumption by appliance/apliance type<br>*Notification: Bills<br>*Notification Frequency: Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | None | None |
| | | Face-to-Face Energy Advice / Energy Audits | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Historical consumption (possibly comparisons)<br>*Notification: Face to Face Advice & Bills<br>*Notification Frequency: Once off & Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | None | None |
| | | Community Energy Saving Schemes | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Historical consumption (possibly comparisons)<br>*Notification: Startup Meetings & Bills<br>*Notification Frequency: Startup Meetings & Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | None | None |
| | Block Tarrifs | Block Tariffs | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Historical Consumption Information, Information on Tariff Bands & Starting Point Consumption<br>*Notification: Bills [& Visual Display Unit]<br>*Notification Frequency: Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation Meter (backcalculate based on Starting Point Consumption) | None | None |
| | Rebate Tariffs | Rebate Tariffs | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Areed energy reduction target, Historical consumption<br>*Notification: Bills<br>*Notification Frequency: Agreed period Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A* | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | None | None |

| Programme Category | Product Group | Product | Controller | Consumer Interface | Internal Communications | Response Monitor | Communications Gateway | External Communications |
|---|---|---|---|---|---|---|---|---|
| | Time of Use Tariffs (TOU) | Static TOU | *Trigger Mode: Manual<br>*Demand Modification: On/Off<br>*Location: General Purpose Outlet (GPO) | *Information: Tariff Price/Timing, Historical consumption<br>*Notification: Bills<br>*Notification Frequency: Billing Cycle (monthly, quarterly, annually)<br>*Input: N/A | None | *Type: Accumulation meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Multiple Register, fixed on installation | None | None |
| | | Dynamic or Real-Time Pricing | *Trigger Mode: Manual [Automatic]<br>*Demand Modification: On/Off [& Modulated]<br>*Location: General Purpose Outlet (GPO) [Central Home Energy Management System] | *Information: Tariff Price & Historical consumption<br>*Notification: Meter Display/VDU [VDU+Moblile/Pager] & Bills<br>*Notification Frequency: Half-houly/Hourly & Billing Cycle (monthly, quarterly, annually)<br>*Input: None (Consumer Preference Input) | None<br>[*Signal Flow: Duplex (Two-way)]<br>[*Medium: Wireless] | *Type: Interval Meter<br>*Data Transfer: Manual Read Locally [Read Remotely]<br>*Tariff: Tariffs can be applied retrospectively with time stamping | *Signal Flow: Simplex (One-way) [Duplex (Two-way)]<br>*Situation: Customer Interface (Meter Display/VDU) [Controller (Central Home Energy Management System)] | *Signal Flow: Simplex (One-way) to Consumer [Duplex (Two-way)]<br>*Connection: [To/]From Aggregator, ESCO or Supplier |
| | | Semi Dynamic Pricing | *Trigger Mode: Manual [Automatic]<br>*Demand Modification: On/Off [& Modulated]<br>*Location: General Purpose Outlet (GPO) [Central Home Energy Management System] | *Information: Tariff Price/Timing & Historical consumption<br>*Notification: Website [VDU+Mobile/Pager] & Bills<br>*Notification Frequency: 1 Day/Week ahead & Billing Cycle (monthly, quarterly, annually)<br>*Input: None [Consumer Preference Input] | None<br>[*Signal Flow: Duplex (Two-way)]<br>[*Medium: Wireless] | *Type: Interval Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Tariffs can be applied retrospectively with time stamping | *Signal Flow: Simplex (One-way)<br>*Situation: Customer Interface (Meter Display/VDU) [Controller (Central Home Energy Management System)] | *Signal Flow: Simplex (One-way) to Consumer<br>*Connection: From Aggregator, ESCO or Supplier |
| | | Critical Peak Pricing | *Trigger Mode: Manual<br>*Demand Modification: On/Off [& Modulated]<br>*Location: General Purpose Outlet (GPO) | *Information: Tariff Price/Timing & Historical consumption<br>*Notification: Meter Display/VDU [VDU+Mobile/Pager] & Bills<br>*Notification Frequency: Agreed Number of Days & Billing Cycle (monthly, quarterly, annually)<br>*Input: None | None | *Type: Interval Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Tariffs can be applied retrospectively with time stamping | *Signal Flow: Simplex (One-way) (One-way)<br>*Situation: Customer Interface (Meter Display/VDU) | *Signal Flow: Simplex (One-way) to Consumer<br>*Connection: From Aggregator, ESCO or Supplier |
| * | Direct Load Control | Direct Load Control | *Trigger Mode: Automatic<br>*Demand Modification: On/Off [& Modulated]<br>*Location: Standalone in Line with Supply | *Information: Incentive<br>*Notification: N/A<br>*Notification Frequency: N/A<br>*Input: N/A | None (*Signal Flow: Simplex (One-way))<br>*Medium: Wired) | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | *Signal Flow: Simplex (One-way)<br>*Situation: Controller | *Signal Flow: Simplex (One-way) to Consumer<br>*Connection: From Aggregator, ESCO or Supplier |
| | Load Limiting | Load Limiting | *Trigger Mode A: Automatic (Limiting of Incoming Service Mains)<br>*Trigger Mode B: Manual [Automatic] (control of EUDs)<br>*Demand Modification A: Limited Mains Supply<br>*Demand Modification B: On/Off<br>*Location A:<br>*Location B: | *Information: Incentive & Curtailment timing<br>*Notification: N/A & Phone<br>*Notification Frequency: Once off & Agreed Time of Stress/Peak<br>*Input: None | None | *Type: Accumulation Meter<br>*Data Transfer: Manual Read Locally<br>*Tariff: Single Register | *Signal Flow: Simplex (One-way)<br>*Situation: Limiting Device | *Signal Flow: Simplex (One-way) to Consumer<br>*Connection: From Aggregator, ESCO or Supplier |
| | Generation Dispatch | Generation &/or Storage Dispatch | *Trigger Mode: Manual Dispatch [Automatic]<br>*Trigger Mode: On/Off<br>*Location: Stand-alone Generation &/or Storage Controller [Central Home Energy Management System] | *Information: Incentive & Historical Consumption [& Generation/Storage Output]<br>*Notification: N/A & Bills [& Real time request for Generation/Storage Support]<br>*Notification Frequency: N/A & Billing Cycle (monthly, quarterly, annually) [Half hourly/Hourly (Requests)]<br>*Input: None [Consumer Preference Input for Routine/Ad-hoc Startup+Override] | None<br>[*Signal Flow: Duplex (Two-way)]<br>[*Medium: Wireless] | *Type: Interval Meter (Generation estimated through Net Import/Export or Capacity) [Interval Meter (Generation measured through seperate Interval Meter)]<br>*Data Transfer: Manual Read Locally<br>*Tariff: Tariffs applied retrospectively | None<br>[*Signal Flow: Simplex (One-way)<br>*Situation: Controller (Central Home Energy Management System)] | None<br>*Signal Flow: Simplex (One-way) to Consumer<br>*Connection: From Aggregator, ESCO or Supplier |

# 9 Conclusions

This report explores the requirements and options for the effective delivery of micro demand response and energy saving products. The requirements are options are identified by consideration of the following issues:

- the structure of the electricity markets in the participating countries and impact of the market characteristics on the incentives and barriers for new demand response and energy saving products to develop;
- the potential requirements of potential purchasers of demand response and/or energy saving products;
- the demand response and energy savings that could be expected to be delivered through the application of time of use pricing, remote / automatic control of end-user loads and end use monitoring a feedback, assessed by way of a high level review of the findings of DSM pilots and case studies;
- the end-use energy consumption characteristics of domestic and small to medium enterprises in the participating countries;
- the mechanisms suitable for the delivery of a range of demand response and energy saving products to households and small and medium enterprises; and
- the minimum technical architecture requirements for the delivery of the range of demand response and energy saving products to households and small and medium enterprises.

The review of the arrangements in place that govern the way that electricity is traded and the roles and activities of the market players highlights, not unsurprisingly, that there are a number of significant differences between the participating countries. These differences lead to in different drivers for demand response and energy saving products across the participating countries, and more importantly, result in different barriers to the development of new products and services.

Whilst the specific requirements of potential purchasers of demand response and / or energy saving products will vary, a set of generic requirements has been identified in terms of the amount of aggregated response required, the preferred profile shape, the notification period provided to customers and the duration over which the demand response should be delivered.

A high level review of a selection of DSM pilots and case studies highlights that the level of energy savings and demand response delivered varies widely across the trials reviewed. Whilst the results are wide ranging, the high level review would suggest that EUMF could deliver energy savings of up to 15%, and that demand response products using time of use pricing, remote and/or automatic switching should be able to deliver peak load reductions of 10 to 15% where heating and cooling loads are prevalent. Without heating and cooling loads, the peak load reductions are likely to be less.

The analysis of energy consumption within the participating countries highlights that, in some instances, there is a general lack of data on how energy is consumed by smaller consumers. This includes both information on energy end uses (particularly for small non-domestic consumers), and on the time of use of the different energy end use categories. As such, has not been possible to differentiate classes of consumers according to their energy end use characteristics. Without such information, it becomes difficult to assess the potential business opportunities associated with aggregating specific customer types. Consequently, any business case evaluation will need to focus on the aggregation of specific end-use loads rather that specific customer types.

The analysis of the available energy consumption data of households and small and medium enterprises demonstrates there is, unsurprisingly, considerable variation in the end-uses of energy within the participating countries. Categorisation of the energy end uses according to their suitability for energy saving and demand response highlights that, due to the variation between the countries, new products will need to be tailored specifically to meet individual circumstances.

A range of different delivery mechanisms that can be used for energy saving and demand response products has been identified. This includes consideration of different approaches to aggregating small consumers and identification of a range of different products that could be used to motivate the consumers to modify their energy consumption. As identified in the review of the electricity markets, the different characteristics of the participating countries imply that there is unlikely to be a 'one-size fits all' solution, rather specific business models will need to be tailored according to individual circumstances.

Technology is an enabling mechanism that ensures that energy saving and demand response products can perform as required. Each product requires a tailored solution, each with its own specific functionality requirements. These requirements are identified in terms of a series of Technical Architecture Components. The minimum requirements for each product considered have been identified, together with a more advanced solution. Whether or not the more advanced solution is commercially viable depends upon whether the additional benefits outweigh any additional costs involved.

Therefore, this report provides a basis for the next phase of the project which aims to evaluate the business case for energy saving and demand response products from the perspective of the aggregator. A range of business options will be considered in order to attempt to identify the combination of end use application, aggregation approach and product type likely to offer to best prospects in terms of ensuring commercially viable business propositions.

# 10 Recommendations

Whilst this report provides a good basis upon with the business case for demand response and energy saving products can be evaluated, it is believed that an improved understanding of the potential business case could be strengthened if the availability of end-use energy consumption data was improved, particularly in terms of the breakdown of end-uses within the small to medium enterprise sector and information on the time of use of energy by end-use category.

In addition, the evaluation of any business model requires a detailed understanding of the environment within which it operates. As such, the interactions between the market players, which inevitably differ from market to market, is a key element in understanding the potential role of the demand aggregator, particularly in terms of identifying and quantifying potential revenue streams.

As such, the following issues need to be considered before a full understanding of the business case for demand response and energy saving products can be fully evaluated:

10.1 Obtaining improved energy consumption data by end-use for households and for small to medium enterprises.

10.2 Obtaining improved information on time of use of energy consumption by end-use.

10.3 Developing a market map to provide a schematic picture of the most relevant stakeholders within a particular market and the main interactions between them. A preliminary market map for the Netherlands can be found in Appendix 2.

# 11 Acknowledgements

The Operating Agent would like to gratefully acknowledge the following for their support and contributions to the preparation of this report.

Pekka Koponen, VTT, Finland

Frédéric Rosentein, Agency for Environment and Energy Management, France

Sarah Dukhan, Agency for Environment and Energy Management, France

Bruno Duplessis, MINES PARIS

Evangelos Karakatsanis, Public Power Corporation, Greece

Konstantinos Tsiroulis, Public Power Corporation, Greece

A.K. Asthana, Bureau of Energy Efficiency, India

Jose Moraga Gonzalez, University of Groningen, Netherlands

Vlasis Oikonomou, University of Groningen, Netherlands

Eise Spijker, Joint Implemention Network, Netherlands

Carmen Rodríguez Villagarcía, Red Eléctrica de España, Spain

Susana Bañares, Red Eléctrica de España, Spain

Jen Carter, EA Technology, UK

Aidan Roberts, EA Technology, UK

# Appendix 1 Overview of Electricity Market and Trading Arrangements

This Appendix provides a summary of the overview of the structure of the electricity market and the overall arrangements in place that determine the way electricity is traded in each of the participating countries. The information was collated using a questionnaire completed by each of the participating countries.

## A1.1 Unbundling

Table A1.1 provides an overview of the current status of unbundling in each of the countries participating in Task XIX, where:

- **Accounting Unbundling** implies that the company keeps separate accounts for each activity as would be required if the activities in questions were carried out by different companies;
- **Functional Unbundling** implies that within a vertically integrated utility, the activities are independent in terms of organisation and decision-making;
- **Legal Unbundling** implies that the operations have been separated from all non-related activities;
- **Ownership Unbundling** implies that the various activities are under separate ownership; e.g. Transmission & Distribution networks are operated under different ownership to generation and supply

**Table A1.1 Unbundling Status in the Participating Countries (for Transmission and Distribution Activities)**

| Country | Accounting | Functional | Legal | Ownership |
|---|---|---|---|---|
| Finland | ✓ | ✓ | ✓ | × |
| France | ✓ | ✓ | ✓ | × |
| Greece | ✓ | ✓ | × | × |
| India | ✓ | ✓ | ✓ | ✓ |
| Netherlands(*) | ✓ | ✓ | ✓ | × |
| Spain | - | - | ✓ | ✓ |
| UK | - | - | ✓ | ✓ |

(*) In the process of moving towards ownership unbundling by 2011

As shown above, the extent to which the various activities have been unbundled varies from country to country. In Greece, the activities have been separated into different functional activities with separate accounting, but are not legally separated to ensure that only regulated, monopoly activities are undertaken within the organisation. With legal unbundling, there should be no possibility for the misallocation of costs between regulated and non-regulated activities, as the organisations have separate workforce, premises and procedures. Although more rigorous than accounting or functional separation, issues may still arise where regulated and unregulated companies are under common ownership, as there could be an opportunity for the regulated company to treat any sister companies more favourably. Spain and the UK have progressed further than legal ownership and have implemented ownership unbundling. In these countries, the monopoly network companies must not be a subsidiary of a company that has interests in generation or retail.

## A1.2 Generation Sector

Table A1.2 below shows the number of generating companies in each of the participating countries. Unless otherwise stated, the data presented below does not include smaller organisations such as municipal and/or industrial CHP schemes that sell surplus generation on the wholesale market. Instead, the data represents the number of organisations actively involved in generation for the wholesale market, and thus indicates the number of companies with large scale generation plant generally connected directly to the transmission system (i.e. does not include embedded generation connected at the distribution level).

**Table A1.2 Number of Generation Companies by Ownership**[38]

| | Publicly owned (Central Gov.) | Publicly owned (State Gov.) | Municipality (Local Gov.) | Privately owned | Concession | Mixed | Total |
|---|---|---|---|---|---|---|---|
| Finland | | | | | | | **~120**[(i)] |
| France | 1 | | n/a | 3 | n/a | | **4** |
| Greece | 1[(ii)] | | | 3[(iii)] | | | **6** |
| India | 6 | 110[(iv)] | | 36[(v)] | | | **152** |
| Netherlands | 1 | | | 4 | | | **5** |
| Spain | | | | 6 | | | **6** |
| UK | | | | 43 | | | **43** |

n/a not available or not known
(i) Most of the generation capacity is owned by limited liability companies, where central / local government are amongst the largest shareholders. In addition, many generation companies are owned by municipalities. Two organisations account for the majority of the generating capacity, each owning 40% and 20% respectively.
(ii) Generation, Transmission, Distribution and Supply are separate departments of the State owned company PPC.
(iii) In addition, about 35 private companies hold a generation licence in order to develop corresponding activities in the future. (i.e. to build and operate a dispatchable unit).
(iv) Includes State Electricity Boards, Electricity Departments, Power Corporations and Management Boards under State or Joint Partnerships existing in the country for Electricity Generation, Transmission and Distribution as at 31/03/2007.
(v) Companies involved in multiple activities

### A1.2.1 Peak Demand

Figure A1.1 shows how the actual peak system demand in each of the participating countries has varied over recent years. The data presented represents the peak demand that was met, thus where load curtailments have occurred due to shortage of generation capacity, the actual peak demand for electricity could have been higher. Both India and Greece have experienced such shortfalls in generation capacity which has been insufficient to meet the actual requirements, resulting in load curtailments. For example, in India during the period 2006/07, the total peak demand on the system was estimated to be 100.7GW, of which only 86.8GW could be met, representing a shortfall of some 14%. Greece experienced a similar situation in 2004 where the peak demand that could be met was 9.4GW at the time of a general black out, compared to an actual estimated demand of 9.6GW. In subsequent years, Greece has initiated load shedding actions, with 500MW of load shed in 2007. Even Finland has, during exceptional cold spells, experienced generation capacity shortages, which in January 2006 almost led to load shedding by disconnecting feeders to certain customers.

[38] Public / state ownership is defined for this survey relative to public/state ownership in the country of survey: e.g. whilst EdF is deemed to state owned in France, its UK subsidiary EDF Energy is considered to be privately owned.

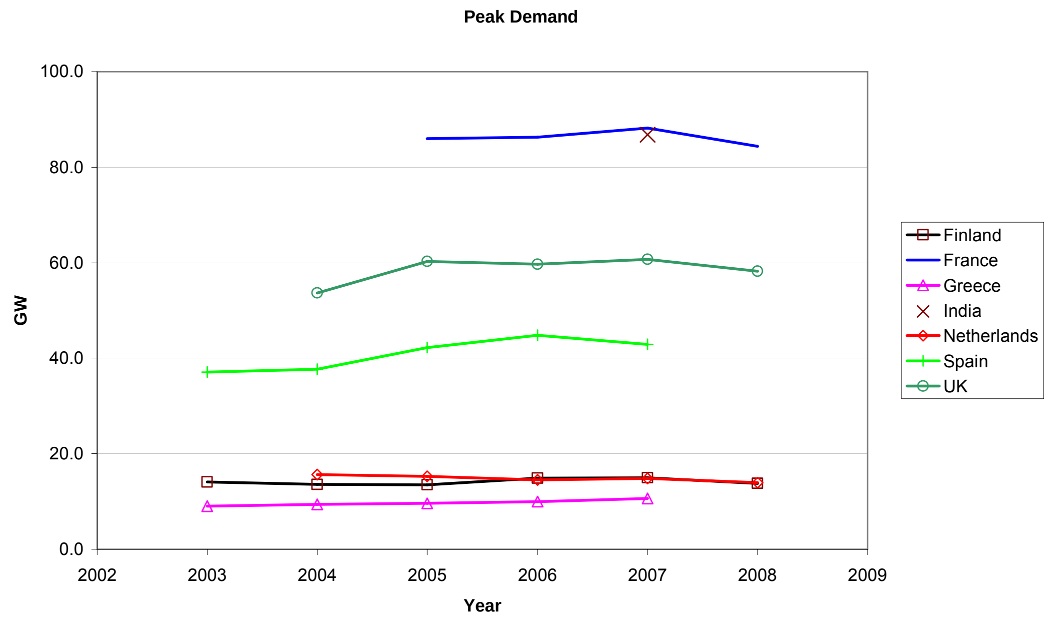



**Figure A1.1 Peak Demand**

### A1.2.2 Installed generating capacity

Figure A1.2 shows how the installed generation capacity in each of the participating countries has varied over recent years. The data presented represents the total installed generating capacity of major[39] power producers, and excludes embedded generation[40]. .

Increasing concerns over global warning has led to interest in 'environmentally-friendly' generation sources. This includes PV, wind and bio-mass systems, and many countries have put specific targets in place for renewable generation sources. The output from wind generators is variable, depending upon the prevailing wind conditions which can vary both from hour to hour and from day to day, which can represent an additional challenge in terms of maintaining the careful balance between supply and demand in real time. The variability associated with wind can increase the cost associated with operating the transmission system in terms of the requirements for additional reserve. This has led to increasing interest in electrical energy storage based solutions to provide a cost effective solution to the challenges of system balancing with high penetration of renewables. However, demand response and energy saving products represent a potential alternative to offset the requirements for reserve created by wind generation. The demand side are able to both reduce demand when the output from wind generators falls, but also have the potential to take extra demand when the wind output is high, for example by bringing forward end-uses of energy such as the use of washing machines, tumble dryers, or the charging of electric storage heaters.

[39] The definition of major power producers will vary from country to county. For the purposes of this report, it relates to those producers whose prime purpose is the generation of electricity, and excludes companies who produce electricity as part of their manufacturing or other commercial activities, but whose main business is not electricity generation. Also excluded is generation energy services companies at power stations on an industrial or commercial site where the main purpose is the supply of electricity to that site, even if the energy service company is a subsidiary of a major power producer.

[40] Data for Finland includes generation from municipal CHP and process industry.

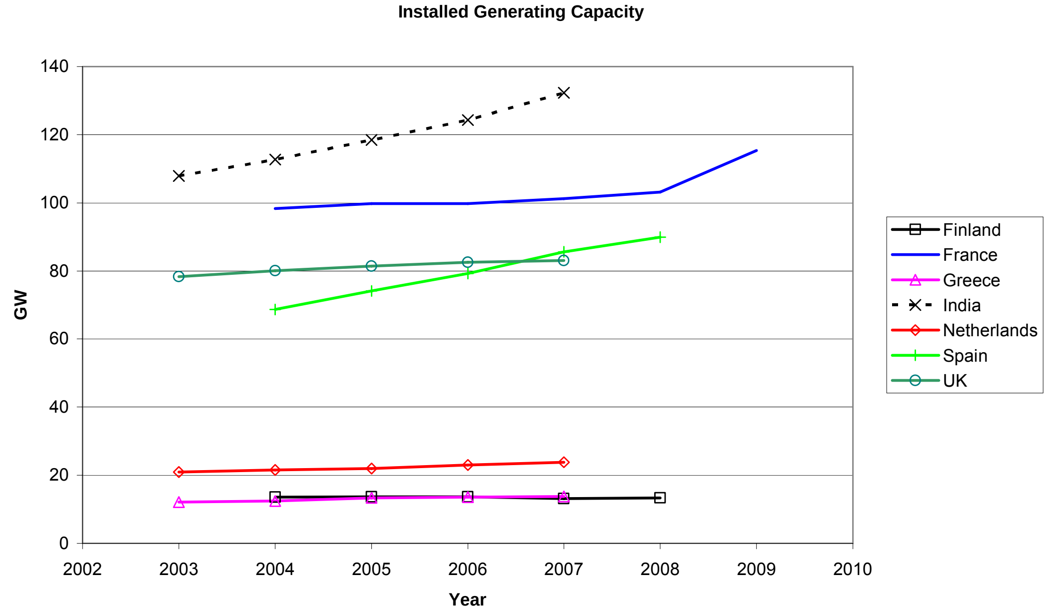



**Figure A1.2 Installed generation capacity**

Figure A1.3 below shows the mix of installed generating capacity in each of the participating countries. The data is repeated in tabular form in Table A1.3, which also indicates the installed generating capacity that can be dispatched at the request of the System Operator, the capacity that is regarded to be non-dispatchable, which includes nuclear base load generating plant with limited capability to adjust output, heat driven CHP plant and intermittent power sources such as wind power or non-controllable hydro for which output varies according to the prevailing conditions.

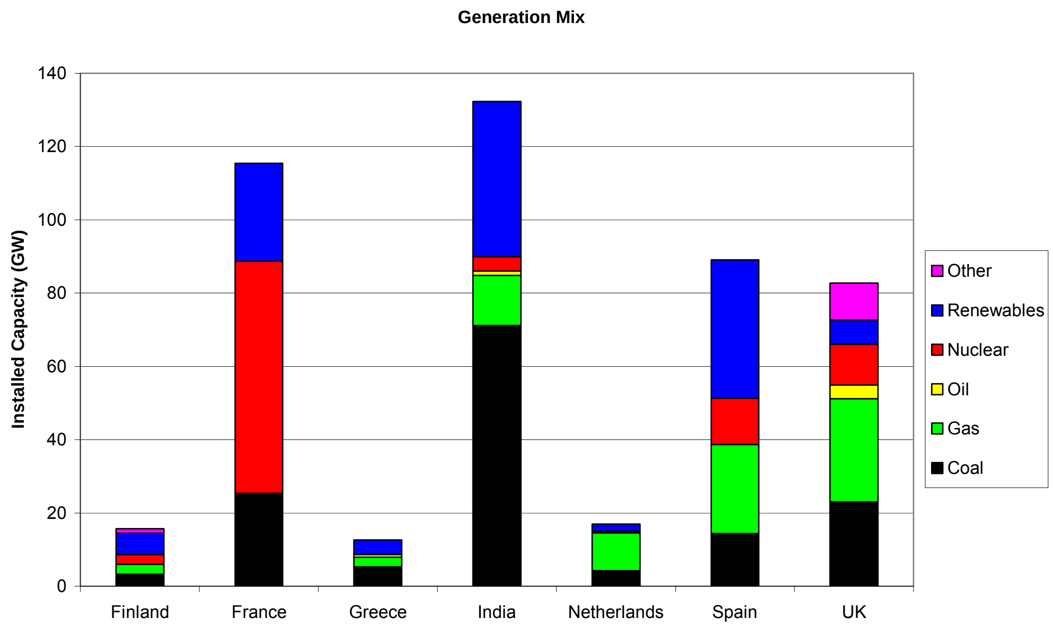



**Figure A1.3 Installed Generating Mix (2007[i,ii])**

i Data for coal fired generation for France includes also gas and oil thermal generation capacity
ii Data for Spain is for 2008, data for France is for 2009

**Table A1.3 Installed Generating Capacity (GW) by type for major power producers[i] in 2007[ii]**

| | Finland | France | Greece | India | Netherlands | Spain | UK |
|---|---|---|---|---|---|---|---|
| Coal | 3.3 | 25.4 | 5.3 | 71.1 | 4.3 | 14.4 | 23 |
| Gas | 2.7 | | 2.6 | 13.7 | 10.3 | 24.3 | 28.2 |
| Oil | | | 0.8 | 1.2 | | | 3.8 |
| Nuclear | 2.7 | 63.3 | | 3.9 | 0.5 | 12.6 | 11 |
| Renewable | 5.8 | 26.7 | 3.9 | 42.4 | 1.9 | 37.8 | 6.7 |
| Wind | <0.1 | 1.4 | 0.9 | | 1.7 | 16.2 | 1 |
| PV | 0 | | <0.1 | | <0.1 | 1.4 | |
| Biomass | 2.6 | | | | <0.1 | 8.5 | |
| Hydro | 3.0 | 25.3 | 3.2 | 34.7[iii] | <0.1 | 11.7 | 4.1 |
| Waste & Other | 0.2 | | <0.1 | 7.8[iv] | | | 1.6 |
| Other | 1.2 | | | | | | 10.0 |
| **Total** | **16.7[v]** | **115.4** | **12.5** | **132.3** | **17.0** | **89.1** | **82.7** |
| | | | | | | | |
| *Dispatchable Capacity* | *7.5[vi]* | | | | | *50.3* | |
| *Non-dispatchable Capacity* | *8.0[vi]* | | | | | *39.6* | |
| *Capacity with variable o/p* | *5.5[vi]* | | | | | *17.6* | |

(i) Data for Finland includes generation from municipal CHP and process industry
(ii) Data for Spain for 2008, data for France is for 2009.
(iii) Large hydro power stations
(iv) Grid interactive renewable power comprising small hydro, wind, biomass, urban and industrial waste as at March 2007
(v) The 16.7GW total installed gross generating capacity includes nearly 1.2GW of system reserves and additional capacity that is not available during the peak demand. The estimated total net generation capacity during the peak demand is 13.0 to 13.6GW.
(vi) Rough estimates, where nuclear, CHP and wind power are considered non-dispatchable and CHP and wind output is considered to vary. These figures do not include imports or system reserves.

## A1.3 Transmission Sector

Table A1.4 shows that the ownership structure of the Transmission System varies between the participating countries. In France, Greece and the Netherlands the Transmission system is publicly owned, whilst in India the eight State Boards are each responsible for the Transmission assets in their state. The UK is the only country in which the Transmission system is wholly owned by private organisations, whilst in Finland there is a mixture of public and private ownership of the Transmission assets. It is also interesting to note that it is not necessarily the case, as shown in Table A1.4, that a country's Transmission System is owned by a single organisation. For example, the Transmission system in the UK mainland is owned and maintained by three separate organisations, one for assets in England and Wales, and two for the assets in Scotland.

**Table A1.4 Number of Transmission Companies by Ownership[41]**

| | Publicly owned (Central Gov.) | Publicly owned (State Gov.) | Municipality (Local Gov.) | Privately owned | Concession | Mixed | Total |
|---|---|---|---|---|---|---|---|
| Finland | | | | | | 1[(i)] | **1** |
| France | 1 | | | | | | **1** |
| Greece | 1[(ii)] | | | | | | **1** |
| India | 1 | 35[(iii)] | | | | | **36** |
| Netherlands | 1 | | | | | | **1** |
| Spain | | | | | 1 | | **1** |
| UK | | | | 3[(iii)] | | | **3** |

(i) A public limited company with mixed ownership structure – 12% state owned, two power generation companies each own 25% (one of which is itself 50.7% state owned), and the remaining 38% is owned by various insurance companies. Ownership unbundling from generation is currently being prepared.
(ii) Generation, Transmission, Distribution and Supply are separate departments of the State owned company PPC.
(iii) Operated as a single system

Whilst the responsibility for the operation of the transmission system is generally undertaken by a single organisation, it is not always the case that the transmission assets are also owned and maintained by that same organisation. Table A1.5 provides an overview of the current situation for the countries participating in Task XIX. The information in Table A1.5 indicates the organisation with responsibility for operation, maintenance and development, even though the activities themselves may be outsourced to another party.

41 Public / state ownership is defined for this survey relative to public/state ownership in the country of survey: e.g. whilst EdF is deemed to state owned in France, its UK subsidiary EDF Energy is considered to be privately owned.

**Table A1.5 Transmission System – Ownership, Maintenance and Operation**

| Country | Single 'system' operation | Owned, operated and maintained(*) by same entity | Additional Information |
|---|---|---|---|
| Finland | Yes | Yes | Undertaken by Fingrid Oyj |
| France | Yes | Yes | Undertaken by RTE |
| Greece | Yes | No | PPC is the owner of the Transmission System.<br>Hellenic Transmission System Operator is responsible for the operation maintenance and development of the system (whilst the actual maintenance and development is undertaken by PPC under the direction of the HTSO). |
| India | No | No | Operation and Maintenance is the responsibility of the respective State Transmission Unit (STU) at State Level.<br>At National Level, the responsibility lies with the Power Grid Corporation. |
| Netherlands | Yes | Yes | Undertaken by Tennet |
| Spain | Yes | Yes | Undertaken by REE |
| UK | Yes | No | Ownership in GB is divided amongst three companies.<br>Operation of whole system undertaken by National Grid. |

(*) This could include outsourcing of tasks such as maintenance, although overall responsibility still remains with the System Operator.

As highlighted above, in the majority of cases a single entity is the owner of the transmission assets, and is also responsible for the operation, maintenance and development of the infrastructure assets. The main exceptions to this are described in further detail below:

- **Greece:** The transmission system is owned by the Public Power Corporation (PPC) S.A., which owns all the HV and EHV lines and substations. The Hellenic Transmission System Operator (HTSO) S.A., which is 51% state owned, is responsible for the physical operation, the maintenance and the development of the system, whilst all maintenance and construction is carried out by PPC under HTSO direction.
- **India:** The electricity system in India is managed as five interconnected regional zones, each having its own regional dispatch centre (operated by the State Transmission Utility, STU) responsible for maintaining system frequency between 48.5Hz and 50.5 Hz within the zone. The Central Transmission Utility (CTU), also known as the Power Grid Corporation, is responsible for operating, maintaining and developing the India's inter-state transmission system and for the operation of the five regional power grids.
- **UK:** The transmission system in GB is owned and maintained by three separate companies. National Grid Electricity Transmission owns the infrastructure in England and Wales. The Scottish system is split into two parts, one of which is owned by Scottish Hydro-Electric Transmission and the other by Scottish Power Transmission. The three sections are, however, operated as a single system by National Grid.

### A1.3.1 Regulation and Income Setting

The Transmission System represents a natural monopoly, and therefore requires regulation to protect consumers, avoid abuse of powers and to ensure that all parties are treated fairly. This includes the requirement to encourage economic efficiency, which can take many forms but generally fall into one of two categories; incentive based regulation or rate of return regulation.

There are two basic forms of price control, rate of return control and incentive based regulation. In simple terms, rate of return (or cost of service regulation) allows a regulated company to set tariffs for the services it provides such that it can recover its costs plus a reasonable rate of return. Traditionally, such rate of return regulation requires each tariff to be individually approved, with the price controls being fixed until they are revisited by the regulator every time the regulated company applies for a tariff change.

Incentive based regulation generally involves relating the allowed change in the average price of a bundle of services or the total revenue associated with an activity to movements in a general price index, such as the Retail Price Index (RPI). In its simplest form, incentive based regulation is expressed in terms of an 'RPI – X' constraint, where the 'X' factor reflects the regulator's requirements for efficiency gains, which is applied for a fixed period of time. This form of control is typically referred to as incentive regulation because it allows a company to increase its profits if it achieves a higher level of efficiency gains than those envisaged when the formula was determined. The regulated company retains these efficiency savings until they are passed on to its customers at the time of the next price review through lower prices. Incentive based regulation involves periodic reviews, when the regulator assesses a company's costs of production and level of demand. This data is used to forecast the required level of earnings for the company, such that it can achieve a specific level of return in each of the years between reviews, after taking account of the need to fund investment and the potential for efficiency gains.

Incentive based regulation allows a company to increase its profits if it achieves a higher level of efficiency gains than those envisaged by the regulator, which are subsequently passed on to consumers at the next price review in the form of lower prices. Thus, incentive based regulation may provide greater opportunities for the development of new demand response products to assist the System Operator with meeting its obligations in terms of maintaining the quality and security of supply where these products can be shown to be more cost effective than alternative services provided by generators.

Table A1.6 below summarises the type of regulation that is in place in the participating countries, and shows that no one type of regulation predominates.

**Table A1.6 Income Regulation for the Transmission System Operator**

| Country | Income Setting | Interval | Incentives to reduce costs |
|---|---|---|---|
| Finland | Rate of return | 4 years | The key factors for incentives (as determined by the Regulator) are the controllable operational costs and the security of supply, for which target levels of expenditure have been set. [42] |
| France | Rate of return | Annual basis | No specific incentive |
| Greece | Rate of return | Annual basis | No specific incentive |
| India | Rate of return(i) | 3 year | Incentive based on reducing transmission losses. Some states also provide for a financial incentive to maintain a high power factor in medium and large establishments |
| Netherlands | Incentive based (RPI-X) | 3 years | Main incentive provided through the X factor, and any outperformance can be retained by the company |
| Spain | Rate of return | Not fixed | Incentives in place – but no details provided |
| UK | Incentive based (RPI-X) and cost recovery | 5 years | The TSO will receive an incentive payment if costs are lower than agreed with the Regulator, and will face a penalty if the costs are higher under a 'cap and collar' arrangement. |

(i) Each state has its own regulatory body

## A1.3.2 Procurement of System Services

Competitive markets are generally regarded to be good for consumers, and therefore, it would seam reasonable to suggest that having competitive arrangements in place for the procurement of system services will lead to overall benefits as well creating the opportunity for new cost effective system services, including those involving the demand side, to be developed.

[42] See http://www.energiamarkkinavirasto.fi for more details

The following table provides an overview of how the System Operator procures the services it needs to maintain the quality and security of electricity supply.

**Table A1.7 Procurement of services by the Transmission System Operator**

| Country | Competitive Tenders / Market Led Arrangements | Long Term Contracts Permitted | Own Generation | Demand Side Providers |
|---|---|---|---|---|
| Finland | ✓ | ✓ | ✓(i) | ✓ |
| France | ✓ | ×? | × | Experimental |
| Greece | × | ✓ | × | × |
| India | ✓ | ✓ | × | × |
| Netherlands | ✓ | ✓ | × | ✓ |
| Spain | ✓ | × | × | × |
| UK | ✓ | ✓ | × | ✓ |

(i) The system operator runs a balancing market to buy services for system balancing from Nordic Regulation Market, but also owns some reserves to handle disturbances (i.e. fast disturbance reserves to ensure system security)

As shown, all of the countries except Greece and India have competitive arrangements in place through which the System Operator secures the services it requires to balance the system. Not all of the participating countries permit long term contracts to be established, which could make it more difficult for an aggregator of small consumers to develop a business case for providing demand response to the System Operator, as common with any competitive market, there may be no guarantee of income over the long term. Finland is the only country which permits its Transmission System Operator to own generation plant for fast (emergency) reserves. Of the 819MW of fast reserve capacity in Finland, 615MW is owned by the Finnish System Operator, Fingrid Oyj.

### A1.3.3 Transmission System Constraints

Demand response provides the System Operator with an alternative approach to managing transmission system constraints rather than, for example, constraining the output of certain generators whilst increasing the output from other generators in order to reduce the power flow on the constrained part of the network. Transmission constraints affect all the participating countries to some degree. For example, transmission constraints across Continental Europe and across the UK-France interconnector have had significant effect on the availability and hence the prices of electricity within the UK. Similarly, the interconnection capacity in the Netherlands is not always able to facilitate power trade flows.

Table A1.8 below provides an overview of the extent to which transmission constraints impact on the flow of energy in the participating countries, where the following three types of constraints have been considered:

- Constraints **within** the country itself;
- Constraints **between** neighbouring countries; and
- Constraints **in** neighbouring countries that impact on power flow into or out of the country.

**Table A1.8 Overview of transmission constraints**

| Country | Within own country | Between neighbouring countries | Within neighbouring countries |
|---|---|---|---|
| Finland | ✓ | ✓ | ✓ |
| France | n/a | n/a | n/a |
| Greece | ✓ | ✓ | ✓ |
| India | ✓ | n/a | n/a |
| Netherlands | ✓ | ✓ | |
| Spain | ✓ | ✓ | ✓ |
| UK | ✓ | ✓ | ✓ |

## A1.4 Distribution Sector

Table A1.9 provides an overview of the ownership structure of the distribution companies in each of the participating countries.

**Table A1.9 Number of Distribution Companies by Ownership**

| | Publicly owned[43] (Central Gov.) | Municipality (Local Gov.) | Privately owned | Concession | Mixed | Total |
|---|---|---|---|---|---|---|
| Finland | | 62 | 28 | | | **90** |
| France | 1(i) | 170 | | (ii) | | **171** |
| Greece | 1(iii) | | | | | **1** |
| India | 110 | 3 | 60 | | | **173**(iv) |
| Netherlands | | 9 | | | | **9** |
| Spain | | | | 4 | | **4** |
| UK | | | 7(v) | | | **7** |

(i) 95% of the population is served by the publicly owned distribution system operated by EDF
(ii) Local authorities in France always own the distribution network and delegate its management and exploitation through a concession status or public-private companies (known as 'régies')
(iii) Generation, Transmission, Distribution and Supply are separate departments of the State owned company PPC.
(iv) The 110 companies include State Electricity Boards, Electricity Departments, Power Corporations and Management Boards under State or Joint Partnerships existing in the country for Electricity Generation, Transmission and Distribution as at 31/03/2007 Of these, 31 are involved in both Generation and Distribution, 5 are involved in Generation, Purchase and Distribution and 24 and involved in purchasing and Distribution.
(v) There are 14 distribution regions in GB, each with its own licence, which are owned by 7 different organisations, i.e. the majority of these organisation have operate more than one of the regional distribution networks.

Unlike the transmission system, distribution networks are generally passively managed, i.e. DNOs do not explicitly use balancing services to manage the system in real time. However, the introduction of distributed generation is placing increasing pressure on distribution network operators, particularly in terms of managing the power flows on networks primarily designed to transport electricity from the high voltage transmission system to end-users.

Therefore, as active network management becomes commonplace, the potential role of the demand side will become increasingly important as DNOs increasingly need to manage the balance of supply and demand across their networks.

43 Public / state ownership is defined for this survey relative to public / state ownership in the country of survey: e.g. whilst EdF is deemed to be state owned in France, its UK subsidiary EDF Energy is considered to be privately owned for the purpose of this survey.

Whilst not widespread, DNOs already have much experience of active management, including the following examples shown here:

- **Finland:** Like in other countries, only the central parts of the distribution networks are covered by network automations and the far ends of the network are managed by mobile crews communicating with the control centre. Exceptions are some DNOs that have implemented network automation extensions to MV/LV transformers and the LV (400V) networks using remotely readable meters as part of this concept. Several DNOs plan to expand their network automation to cover MV/LV transformers and the LV customer connections. In terms of demand side flexibility, some power line carrier control systems are in place, but these are now rarely used and will be removed when Smart Metering is rolled out. However, some of the small DNOs did use the system during the national power shortage in January 2006.
- **India:** Most distribution companies face power shortages during peak load. Some companies have initiated energy saving devices at the consumer to reduce peak loads, such as replacement of incandescent bulbs with CFLs, use of star label appliances, provision of subsidies for domestic customers with solar energy, and penalties for large customers with low power factors.
- **Netherlands:** Although DNOS do not currently actively manage their networks, the first step towards more active network management are being taken, which includes:
    d) Smart Metering;
    e) informing end-users about the possibility of generating their own energy by means of solar power systems;
    f) grids capable of handling two-way power flows to accommodate the rise of decentralised generation
- **UK:** There is a general view in the UK that networks will have to become more actively managed to fulfil national renewable energy goals. As such, DNOs have commissioned projects such as dynamic circuit ratings and voltage control schemes. In the near terms, communication and control advances that enable generation constraints to be lifted will be considered.

One example of an actively managed network can be found in the Orkney Islands, located off the northern tip of Scotland, which is now a significant exporter of energy (from renewable devices). Generators quickly used up the theoretical transfer capacity of the subsea cables. Subsequent generators have been equipped with controllers and communications, so that they can fit into the ‘gaps’ created by the intermittency of existing generation. A last-on, first-off algorithm is used. In this case, the reinforcement upgrade would have been in the region of £30M, with the active scheme costing around £200k.

Active voltage control is used at several sites, having been running since 2005 at one site. The schemes control voltage on distribution networks with DG, keeping voltage within limits at all locations and at all times. In one case, the implementation of a £175k active scheme obviated a £1M reinforcement.

Inline voltage regulators are active devices which are not widely used in the UK, but could become more prevalent in the future.

There are also examples of more traditional forms of what could today, be called active management. An example of this might be the connection of a large wind tunnel, with running subject to the spare supply capacity and particular network configuration at the time.

### A1.4.1 Distribution Network Constraints

Constraints are an ubiquitous feature of any network, although, as shown by Table A1.10 the impact of these constraints affects the operation of networks to a varying extent.

**Table A1.10 Distribution Network Constraints**

| Country | Details of distribution network constraints |
|---|---|
| Finland | In rural networks, distribution network constraints do impact on the demand side (It is recognised that limiting demand peaks can defer or avoid network reinforcement and improve restoration times after faults). In urban networks, the capacity of the distribution network does not constrain demand under normal situations. The existing rural and sub-urban distribution networks in general have enough capacity to enable loading of the batteries of full penetration of electric cars, if some load control is applied. |
| France | No significant impact. |
| Greece | No significant impact. |
| India | Managing supply to customers during peak demand hours has a significant impact on the operation of the distribution network, as does high distribution losses |
| Netherlands | No information available, but levels of network disturbances could indicate that networks are becoming more constrained. |
| Spain | No significant impact |
| UK | Some constraints beginning to occur on the networks, often as a result of increased distributed generation. Active network solutions are likely to be used in these circumstances. |

*N.B. Care is recommended in interpreting these results, as it is not possible to ensure that the scale of the responses provided above is comparable. For example, in Finland long distances together with a strict attitude towards power quality requirements contribute to the need to take into account the network constraints. In many EU countries (possibly including some of those marked with "no significant impact", may not fully reflect the integrity of the distribution networks.*

## A1.5 Retail Sector

Table A1.11 below shows the number of supply companies in each of the participating countries, together with an overview of the ownership structure of these organisations. Unless otherwise indicated, the data excludes parties that are not actively involved in the supply of electricity to end-users, for example it does not include those organisations that hold a supply licence in order to allow them to purchase small amounts of electricity in order to avoid exposure to imbalance charges.

**Table A1.11 Number of Supply Companies by Ownership[44]**

| | Publicly owned[43] (Central Gov.) | Municipality (Local Gov.) | Privately owned | Concession | Mixed | Total |
|---|---|---|---|---|---|---|
| Finland | | | | | | **74(i)** |
| France | 1 | 170 | 14 | (ii) | | **185** |
| Greece | 1(iii) | | 55(iv) | | | **32** |
| India | | 3(iv) | 60(v) | | 89(v) | **(iv)** |
| Netherlands | | ~6(v) | ~16(vi) | | | **22** |
| Spain | | | 7 | | | **7** |
| UK | | | 69(vii) | | | **69** |

44 Public / state ownership is defined for this survey relative to public/state ownership in the country of survey: e.g. whilst EdF is deemed to state owned in France, its UK subsidiary EDF Energy is considered to be privately owned.

(i) This relates to all retail Suppliers registered with the Energy Market Authority and includes some retail Suppliers that only occasionally offer electricity to customers outside a certain limited area, such as a municipality. Of the 74 retail Suppliers, 7 do not have an obligation to supply in any distribution network.
(ii) Local authorities in France always own the distribution network and delegate its management and exploitation through a concession status or public-private companies (known as 'régies')
(iii) Generation, Transmission, Distribution and Supply are separate departments of the State owned company PPC.
(iv) By the end of October 2009, 55 private companies hold a supply licence while 32 of them are actively participating in the market.
(v) Supply of electricity to end-users is undertaken by the Distribution companies, therefore, see Table A1.9 for details
(vi) Approximately 75% of supply companies are entirely under private or foreign ownership. The remaining are partially publicly owned. Numbers shown include two demand aggregators
(vii) Number of supply licenses issued as at 23/03/09. The majority of the supply market (>99% of domestic electricity supply and >90% of electricity supply for small businesses with an annual spend of <£10,000) is dominated by six companies.

### A1.5.1 Liberalisation of the Retail Sector

The extent of market liberalisation in the retail sector is another important factor in determining the potential for demand response products. Since 2007, all consumers across the European Union have had the freedom to choose their electricity Supplier. However, not all markets across Europe have established a dynamic and competitive retail market. For example, all price controls within the retail market in the UK were removed in 2002, including for all residential consumers. However, electricity is very much regarded as a public service in France, and consequently there has been much less of an appetite nationally for a competitive retail market to develop. As a result, approximately only 2% of residential consumers in France have opted to take a non-regulated electricity tariff.

Market liberalisation provides the opportunity for new Suppliers to enter the market, and efforts to win and retain customers should provide an important catalyst for energy Suppliers to develop new business offerings in order to differentiate themselves from the incumbent energy Supplier. Such business offerings could include demand response as a means of optimising energy purchasing costs.

However, the down-side of market liberalisation is the issue of asset stranding which can occur when consumers are free to switch energy Supplier with little or no notice. Up until 2007[45], energy consumers in the UK were permitted to switch energy Supplier with only 28 days notice. This meant that any Supplier investing in new technology to facilitate demand response or energy saving could risk losing the consumer to another Supplier after the hardware was installed. This was recognised as a major barrier to the implementation of such products, and as such, energy Suppliers are now permitted to offer consumers long-term contracts.

In almost all the participating countries all consumers are able to choose their electricity Supplier. The only exception to this being consumers in India. However, the actual extent to which full competition in retail has developed in the other countries varies significantly between the countries. For example, in Greece, the proportion of electricity supplied to consumers competitively accounts for less than 1% of all electricity sales to end-users. The proportion is similarly low in France, where only 2% of domestic customers have opted to move away from their 'incumbent' energy Supplier. In Finland, in the case of consumers settled using profiles, the incumbent energy Supplier is treated differently as the time variations of the difference of the real power consumptions and the load curves are 'credited' to the incumbent Supplier, and as a result other retail Suppliers cannot benefit from demand response and consequently bear higher risks. In 2012/13 the load curve based settlement system will be replaced with settlements based on actually hourly metered values, and as such will create a 'level playing field' for all retail Suppliers.

45 A trial relaxation of the '28 day rule' was initiated in 2004.

**Table A1.12 Number of consumers who have switched from their incumbent Supplier**

| Country | % Sales | | % Customers | |
|---|---|---|---|---|
| | All | Domestic | All | Domestic |
| Finland | n/a(i) | n/a(i) | n/a(i) | n/a(i) |
| France | 32% | 0.6% | 4% | 2% |
| Greece | 0.7% | 0% | ~0.17% | 0% |
| India | | | | |
| Netherlands | n/a(ii) | n/a(ii) | n/a(ii) | n/a(ii) |
| Spain | | | | |
| UK | n/a | n/a | n/a | 54(iii)% |

(i) There are no regulated tariffs in Finland. No statistics available on how many customers have moved from their local Supplier, only on the number of customers switching annually.
(ii) No statistics available on number of customers that have switched. On average, 8% of customers switch electricity Suppliers annually.
(iii) Of these, only approximately 80% have only switched Supplier once.

The following table provides an overview of the minimum notice that customers without fixed term contracts are required to provide in order to change their energy Supplier. The table also shows the maximum length of contracts that are permitted. This can have a significant impact on the potential for aggregators of small consumers to 'lock-in' new participants to ensure that the capital costs of any dedicated equipment required to implement demand response and energy saving products can be recouped.

**Table A1.13 Supplier Notice Periods**

| Country | Minimum notice that must be provided to switch Supplier(*) | Long term contracts permitted |
|---|---|---|
| Finland | Customers can change retail Supplier free of charge up to a maximum once per year In most contracts, the retail Supplier is able to change the tariff with much shorter notice. | ≤ 2years for fixed price contracts |
| France | | |
| Greece | 30 days notice | n/a |
| India | | |
| Netherlands | 30 days notice | Yes |
| Spain | | |
| UK | 28 days notice | Yes, 1 – 2 year contracts typically available |

(*) minimum term only applies where there is no long term / fixed length contract in place.

### A1.5.2 Energy Savings Targets within the Energy Sector

Targets to reduce energy consumption and greenhouse gas emissions create a positive driver that could encourage the adoption of the micro demand response and energy saving products that fall within the scope of this project. For example, the European Union has agreed a climate change package to deliver a 20% cut in emissions, a 20% improvement in energy efficiency and a 20% increase in renewables by 2020. Individual countries within the European Union have different implementation plans to ensure that both their specific obligations are met and that the overall commitment is achieved. The following table therefore, highlights whether any specific energy saving obligations have been placed on Energy Suppliers.

**Table A1.14 Overview of energy saving targets placed on Suppliers**

| Country | Energy Saving Target | Details | Funding | Penalty |
|---|---|---|---|---|
| Finland | × | On a voluntary basis only, where companies receive state aid in return for agreeing specific targets. | State | Return of any state aid received. |
| France | ✓ | White certificate system | | 2c€/kWh_cumac |
| Greece | × | No energy saving target or other obligation has been placed on Suppliers to date as EU Directive 2006/32 has not yet been transferred to national legislative framework. | | |
| India | | 10,000MW of avoided generation capacity over the period 2007 to 2012 (i) | Government of India | |
| Netherlands | ✓ | Targeted mainly at buildings, and aims to make 500,000 buildings 30% more efficient over 2008-2011, increasing to 2.4 million buildings by 2020. | | None |
| Spain | | | | |
| UK | ✓ | Scheme is called the Carbon Emissions Reduction Target (CERT), the current phase of which runs from 2008 to 2011. The scheme is directly targeted at domestic customers, and at least 40% of the target much been achieved via 'priority' customers – low income / elderly. | Levy paid by end-users | Not defined, but regulator has power to impose a penalty or secure compliance. |

(i) The target applies to the Bureau of Energy Efficiency, Ministry of Power, not for individual Suppliers.

## A1.6 Current status of Smart Meter roll-out

Table A1.15 below shows the extent to which Smart Meters have been rolled out in each of the participating countries.

**Table A1.15 Smart Metering Roll Out**

| Country | Details |
|---|---|
| Finland | Rolled out to 1million customers (out of a total of 3.1 million). Legislation requires that at least 80% of customers in each DSO region have Smart Metering with hourly interval metering by 1 January 2014. The settlement of all hourly metered customers must be based on hourly metered data by 1 January 2012 and immediately for those hourly metered customers that have a retail product based on hourly consumption. All customers consuming over 3x63A are required to have hourly metering by 1 January 2010. The new metering systems are required to be able to transfer at least one load control signal to the customer. |
| France | Meter stock comprises 33 million meters, of which 16.5 million are one rate mechanical meters, 9 million are two rate mechanical meters (peak / off-peak) and 7.5 million are electronic meters (with other features, e.g. colour specification for tariffs such as 'Tempo'. |
| Greece | All HV and MV customers have meters with AMR capability. |
| India | AMR planned for HV customers in selected states. |
| Netherlands | AMR for large users. Smart metering legislation initially proposed mandatory installation and use of Smart Meters in households. However in April 2009 this requirement was removed. Now installation of Smart Meters in households is on a voluntary basis. |
| Spain | |
| UK | AMR for large users (<100kW).<br>A change has been made to licences to facilitate the roll out of advanced meters to non-domestic customers (profile classes 5 to 8) over the five years to 2014.<br>The Energy Act 2008 gave the Secretary of State powers to mandate Smart Meters for domestic customers, and it is expected that the decision will come in the next 12 – 18 months. It is generally anticipated that Smart Meters will be rolled out to most domestic customers by 2020. |

# Appendix 2 Market Map

Figure A2.1 shows a preliminary market map for the Netherlands.

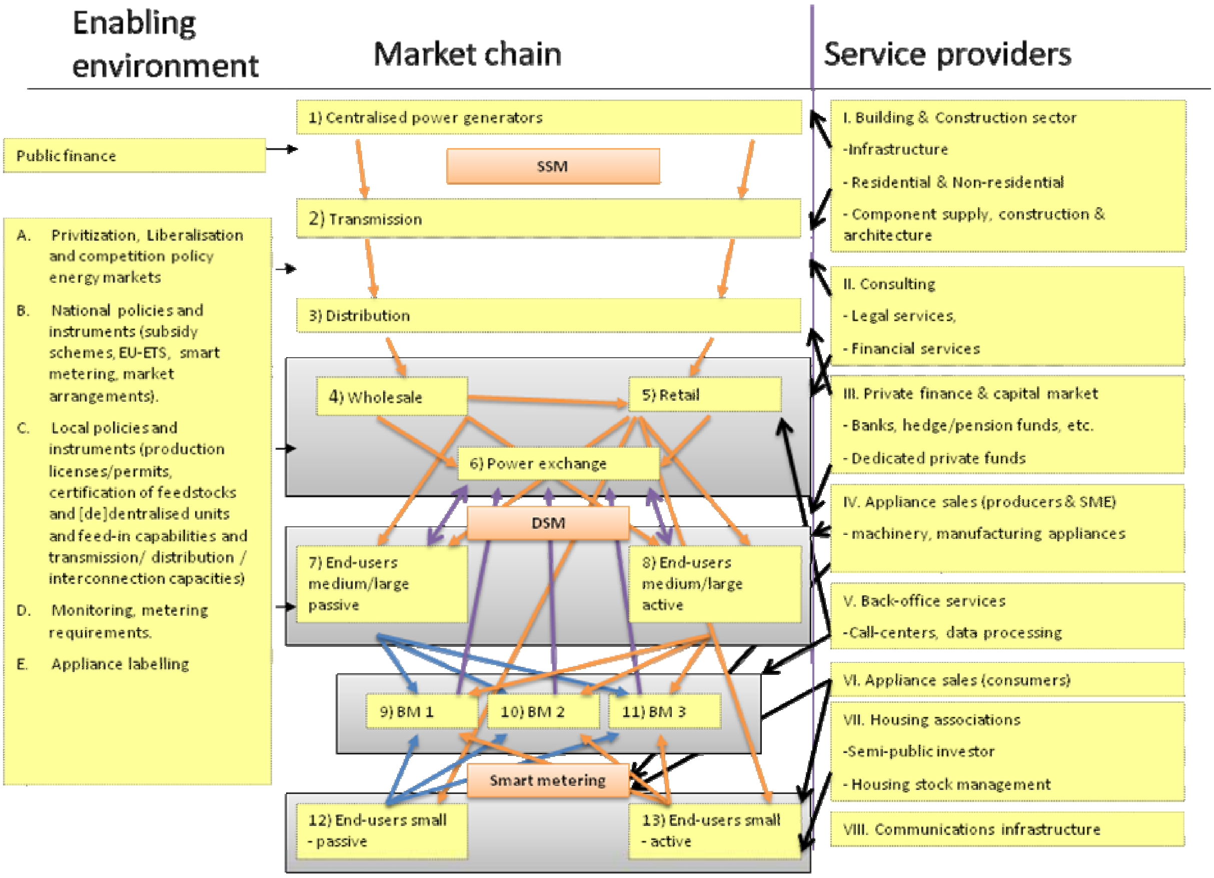



**Figure A2.1 Preliminary market map for the Netherlands electricity market**

# Appendix 3 Electricity Consumption by Residential & Commercial Consumers

This Appendix provides a summary of the consumption by Residential and Commercial Consumers. The information was collated using a questionnaire completed by each of the participating countries. As noted in the main body of the report, further information on how and when electricity is consumed would be useful to those developing demand side activities.

Electricity is used by domestic and small commercial consumers in a variety of ways. By understanding these ways, the '*end uses of electricity*', a clearer picture of the potential for demand response and energy saving programmes to change demand evolves. This section therefore considers how energy is used within the residential and small and medium enterprise sectors within the participating countries, and identifies the main opportunities for demand response and energy saving programmes.

**Table A3.1 Electricity Consumption in Participating Countries in 2007 (TWh)**

| | Industrial | Commercial | Residential | Transport | Other |
|---|---|---|---|---|---|
| **Finland** | 48.0 | 16.9 | 22.4 | | 3.0 |
| **France** | 123.5 | 141.7 | 141.8 | 12.2 | |
| **Greece** | 15.2 | 15.9 | 18.0 | | 5.9 |
| **India*** | 265.0 | 46.6 | 120.9 | 11.0 | 133.6 |
| **Netherlands** | 41.3 | | 24.3 | 1.6 | 51.3 |
| **UK** | 117.1 | 101.2 | 115.1 | | |

(*) Data for period April 2007 to March 2008

Table A3.1 shows the annual consumption for the participating countries for 2007 by consumer type. The split between the different consumers varies across the countries with some, such as Greece and the UK, having a relatively even split between industrial, commercial and domestic consumption, whilst others see a significant difference between the demands of different sectors. Whilst transport is presently of minimal significance in the majority of the countries, it is anticipated that consumption by transport will be of increasing importance in the future. As outlined in Section A3.1.8, many of the participating countries either already have targets in place to promote the use of electric vehicles, or expect to do so in the near future.

In order to fully evaluate the potential impact of demand response and energy saving programmes, it is necessary to understand both the quantity of energy used by specific end use application and the time that the energy is used. Whilst data on the end-uses of electricity is generally available for residential consumers, information on commercial consumers and the time of consumption (for both residential and commercial consumers) is less readily available. The ways in which energy is consumed are, however, gaining an increased level of importance as different participants from Government to utilities to end consumers try to gain a clearer picture of how energy is used and the implications of its usage. Some of the participating countries have indicated that they envisage work to be carried out within their country to address this current lack of data on consumption. There are, however, some gaps in this section which highlight areas where clearer information may be beneficial to understanding of the end uses in the residential and small commercial sectors.

## A3.1 Residential demands

There are many demands for electricity within the residential sector, including heating; air conditioning; lighting; cold appliances for food refrigeration; wet appliances for laundry and dishwashing; consumer electronics (such as televisions, DVD/video players, set-top boxes, music players etc.); and increasingly Information Communication Technology appliances (such as computers, printers, routers, mobile telephones, etc.). In the participating countries, residential electricity consumption ranges between 2.7% and 34.5% of total electricity consumption. Table A3.2 shows the consumption in the residential sector across the participating countries by end use.

**Table A3.2 Residential Consumption by End Use (GWh)[a,b]**

| | Finland | France | Greece | Netherlands | Spain | UK |
|---|---|---|---|---|---|---|
| **Heating** | 6,907 | 41,883 | 311 | 35 | 4,000 | 13,977 |
| **Hot Water** | | 18,523 | 3,151 | 1,750 | 2,264 | 16,184 |
| **A/C** | 621 | | 935 | 3 | 1,324 | |
| **Lighting** | 2,516 | 8,800 | 2,199 | 4,383 | 8,294 | 17,489 |
| **Cold Appliances** | 1,461 | 16,516 | 3,303 | 4,807 | 7,409 | 15,209 |
| **Wet Appliances** | 652 | 15,419 | 1,270 | 3,684 | 2,326 | 13,857 |
| **Consumer Electronics** | 834 | | | | 6,589 | 20,533 |
| **ICT** | 407 | | | | | 6,118 |
| **Cooking** | 653 | 10,045 | 2,804 | | | |
| **Saunas** | 852 | | | | | |
| **Car Heating** | 218 | | | | | |
| **Fans** | | | | | | |
| **Other** | 2,572 | 3,0617 | 2,125 | 8,721 | 18,110 | 11,731 |
| **Total** | **17,693** | **141,803** | **16,098** | **23,383** | **50,316** | **115,098** |

a Data for Finland relates to 2006, Data for France, Netherlands and the UK relates to 2007, Data for Spain relates to 2008, and Data for Greece is averaged over the years 2001 to 2005

b. No data by appliance type available for India.

Whilst EUMF has the potential to impact on all end-uses of electricity by increasing customer awareness, some end-uses will be less suitable for demand response programmes than others. Therefore, the following sections considers the suitability of the various end-uses of energy for demand response. In particular, the end-uses that can be interrupted remotely or automatically with little or no notice are identified, together with the end-uses that can be shifted or rescheduled, provided that advance notification is provided. In addition, the behavioural changes that could be motivated through the use EUMF in order to deliver energy savings are also highlighted.

### A3.1.1 Space Heating

In excess of 100TWh of electricity is consumed within the participating counties for heating and air conditioning each year. These loads typically coincide with times of peak demand and can, in most cases, be interrupted with little or no notice and therefore make ideal candidates for demand response. More importantly, provided the interruptions are of minimal duration, the disruption to the end-user will be often be negligible. Rather than turning off heaters and air-conditioners, it is also possible for the thermostat to be 'set-back' for a short period to reduce the heating / cooling load of the house for a limited duration.

The use of storage enables the length of time that heaters or air-conditioners can be turned off to be extended without impacting on comfort. If the storage capacity is sufficient, it also enables these loads to be shifted away from peak periods entirely, which could be useful for increasing demand during the night or optimising the use of variable renewable generation. Storage options include the use of hot water storage in insulated cylinders or the use of night storage heaters in place of direct electric heating. Split air-conditioning units are more commonly used in residential applications, with single units serving selected rooms. Central units employing a water, glycol or refrigerant circuit to provide cooling to the whole building are less common in the household sector, although they are used in limited numbers of larger properties. As such, air-conditioning loads in the residential section are less well suited to load shifting.

Table A3.3 below shows the proportion of residential electricity consumption attributable to electric heating in the participating countries, together the proportion of households with electric heating.

**Table A3.3 Electric space heating**
**Prevalence and consumption**

| | Electricity consumption for heating (GWh)* | % of total consumption of residential sector | % of properties with electric heating** | % of properties with storage heating |
|---|---|---|---|---|
| Finland | 6,907 | 39% | 24.4% | 13.9% |
| France | 41,883 | 30% | 30.4% | 1% |
| Greece | 311 | 2% | 8.1% | |
| Netherlands | 35 | <1% | | |
| Spain | 4,000 | 8% | 26.8% | |
| UK | 13,978 | 12% | 8% | 4.2% |

(*) Data is for 2007
(**) All types of electric heating, including storage heating

As indicated in Table A3.3, the use of electric heating varies significantly between the participating countries. Electric heating accounts for a significant proportion of residential electricity consumption in Finland (39%) and France (30%), making electric heating an obvious target for demand response and energy saving programmes in these countries.

Over half of the electrically heated households in Finland use storage heating, reflecting, in part, the successful application of time of use tariffs to encourage the shift of heating loads into the off-peak period. The charging of storage heaters during the off-peak provides limited potential for demand response, for example for the provision of providing reserve services to the system operator or for optimising the use of renewable variable generation.

The majority (99%) of households in France utilise direct electric heating. Direct electric heating loads typically make a significant contribution to system peak demand and network constraints, and therefore represents a significant opportunity for demand response in Finland and France. Direct load control in houses with direct electric heating was widely applied in Finland before the introduction of competition in the electricity retail market. For example, during the winter of 1996-1997, field tests were conducted with almost 9,000 electrically heated houses. Participation in the trial was voluntary, and proved popular because very few customers noticed any loss of comfort but received a small reduction in their tariff. The controllable power was a-priori estimated to be about 3.5 kW/house on average. Such direct load control systems are now little used in Finland, mainly as a result of the move towards competition.

The use of electric heating is currently at a reasonably modest level in Spain, representing 8% of the electricity consumed by the residential sector. However, with little or no storage heating used, this level of consumption makes a significant contribution to the peak demand in Spain. This, coupled with the fact that electric heating has grown significantly in Spain over recent years, driven mainly by an increase in the number of reversible air-conditioning units, makes electric heating load an important demand response resource for Spain.

Although electric heating represents 12% of electricity consumption by the household sector in the UK, over half of electrically heated households employ storage heating. There is significant experience of optimising the charging of night storage heaters in the UK. For example, it is believed that there are some 2.5 million[i] meters in the UK with a Radio Teleswitch that offer flexibility for dynamic switching, i.e. where the Supplier can vary the time of the off-peak period[46].

Standard storage heater control allows charging (at off peak times) typically over a 7 hour period set by a time clock for the heating circuits. The only control of charge is by the householder varying the settings of the individual heaters – thus turning demand down during periods of warm weather. There are however a number of systems which provide more sophisticated control that automatically limits charging during warm weather. Some of these provide the means of flexible charging regimes according to price signals and include the CELECT control algorithm, Credanet and Weather Compensation Control, which are described briefly below.

### CELECT

The demand control algorithm (CELECT) (ControlELECTric) was applied to homes with a mix of storage and direct heating demand. The algorithm scheduled the charge and release of energy from the storage heating based on half hourly price messages received by broadcast radio, 24 hours ahead. The direct heating was used to support the heat output of the storage heating in high price times. The energy cost saving using the algorithm was 15% but improved comfort and temperature stability were also obtained. A learning algorithm was included which learned the heat loss parameters for each house based on external temperatures. A major feature of this control regime was that it was automatic and although customers could switch their heating off and/or adjust thermostat set points, they could not switch heating on.

CELECT, whilst very successful in its trial in the early to mid 1990s, has now been abandoned due to barriers introduced by the competitive market (basically full half hourly metering would be required to track the demand changes brought about by the daily changes in heat demand and price signals).

### Credanet

Credanet is a reduced version of the CELECT system which relies on intelligence at each storage heater to determine the amount of heat required and when the heaters are charged.

### Weather Compensation Control

Several weather compensation devices exist that vary the charge take of storage heating according to the ambient temperature. All of these simply limit the charging period according to a time – temperature algorithm. However, one of these systems – Mainsborne – does offer the potential for simple two-way communication with the house and metering system, using power-line signals between the house and the local substation.

This system has been extensively trialled in blocks of flats in the London area. As well as providing the charge limiting required at the storage heater, data was also collected of half-hourly meter reads for all of the flats. Again, this data was not used in the settlement process, but the method is proved.

46 No figures were available on the number of meters that can be dynamically switched using other methods

The system also has the flexibility to alter the charge / temperature algorithm by, for example, allow different blocks of charge time to be made available during the day. It is believed that at least one major Supplier is currently interested in investigating the use of multi-charge periods. Although this is still at the theoretical investigation stage, the long term aim would be to include the technique in the Suppliers Energy Efficiency Commitment target (a UK Government set target for energy Suppliers to introduce energy efficiency measures).

### A3.1.2 Water Heating

Table A3.4 illustrates the electricity consumed for heating domestic hot water and the proportion of households with electric water heating. In almost all of the countries, electricity is not the sole fuel used to heat water, but it is commonly used to heat water instantaneous or to supplement other fuels. Increasingly, it is being used to supplement water heating by solar thermal systems. In the UK, for example, a relatively high proportion of properties have some form of electric water heating compared to the number of properties that use electricity for space heating (63% compared to 8%). This difference is the result of the adoption of ‘power showers’ which rely on electricity to heat the water and to increase the water pressure.

**Table A3.4 Residential Hot Water & Storage Prevelance and Consumption**

| | Electricity consumption for water heating (GWh)* | % of total residential consumption | % of residential properties with Electric Water Heating | % of residential properties with Immersion Tank |
|---|---|---|---|---|
| Finland | | | 30-35% | ~90% |
| France | 18,523 | 13% | 44% | ~40% |
| Greece | 3,151 | 20% | 97% | <1% |
| | 1,750 | 8% | | |
| Spain | 2,264 | 5% | 15% | |
| UK | 16,184 | 14% | 63% | 76% |

(*) Data for 2007

Table A3.4 also outlines the proportion of properties with an immersion tank that could provide thermal storage to enable hot water loads to be shifted. In Finland and the UK, a significant proportion of households would need minimal capital investment to participate in such a programme. In Greece, present arrangements for instant heating of hot water would require substantial changes and may therefore be more prohibitive.

### A3.1.3 Air Conditioning

The data on air conditioning in residential properties is shown in Table A3.5. The proportion of properties with air conditioning varies significantly from less than 1% in France and Spain to over 70% in Greece.

**Table A3.5 Residential air conditioning Ownership and Consumption**

| | Electricity consumption for air-conditioning (GWh)* | As a % of total residential consumption | % of properties with air conditioning |
|---|---|---|---|
| Finland | 621 | 4% | <5% |
| France | | | <1% |
| Greece | 935 | 6% | 82% |
| Netherlands | 3 | <1% | 32% |
| Spain | 1,324 | 3% | <1% |
| UK | 621 | <1% | <5% |

## A3.1.4 Cold & Wet Appliances

The energy consumption of cold and wet appliances is in shown in Table A3.6. After heating and cooling, these loads are usually considered to be the most discretionary (i.e. the loads with the greatest opportunities for load shifting).

**Table A3.6 Wet and Cold Appliances[47] Ownership and Consumption**

| | Electricity Consumption for Cold Appliances (GWh) | % of households with 1 or more cold appliance | Electricity Consumption for Wet Appliances (GWh) | % of households with 1 or more wet appliance |
|---|---|---|---|---|
| Finland | 1,461 | >66% | 652 | >88% |
| France | 16,516 | 92.5% | 15,419 | 70.8% |
| Greece | 3,303 | 100% | 1,270 | 91% |
| Netherlands | 4,807 | | 3,684 | |
| Spain | 7,409 | 99.3% | 2,326 | 99.6% |
| UK | 15,209 | >65% | 13,857 | >96% |

The ability to shift loads with wet appliances is technically possible, although there are no ‘smart’ appliances currently mass-marketed. A modern A-rated washing machine, for example, uses approximately 0.64kWh of electricity per load of washing on a 40°C wash[48]. Most consumers are likely to have a time that they require the wash to be completed by but can be flexible as to when the wash occurs (provided that there are no negative impacts such as additional creasing of the clothing). ‘Smart’ wet appliances could be preset by consumers according to their preferences and then run in response to a signal as part of a demand response programme.

Shifting the loads associated with cold appliances tends to be slightly more problematic, although is still possible. The longer the cold appliance avoids its compressor operating then the more likely the temperature within the appliance is to increase, with potential consequences for food safety in the most extreme scenario. One solution would be for such

47 Some of the participating countries break this information into how many households own different categories of appliance within the group (i.e. fridge, freezer and chest freezer). It is not clear how much overlap there is between these categories so the largest proportion has been taken as the absolute minimum of properties with 1 or more of these appliances.

48 Market Transformation Programmes, Briefing Notes BNW05, available at http://www.mtprog.com/cms/product-strategies/sector/domestic

appliances to be set to run slightly colder than is normally required to provide for a greater tolerance regarding temperature. Alternatively, it would potentially be possible for the energy consumption to be modulated, rather than being cut completely, for the period that response is required. This would still allow the compressor to run but drawing less power, although the cycle would probably take longer to complete.

In relation to energy saving opportunities, the majority of the participating countries have already instigated schemes to promote more energy efficient versions of these appliances, through labelling requirements and agreements with manufacturers to phase out less efficient models. The challenge is to encourage consumers to consider replacing these appliances once more efficient alternatives are available, rather than when their existing appliance is no longer fit for purpose. The Market Transformation Programme in the UK has, for example, predicted life spans of 12-16 years for wet appliances and 12-17 years for cold appliances[49].

EUMF could be used to encourage consumers to consider replacing their existing appliances but may be more appropriately used to educate consumers in how they can use their existing appliances more efficiently. The difference in operating costs between a well stocked cold appliance and one only partly loaded may help consumers make informed choices. Similarly, the difference in cost between running a load of laundry at 30$^{o}$C, compared to 60$^{o}$C may be of use.

Whilst there is some divergence in ownership of these appliances across the participating countries, the proportion of households with one or more of each type of appliances is significant in most of the countries as illustrated in Table A3.6.

### A3.1.5 Lighting & Cooking

Lighting is a significant end use for many residential customers, accounting for 6-19% of residential consumption in the participating countries. A breakdown of electricity used for cooking was only available from some of the participating countries but is also a significant end use.

**Table A3.7 Electricity Consumption by Lighting and Cooking appliances**

| | Electricity Consumption by Lighting Appliances (GWh) | Electricity Consumption by Cooking Appliances (GWh) |
|---|---|---|
| Finland | 2,516 | 653 |
| France | 8,800 | 10,045 |
| Greece | 2,199 | 2,804 |
| Netherlands | 4,383 | |
| Spain | 8,294 | |
| UK | 17,489 | |

49 Market Transformation Programmes, Briefing Notes BNW05, BNW06, BNW07 & BNC08, available at http://www.mtprog.com/cms/product-strategies/sector/domestic

Unlike some of the other end uses, consumption by lighting and cooking tends to be made up of multiple, reasonably small appliances, typically associated with comfort and convenience. The majority of residential consumers have limited flexibility as to when they use electricity for these uses, responding to basic stimuli such as darkness and hunger. Programmes to target these end uses need to be sensitive to how fundamental consumers consider these to be.

It is therefore unlikely that these end uses could be targeted for demand response programmes in any of the participating countries. These end uses may, however, be suited for consideration as part of energy saving programmes. The challenge in designing energy saving programmes to tackle lighting is how relatively small the consumption is on an individual appliance basis, compared to the comfort associated with spaces being well lit. The majority of customers are probably more likely to respond if EUMF information is aggregated for all lighting, rather than on an individual appliance basis. At that point, the cost of having lights on in empty rooms, for example, is likely to be more visible and therefore prompt behavioural change.

Similarly, many appliances used in cooking (such as electric kettles, toasters and microwaves) will have relatively small consumption as they are used for a few minutes. energy saving programmes may be effective in promoting efficient usage of these appliances (i.e. only boiling the amount of water required in a kettle) but only if consumers do not feel that their comfort or convenience is being unduly sacrificed.

Electric cookers (hobs and/or ovens) may be an exception to this. Ovens, in particular, tend to be used for a much longer period of time and there is likely to be scope to encourage a more efficient use of these. Consumers could be encouraged via EUMF to fill their oven, rather than cooking the majority of their meal on the hob and just warming a small component of the meal in the oven. The study conducted by Mansouri and Newborough[50] in the late 1990's would suggest that EUMF provision in relation to Cookers can result in energy saving. This was a relatively small study, carried out over a period of 16 weeks, so is perhaps not the most conclusive trial but would indicate that households will respond to information on their cooking habits. The success of any programmes targeting cookers will depend on culture and eating habits and may take time to establish significant changes in how consumers prepare food.

It may be more appropriate to tackle the energy usage of these appliances at the point the appliance is purchased, through energy labelling programmes and/or limits on consumption by different appliance types (either mandatory or voluntary schemes led by the manufacturers). Such programmes are outside the scope of this project but may prove to be a more effective means of delivering energy saving for these end uses. The degree to which these programmes are likely to be successful will depend on the extent to which these appliances have already been targeted. The European Union has dedicated a significant amount of attention to lighting but there may be other opportunities in relation to appliances for cooking.

50 As discussed in Task XI, Subtask 1 Report, 'Smaller Customer Energy Saving by End Use Monitoring and Feedback', available at http://www.ieadsm.org/ViewTask.aspx?ID=17&Task=11&Sort=0

### A3.1.6 Consumer Electronics & ICT

The availability of data on consumption by consumer electronics and ICT appliances within the residential sector was only available in a small number of the participating countries, although presumably makes up a significant proportion of the 'Other' section in those countries that were unable to provide statistics. Table A3.8 illustrates the consumption by consumer electronics and ICT and the number of households in the participating countries that own one or more colour television and those with one or more home computer or laptop. Whilst the penetration level of colour televisions is almost 100% for many countries, the number of appliances owned by household is increasing in many countries. Similarly, it seems reasonable to suggest that the ownership rate of home computing equipment is likely to increase over the next five to ten years.

**Table A3.8 Televisions & Home Computing Ownership and Consumption**

| | Electricity Consumption by Consumer Electronics (GWh) | % of households with 1 or more television | Electricity Consumption by ICT (GWh) | % of households with 1 or more PC/laptop |
|---|---|---|---|---|
| Finland | 834 | 100% | 407 | >76% |
| France | | 97.3% | | 58.9% |
| Greece | | 95% | | 65% |
| Spain | 6,589 | 100% | | |
| UK | 20,533 | 98% | 6,118 | 70% |

It therefore seems reasonable to suggest that consumer electronics and ICT make up a substantial proportion of residential consumption. It also seems likely that the energy consumed by this group of appliances is likely to increase as energy efficiency gains are outweighed by increased ownership rates. EUMF information may therefore be important in educating consumers about the energy consumption of these devices to allow them to make informed choices about how these appliances are used. Aggregation of some of the appliances, perhaps on a room-by-room basis, within this subset may make it easier for consumers to manage the information.

These appliances are predominantly associated with comfort and convenience and there are therefore likely to a number of barriers that will need to be overcome in order to target these with demand response programmes. Critical Peak Pricing, for example, is likely to need to be at a significant premium for many consumers to delay watching their favourite TV programme. One possible subset which may prove to be the exception is laptop computers (and other devices with similar battery incorporated) as consumers could be encouraged to charge their batteries prior to the peak and then operate using the battery at peak times. At present, there are not any models marketed that permit such operation to be scheduled automatically so this would be dependent on consumers taking the necessary actions.

### A3.1.7 Other Demands

Some of the participating countries have specific demands that are quite unique either to the country or to the region it falls within. The most significant example is the use of saunas in Finland. 852GWh of electricity was consumed by Finland's saunas in 2007, which equates to 4.8% of the electricity consumed by the residential sector that year. Whilst there have been some measures to tackle consumption by these installations, it may be an area that Finland could specifically consider targeting for both demand response and EUMF programmes.

### A3.1.8 Future Opportunities

The previous sub-sections have predominantly focused on existing consumption patterns as data is more readily available for these end uses. There are, however, a number of drivers within the participating countries which are likely to result in changes to these patterns.

One example of this is the plans and schemes being developed in a number of the countries to facilitate the adoption of Electric Vehicles, as illustrated in Table A3.9. The charging patterns of these may be suitable for consideration as part of a demand response programme.

**Table A3.9 Targets for Electric Vehicles**

| | Yes | No | Plans to Introduce |
|---|---|---|---|
| Finland | | | √ |
| France | √ | | |
| Greece | | x | |
| India | | x | |
| Netherlands | | | √ |
| Spain | | | ? |
| UK | | | √ |

## A3.2 Small Commercial Demands

This project is also looking at the opportunities for demand response and energy saving through EUMF with Small Commercial Consumers. For the purposes of this project, these consumers have been defined as "*individual sites with a maximum demand of up to 100kW*," as discussed in Section 2. Unlike residential consumers where there is a degree of homogeneity, there are many different types of small commercial organisations each with differing patterns of electricity consumption.

The difficulties experienced in collating data for these consumers were even greater than those for experienced with regard to residential consumers. Whilst data was not available specifically for customers with demands < 100kW, data on the consumption by sub-sector was generally available, as summarised in Table A3.10.

**Table A3.10 Breakdown of Consumption by Commercial Sub-sectors (GWh)[i]**

| | Finland | France | Greece | UK |
|---|---|---|---|---|
| Retail | 3,024 | 27,087[(ii)] | 5,496 | 35,000 |
| Commercial Offices | 3,374 | | 1,482 | 9,940 |
| Hotels & Catering | 1,323 | 9,740 | 3,027 | 12,280 |
| Government buildings | 4,159 | 30,521[(iii)] | 1,318 | 3,090 |
| Education | 1,264 | 5,117 | 452 | 5,600 |
| Sports & Leisure | | 6,730 | 227 | 5,630 |
| Warehouses | | | | 12,530 |
| Health | 1,198 | | | 2,670 |
| Communication & Transport | | 3,169 | | 5,460 |
| Public Lighting | | | 597 | |
| Other (unknown) | 1,420 | | | 4,930 |
| **Total** | **15,762** | **82,364** | **12,599** | **97,120** |

(i) Data for Finland is for 2000, Data for France and the UK is for 2007, Data for Greece is an average over the years 2001 to 2005
(ii) Includes energy consumption by warehouses
(iii) Includes energy consumption by commercial offices

End-use consumption by sub-sector was only available for France, Greece and the UK, so the following discussion on commercial end uses is limited to the data available from these countries.

### A3.2.1 Cooling & Ventilation

Cooling and ventilation makes a contribution across all sectors in all three countries, as shown in . Generally, it makes a larger proportional contribution across the French and Greek sectors than it does in the UK, which is largely to be expected given the differences experienced in climatic conditions across the three. The exception to this is in Commercial Offices in the UK, this end use accounts for 21.5% of the sector's consumption.

**Table A3.11 Consumption for Cooling & Ventilation (GWh)**

<table>
<tr><th></th><th>France</th><th>Greece</th><th>UK</th></tr>
<tr><td>Hotels and Catering</td><td>1,173</td><td>969</td><td>1,310</td></tr>
<tr><td>Retail [a]</td><td>3,541</td><td>824</td><td>3,470</td></tr>
<tr><td>Commercial Offices</td><td rowspan="2">5,328</td><td>296</td><td>2,130</td></tr>
<tr><td>Government buildings</td><td>224</td><td>140</td></tr>
<tr><td>Sports and Leisure</td><td>928</td><td>88</td><td>580</td></tr>
<tr><td>Warehouses</td><td></td><td></td><td>690</td></tr>
<tr><td>Communication & Transport</td><td></td><td></td><td>370</td></tr>
<tr><td>Education</td><td>232</td><td>54</td><td>90</td></tr>
<tr><td>Health</td><td></td><td></td><td>10</td></tr>
</table>

[a] includes the Wholesale Commercial Sector

Unlike residential consumers, the consumer responsible for the cooling and ventilation of the site may be removed from those using the system. It is therefore essential that energy saving programmes address the needs and concerns of both parties. EUMF programmes can be used to identify how cooling and ventilation systems are using energy and may also identify inefficiencies in their use which can then be tackled. It may be preferable, for example, to limit the degree to which individuals working for the organisation or using its services, in the case of hotels and similar, can access the settings. This is particularly important for centralised cooling and ventilation systems.

As mentioned in relation to residential consumers, cooling systems can be a successful target for demand response programmes. Commercial systems tend to be larger and with a degree of central control which reduces the infrastructure requirements for demand response schemes.

### A3.2.2 Space Heating & Hot Water

Table A3.12 illustrates the electricity consumed for space and water heating across the sub-sectors. The proportion of electricity consumption used for heating varies from 2% in Greek Government Buildings to 21.7% in UK Sports and Leisure Centres. The proportion associated with Hot Water is between 0.4% in the UK Health sector and 16.3% in France's Sports and Leisure sector. This proportion depends on the typical fuel mix for heating in the participating countries. In countries, such as France[51], where electricity plays a more significant role in the fuel mix for heating, the opportunities for targeting this end use are more significant than in countries such as the UK[52] where natural gas is the more dominant fuel.

[51] Greece - average consumption for heating is 18.1% across the whole commercial sector and 8.6% for hot water.
[52] UK - average consumption for heating is 14.6% across the whole commercial sector and 2.9% for hot water.

**Table A3.12 Electricity Consumption by Space and Water Heating (GWh)**

| | France | | Greece | | UK | |
|---|---|---|---|---|---|---|
| | Space Heating | Hot Water | Space Heating | Hot Water | Space Heating | Hot Water |
| Hotels and Catering | 1,513 | 760 | 459 | 211 | 880 | 570 |
| Retail [a] | 4,252 | 1,556 | 1,099 | 550 | 5,020 | 1,020 |
| Commercial Offices | 6,194 | 551 | 148 | 30 | 1,960 | 210 |
| Government buildings | | | 26 | 13 | 640 | 170 |
| Sports and Leisure | 1,312 | 1,094 | | 7 | 1,220 | 50 |
| Warehouses | | | | | 1,780 | 110 |
| Communication & Transport | | | | | 750 | 120 |
| Education | 986 | 574 | 36 | 23 | 470 | 390 |
| Health | | | | | 310 | 10 |

[a] includes the Wholesale Commercial Sector

EUMF has the potential to help organisations understand how they are heating their properties and any perverse behaviours that are occurring. It is probably beneficial to consider monitoring heating and cooling at the same time to ensure that no inefficiencies occurring as a result of both systems being run at the same time. Standard energy saving measures, such as insulation and turning thermostats down, can also be considered, as well as whether is appropriate to consider switching fuel. Solar thermal may, for example, be an appropriate alternative to using electric instant water heaters.

As discussed in relation to residential consumers, heating presents a good opportunity for demand response programmes, especially in storage in integrated within the systems. However, in commercial buildings, hot water is more likely to be supplied on demand, rather than being heated and stored in an immersion tank or similar. There are therefore likely to be additional capital incurred in establishing these programmes. However, these costs should not create too significant a burden.

One of the significant challenges faced in developing demand response and energy saving programmes in the commercial sector is in relationship to ownership of the building. It is relatively common for commercial buildings to be owned by private landlords and rented by the occupants. As such, it can often be unclear who should be responsible for paying for capital expenditure on the fabric of the building. Developing approaches that can tackle this challenge are likely to lead to a greater success rate for these programmes.

### A3.2.3 Lighting

Lighting is a significant end use, accounting for between 15% in Greece's Retail sector and 63.2% in the Health sector in the UK and is broken down in Table A3.13. As with the residential sector, this is an end use that is intrinsically linked to comfort, convenience and health and safety, particularly in the commercial sector. Consequently, it is not appropriate to develop programmes that leave individuals in the dark.

**Table A3.13 Consumption for Lighting (GWh)**

| | France | Greece | UK |
|---|---|---|---|
| Hotels and Catering | | 515 | 3,940 |
| Retail [a] | 6,230 | 824 | 15,180 |
| Commercial Offices | 9,156 | 415 | 3,210 |
| Government buildings | | 369 | 720 |
| Sports and Leisure | 2,625 | 75 | 1,890 |
| Warehouses | | | 5,400 |
| Communication & Transport | | | 2,620 |
| Education | 1,996 | 75 | 2,870 |
| Health | | | 1,680 |

[a] includes the Wholesale Commercial Sector

There are still opportunities for EUMF in identifying where and when electricity is being consumed and identifying easy energy saving opportunities, such as ensuring lights are switched off when spaces are unoccupied. The use of automatic sensor switches and low energy light bulbs, where appropriate, are other relatively easy energy saving measures that can be implemented.

As with residential consumers, this end use is not particularly suited to demand response programmes, although there may be some secondary benefits from tariff programmes.

### A3.2.4 Computing

Only the UK was able to provide information on the amount of energy consumed by computing functions in this sector. The proportion of consumption within a sub-sector ranged from 1.8% in the Communications and Transport sector to 17.5% in Government Buildings. As with lighting, EUMF has the potential to enable organisations to understand when they are using electricity for computing functions and to identify any energy saving opportunities, such as standby consumption from computing equipment left on when sites are unoccupied. It can also be used to identify demands that could potentially be shifted to off-peak periods, such as servers performing back-up actions.

As with residential ICT usage, there are limited opportunities for demand response programmes to target computing functions. However, laptops using their batteries during peak periods could present a significant opportunity in the commercial sector. The use of docking systems, connected to a central control system, could be used to aggregate a potentially significant level of load and to switch automatically between power sources, with minimal inconvenience to the user.

### A3.2.5 Other End Uses

Electricity consumed in catering activities was available for the UK and France and for the Hotel and Catering sector in Greece. Unsurprisingly, the largest proportion was consumed by the Hotels and Catering sector in these countries. In the remaining sectors, the proportion of consumption varies from 1.5% to 15.3%. As with the residential sector, this end use is associated with comfort and convenience and is therefore not particularly well suited to demand response. The exception to this is any refrigeration appliances which could be considered, as discussed in relation to residential cold appliances.

A significant proportion of the energy consumed across the categories of organisation could not be identified. This varied from 6.1% in the Commercial Offices sector in the UK to 52% in Greece's Government Buildings Sector. A greater understanding of how this energy is being consumed would allow all parties, from Government to utilities to consumers, to be able to reduce these end uses and to then consider their suitability for demand response programmes.

EUMF would provide the visibility as to how this energy is being consumed and then further analysis would enable appropriate measures to tackle this consumption appropriately.

---

[i] Radio Teleswitching Sub-Group Meeting Notes, 13 March 2003