IEA Implementing Agreement on Demand Side Management Technologies and Programmes

Task VIII
Demand Side Bidding in a Competitive Electricity Market

Sub-task 4 Report

Technologies for Demand Side Bidding

October 2001

IEA Demand-Side Management Programme

The International Energy Agency (IEA) was established in 1974 as an autonomous agency within the framework of the Economic Cooperation and Development (OECD) to carry out a comprehensive program of energy cooperation among its 25 Member countries and the Commission of the European Communities.

An important part of the Agency's program involves collaboration in the research, development and demonstration of new energy technologies to reduce excessive reliance on imported oil, increase long-term energy security and reduce greenhouse gas emissions. The IEA's R&D activities are headed by the Committee on Energy Research and Technology (CERT) and supported by a small Secretariat staff, headquartered in Paris. In addition, three Working Parties are charged with monitoring the various collaborative energy agreements, identifying new areas for cooperation and advising the CERT on policy matters.

Collaborative programs in the various energy technology areas are conducted under Implementing Agreements, which are signed by contracting parties (government agencies or entities designated by them). There are currently 40 Implementing Agreements covering fossil fuel technologies, renewable energy technologies, efficient energy end-use technologies, nuclear fusion science and technology and energy technology information centres.

The Demand-Side Management Programme is a new collaboration. Since 1993, the 17 Member countries and the European Commission have been working to clarify and promote opportunities for DSM.

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

A total of 10 Tasks have been initiated, 4 of which have been completed. Each Task is managed by an Operating Agent from one of the participating countries. Overall control of the program rests with an Executive Committee comprised of one representative from each contracting party to the Implementing Agreement. In addition, a number of special ad hoc activities--conferences and workshops--have been organised. The Tasks of the IEA Demand-Side Management Programme, both current and completed, are as follows:

Tasks:

Task I*	International Database on Demand-Side Management
Task II	Communications Technologies for Demand-Side Management
Task III*	Co-operative Procurement of Innovative Technologies for Demand-Side Management
Task IV*	Development of Improved Methods for Integrating Demand-Side Management
Task V*	Investigation of Techniques for Implementation of Demand-Side Management Technology in the Marketplace
Task VI*	DSM and Energy Efficiency in Changing Electricity Business Environments
Task VII	International Collaboration on Market Transformation
Task VIII	Demand Side Bidding in a Competitive Electricity Market
Task IX	The Role of Municipalities in a Liberalised System
Task X	Performance Contracting

* completed Task

For additional information contact the DSM Executive Secretary, Anne Bengtson, Box 621, 182 16 Danderyd, Sweden, Telephone: +46/8/510 50830, Fax: +46/8/510 50831, E-mail:anne.bengtson@ telia.com. Also, visit our web site at <http://dsm.iea.org>.

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1 Summary

The objective of this report is to provide a practical guide to both electricity customers and suppliers about the characteristics and benefits of demand side bidding (DSB). In particular, information is presented on:

- the different categories of DSB product
- the role of those products within the electricity supply chain and in particular within liberalised electricity markets
- the time-scales over which each category of product operates
- the type of control and monitoring facilities that are required by a customer who wished to offer different types of DSB products

Practical examples are presented to illustrate the workings of DSB in a number of different circumstances.

2 Introduction

Demand side bidding (DSB) is a mechanism that enables the demand side of the electricity market to participate in energy trading. More specifically, DSB allows electricity consumers to offer a specific reduction in demand, at a given point in time, in return for a specified income.

This has important implications for the efficient operation of any electricity supply network. For example, maintaining the balance between electricity supply and demand, and maintaining the quality and security of supply are both the responsibility of the System Operator. Generally this is achieved by calling upon generators to bring additional plant on-line at times of difficulties. DSB provides an alternative solution by calling on consumers to make load reductions. Therefore, DSB is a way of rewarding consumers for having the flexibility to make a short-term, discrete changes in demand, that will help deliver a secure and reliable electricity supply system.

DSB has several important implications in terms of the overall efficiency of electricity supply, both from an economic and an environmental point of view. In the short term, avoiding the need to call upon expensive, reserve generators reduces overall market costs. In the long term, reducing both the size of networks and the number of generators required may result in lower costs. Almost always, reserve generators will be less efficient, and produce higher CO_2 emissions, than base load plant. There is also an added energy penalty in starting them up and holding them in a state of readiness. DSB can thus be regarded as a means of optimising overall system energy efficiency, by reducing the need for such plant.

DSB is perhaps most relevant to large consumers, with a high level of annual electricity consumption, who are willing and able to re-schedule loads in order to generate a new income stream. Income could be in the form of a participation (or availability) payment or as a price for the units of electricity that were not consumed.

Small consumers may also be able to participate in DSB, albeit in a more indirect way than large consumers. For example, they may allow their electricity supplier to automatically schedule control of their heating supplies and hot water production, thus enabling the supplier to directly participate in DSB. A small customer will not usually generate any income from this service, but will receive a reduced tariff that reflects the lower cost of supplying such a customer. Nevertheless, this does represent one form of DSB that is already in operation in the vast majority of countries.

DSB can take many forms, each known as a DSB ‘product’. These are defined by:

- who buys the consumers’ offer to reduce consumption
- what the implications are for the electricity network
- the time-scales over which the whole process occurs

Many of the DSB products can be grouped together into categories of similar products.

The income generated through participation in DSB will vary according to the nature of the DSB ‘product’. However, in general the income will be somewhere between the cost to the consumer of providing the product (lost revenue, lost production, alternative fuel costs), and the cost of whatever alternatives there are to DSB (e.g. the cost of bringing an additional generator on-line).

This report provides a practical guide to the characteristics and benefits of demand side bidding (DSB). It is written from the point of view of consumers, or suppliers of groups of consumers, to help them identify opportunities to participate in DSB in an active manner.

Section 3 is a brief discussion of the various participants in the DSB process. Section 4 then goes on to list the various DSB products that are available, and discusses their characteristics, including who sells and buys them. It is important here to realise that the seller of the DSB product is the person who makes the agreed load reduction – i.e. the seller of a DSB product is usually a consumer (or buyer) of electricity.

The report then proceeds in Section 5 by highlighting the mechanisms required to enable demand side bidding. In particular, the types of load control and monitoring required for a consumer to offer a DSB product to the market are examined. This information is given separately for each DSB product.

Section 6 presents several examples of DSB in practice.

A closely related topic to Demand Side Bidding (DSB) is Demand Side Management (DSM). This latter topic typically involves a consumer making a sustained or permanent change to the way they consume electricity, in order to reduce costs. The change may be in their consumption profile (re-scheduling periods of high cost consumption to periods of lower cost), or, more likely, it may involve an overall reduction in electricity consumption The similarities between DSB and DSM arise from the technologies shared by the two. These differences are explained in Appendix A at the end of the report.

The definition of DSB used here implies ownership of the right to consume a given amount of electricity at a given time. This right can then be traded by reducing demand in return for a specified income – in effect selling non-consumption of electricity. A wider definition of DSB is possible, which encompasses price setting in wholesale markets. This report concentrates on the narrow definition of DSB involving a change in demand, as this is the area where consumers are most likely to become directly involved. A brief introduction to DSB for price setting in wholesale markets is included as Appendix B.

Any electrical load that can be re-scheduled, deferred, temporarily avoided or substituted with an alternative fuel, can, in principle, be used for DSB. Appendix C gives a list of consumer processes that lend themselves to DSB. These are presented as an aid to prospective sellers of DSB products, to help them identify suitable opportunities for themselves.

3 Participants in Demand Side Bidding

Many different parties are involved in demand side bidding. Each of the main participants is briefly explained in the following Sections.

3.1 Demand Side Bidders

Demand side bidding relates to participation in electricity trading by consumers of electricity. Therefore, an electricity consumer represents the demand side bidder. A consumer can participate in electricity trading if they are in receipt of a contract that gives them the right to consume electricity and has electrical loads that can be controlled, or scheduled. The right to consume electricity will be at an agreed price, which relates to the tariff structure that is included in the contract. The maximum amount of electricity a consumer can sell at any one time is equal to the customer's total controllable demand at the relevant time. If a consumer sells a block of electricity then they are required to switch off the necessary equipment to fulfil their commitment. This is the concept of 'non-consumption' that characterises a demand side bid. That is, a demand side bidder sells non-consumption of electricity they have the option to consume.

Although it has been suggested that an electricity consumer fulfils the role of demand side bidder, it is possible that an electricity supplier could also be a bidder. This is possible when a supplier has customers on interruptible supply tariffs. In effect, a supplier could decide to undertake DSB by controlling its customers' demand. The benefit of such an action would clearly accrue to the supplier, although it is likely that some of the benefits would be passed on to the relevant customers in order to make interruptible tariffs an attractive proposition.

3.2 Demand Side Aggregators

In order for a consumer to engage in DSB, it is necessary to use the services provided by a demand side aggregator. A demand side aggregator is defined as an organisation that co-ordinates DSB by more than one participant. Such organisations are crucial in enabling customers to participate in DSB. In practice, it is not feasible for one electricity consumer to offer DSB products in the electricity wholesale market because the administrative cost and complexity would be too high. In particular, it would require an investment in electricity trading systems for submitting bids and receiving notification of acceptance and the employment of skilled personnel. However, an aggregator can play an extremely useful role in facilitating DSB amongst many consumers by combining numerous minor bids together to form a major bid that can be traded in the wholesale electricity market. In addition, an aggregator is also likely to be responsible for ensuring each demand side bidder has the appropriate control and monitoring equipment is in place to fulfil their bid. In practice, any organisation can act as a demand side aggregator. However, it is a role that may be most attractive to an electricity supply company.

Traders may have a similar role to play here as well. Traders are different from the other market participants in that, although they are involved in the purchasing and selling of electricity, they themselves are not involved in the generation, transmission or distribution of the electricity and they never take final delivery of any electricity they purchase. However, they are prepared to take risks, and expect to be rewarded financially for doing so.

3.3 Demand Side Buyers

A demand side buyer is essentially a purchaser of demand side bids. Such purchasers are those organisations that are involved in the wholesale electricity market and have a need to balance electricity supply and demand or maintain the quality and security of supply. In particular, electricity suppliers, generators, the System Operator and network companies all represent potential demand side buyers.

3.4 Summary

This Section has provided a brief introduction to the participants in demand side bidding. In particular, the information has highlighted that electricity consumers are the sellers of demand side bids, albeit through the services of a demand side aggregator. In addition, it has been acknowledged that there are many potential buyers of demand side bids. The rationale for purchasing such bids clearly varies and this is what defines different types of DSB products. The actual types of DSB products that may be provided by a consumer are examined in more detail in the following Section.

4 Categories of DSB product

There are five main categories of DSB product:

- DSB to maintain quality of supply
- DSB to solve network constraints
- DSB for electricity balancing
- DSB for access to market prices
- DSB for price setting

In the context of this report, DSB is used to mean consumers reselling, or selling the non-consumption of, electricity that they have already secured the right to consume. DSB for price setting falls outside of this definition (see Appendix B), as it usually involves no change in demand. However, it can be important in facilitating the other types of DSB that do involve a change in demand, and brief discussion of products within this category are therefore included. There are similarities between DSB for access to market prices and DSB for price setting, with a degree of overlap between the two, as will be explained later.

The main difference between the above categories is the length of notice a demand side bidder is given before they must manipulate their load in the agreed manner. This scheduling time frame also affects the type of control and monitoring mechanisms that are required by the bidder (this specific issue is examined in the following Section).

The scheduling time-frame associated with each particular DSB category is depicted in Figure 1. Here each DSB category has been allocated to one of three main time-frames, with the different periods defined as ‘months ahead of trading’, ‘day ahead of trading’ and ‘within day trading’. The within day trading time-frame can be either several hours ahead of delivery or immediately at the time of delivery. In some markets, the ‘spot’ market closure coincides with the end of the day ahead of trading. However, there is a tendency, as markets develop, for this to get closer to the point of delivery.

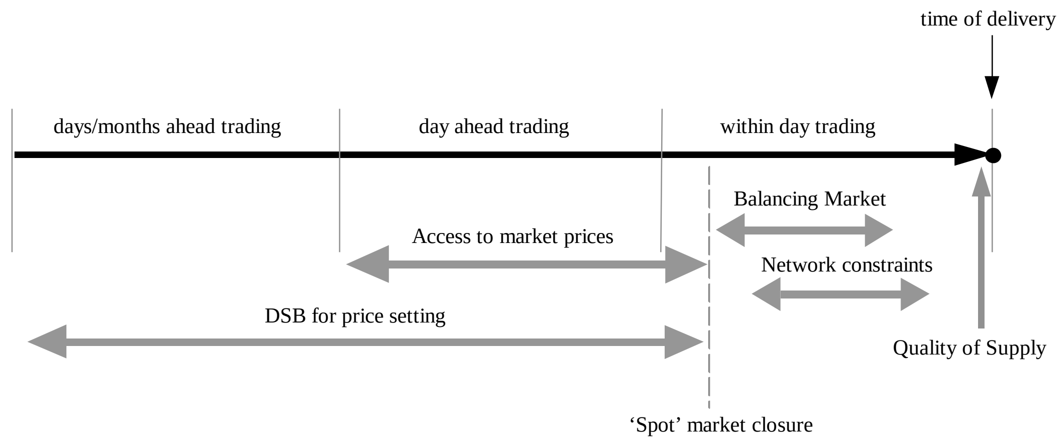


Figure 1. Time-frame for bids associated with different DSB categories

Countries with liberalised electricity markets will have products available that fall into most, if not all, of these categories. Seven broad types of DSB product have been identified. These can be grouped into the five categories as follows:

1. DSB to maintain quality of supply	i)	Ancillary services (of various types)
2. DSB to solve network constraints	ii)	Distribution constraints
	iii)	Transmission constraints
3. DSB for electricity balancing	iv)	Balancing market
4. DSB for access to market prices	v)	Spot markets
5. DSB for price setting	v)	Spot markets
	vi)	Bilateral contracts
	vii)	Supply contracts

Spot markets can fall into two categories – DSB for access to market prices and DSB for price setting. This will be explained in the relevant Sections later.

Each of the different DSB categories will now be discussed. For each DSB category, information is presented on:

- The function of the product(s) within the electricity supply chain;
- The scheduling time frame;
- The potential sellers of the product(s);
- The potential buyers of the product(s);
- The alternatives available to the buyer of a product if the demand side do not, or cannot, participate.

4.1 DSB to maintain quality of supply

By far the most common types of DSB product currently in use, are those that fall into the category of maintaining the quality of supply, and, therefore, it is this area that will be dealt with first.

It is the responsibility of the System Operator to maintain a secure and stable transmission system at all times. This is achieved through the purchase of a number of different types of Ancillary Service. Historically it has been generators who have provided these services, but increasingly System Operators are purchasing services from large consumers as a more efficient and cost effective alternative.

There are several types of DSB Ancillary Service contract. The various contracts differ only in the alternatives that are available to the use of DSB. Therefore, the general characteristics of DSB Ancillary Service contracts are described in Table 1, with additional information provided separately on the specific details of each type of Ancillary Service and the generator based alternatives to DSB.

Table 1. Properties of DSB Ancillary Service Products

Product Function	The aim of DSB Ancillary Service contracts is to assist in maintaining the quality and security of electricity supply. The quality of electricity supply refers to the voltage and frequency at which electricity is delivered. This quality can fluctuate due to rapid changes in the amount of electricity being generated or consumed. Therefore, a DSB Ancillary Service contract will require a rapid response to maintain quality within the agreed limits.
Scheduling Time	Negotiation of DSB Ancillary Service Contracts will usually take place in the days and months ahead of actual product delivery. However, product delivery will generally involve no notification, as an instantaneous response is required.
Seller	A seller of a DSB Ancillary Service contract is any customer or supplier / aggregator (acting on behalf of a group of customers) who can sell electricity. In effect, a demand side bidder sells 'non-consumption' of electricity they have the option to consume.
Buyer	The buyer of a DSB Ancillary Service contract is typically the System Operator.
Alternatives	DSB Ancillary Service contracts compete with the services offered by generators. However, the nature of these alternatives varies by the specific purpose of the particular ancillary service.

There are four types of DSB Ancillary Service contract in use for maintaining the quality of supply. These are:
1. Frequency control
2. Voltage Control / Reactive Power
3. Reserve
4. Black Start

Frequency control
The frequency of any transmission system must be maintained within a specified narrow band (e.g. 49.5 to 50.5 Hz). This is achieved by automatically balancing demand and generation. All generators are required to provide a minimum level of frequency control. Generators can also provide additional frequency response by increasing their output at short notice to compensate for unexpected changes in demand or generation. Such a service can be offered by:
- partially loaded steam plant
- partially loaded gas turbines
- pumped storage

Voltage Control / Reactive Power
These services can be provided by:

- Synchronous Generators – synchronous generators can be made to generate or absorb reactive power depending upon the excitation applied.
- Synchronous Compensators – can provide reactive power without producing any real power (Typically, these are smaller generators, which once run up to speed and synchronised to the system, can be declutched from their turbine to provide reactive power and no real power).
- Capacitors and Inductors – connected to the system to adjust voltage levels.
- Transformers – tap changers
- Transformers – boost voltage

Reserve
Contingency needs to be available in case of unexpected changes to demand or available generation. This is provided by:

- Standby generation – a generation station held in a state of readiness to generate at short notice. Under these circumstances, fuel will be used to prepare the boiler and maintain it in a state of readiness.
- Partially loaded steam plant
- Partially loaded gas turbines
- Pumped storage
- Load reduction

Black Start
This is an important quick response service for which there is no DSB alternative. However, the nature of this service is explained for completeness. Black start is the recovery procedure from a total or partial failure of the electricity transmission system. Generators, with the exception of some small hydro-electric generating stations, take electricity from the transmission system in order to start up. Therefore, to be able to 'black start' a generator must have auxiliary supplies. Gas turbines or diesel generators using a battery for start-up generally provide this.

4.2 DSB for Network Constraints

There are two DSB products that fall into this category:

1. Distribution constraints
2. Transmission constraints

They differ mainly in respect to the Buyer of the product. The buyer for distribution constraints is the local area Distribution Company within whose region the consumer is located. Transmission Constraints are another type of Ancillary Service purchased by the Transmission System Operator.

Both are areas where DSB is used at present, although how widespread the need for such products is, depends upon the physical layout of the network.

Table 2. Properties of DSB Network Constraints Products

Product Function	A DSB Network Constraint contract is aimed at enabling an electricity transmission or distribution company to overcome a physical constraint on the network. Network constraints are 'bottlenecks' that occur on the network, which mean that the required quantity of electricity cannot be delivered over the constrained part of network because it is already operating at full capacity.
Scheduling Time	Negotiation of DSB Network Constraint contracts will usually take place in the days and months ahead of actual product delivery. Usually a few hours notice is given of the required product delivery.
Seller	A seller of a DSB Network Constraint contract is any customer or supplier / aggregator (acting on behalf of a group of customers) within that network, who can sell electricity. In effect, a demand side bidder sells 'non-consumption' of electricity they have the option to consume.
Buyer	The buyer of this particular DSB product is the operator of that part of the network that is constrained.
Alternatives	Without the participation of the demand side, a Network constraint can only be alleviated with generation that can feed the constrained area without passing through the 'bottleneck' (e.g. an embedded generator in the case of a distribution network). In the longer term, the network may need to be reinforced.

4.3 DSB for Electricity Balancing

Unlike most other tradable commodities, the supply and demand of electricity needs to be kept in balance at all times. Imbalances can occur through the unexpected loss of a generator or through error in the forecasting of demand. The use of intermittent renewable sources of electricity (wind, solar) may also add to imbalance problems.

The trading of non-consumption or rescheduling consumption to assist with the balancing process is an area that is likely to increase in importance as the operation of balancing markets become better understood.

Table 3. Properties of DSB Balancing Market Products

Product Function	A DSB Balancing Market contract is aimed at enabling the System Operator to equate total electricity demand and supply in each trading period through buying or selling electricity in a Balancing Market. This service is required because of the inevitable errors that arise in predicting demand.
Scheduling Time	Scheduling of DSB Balancing Market contracts (submission and acceptance of bids) will usually take place in the day of actual bid delivery, usually only a few hours ahead of the relevant trading period.
Seller	A seller of a DSB Balancing Market contract is any customer or supplier / aggregator (acting on behalf of a group of customers) who can sell electricity. In effect, a demand side bidder sells 'non-consumption' of electricity they have the option to consume.
Buyer	The buyer of a DSB Balancing Market contract is usually the System Operator. However, in those wholesale electricity markets that rely solely on self-dispatch of generators, any market participant could purchase this particular DSB product.
Alternatives	DSB Balancing Market contracts compete with the services offered by generators.

4.4 DSB for access to market prices

As we have seen with the first three categories of DSB product, once a consumer, or a supplier acting on behalf of a group of consumers, has obtained the right to consume a given amount of electricity, he can trade this right or option to consume, by in effect selling non-consumption. Logically, this trade can also take place on the spot market (or pool) which generally operates a day ahead of actual consumption.

The consumer (or supplier) will bid a reduction in his consumption at a given point for a given length of time. Alternatively he may aim to reschedule his demand to take advantage of periods of predicted low cost, and avoid periods of predicted high cost, and will make corresponding bids of reduced and increased consumption at various times during the day.

A simple example is the case of the UK electricity pool prior to April 2001, where a limited number of large customers were allowed to bid a short lived reduction in demand, directly into the pool – the bids being treated as offers for negative generation. The properties of this type of bid are described in Table 4.

Table 4. Properties of DSB Spot Market Products (access to market prices)

Product Function	The securing of electricity supplies at the lowest cost to the consumer through active market participation.
Scheduling Time	Scheduling of bids in Spot Markets (submission and acceptance of bids) usually takes place in the day ahead of actual delivery.
Seller	A seller of a DSB Spot Market product is any customer or supplier (acting on behalf of a group of customers) who can sell electricity into the wholesale electricity Spot Market. In effect, a demand side bidder sells 'non-consumption' of electricity they have the option to consume. Energy Traders may also have an important role here.
Buyer	The buyer of this particular DSB product is any customer or supplier (acting on behalf of a group of customers) who can purchase electricity from the wholesale electricity Spot Market. Energy Traders may also have an important role here.
Alternatives	Non-consumption Spot Market DSB products compete with generators.

Whilst DSB for access to market prices is little used at present, it is perhaps the area with the greatest potential, both in terms of increasing the number of consumers involved in DSB and in reducing overall prices. Suppliers will play a crucial role here, in that small consumers will not have the means to directly enter the electricity market. It may well also be an area where energy Traders or Demand Side Aggregators play an important role.

4.5 DSB for price setting

As was discussed at the start of Section 3, DSB is used, in the context of this report, to mean consumers reselling, or selling the non-consumption of, electricity that they have already secured the right to consume. DSB for price setting largely falls outside the scope of this definition. However, the products within this category facilitate other types of DSB that do involve a change in demand, and thus a brief discussion of them will be useful.

There are basically three DSB products that fall within this category

1. Spot markets
2. Bilateral Contracts
3. Supply Contracts

Spot markets generally operate a day ahead of actual consumption, whilst bilateral and supply contracts may be negotiated months in advance. (More detailed information on these products is given in Appendix B)

Spot markets

Spot markets can be used to secure supplies to cover a customers total demand requirement (or that of a Supplier acting on behalf of all of his customers). Whilst the prime function of the spot market is price setting, it can also be used to re-trade electricity as discussed in Section 4.4 above.

Bilateral Contracts
A bilateral contract is an agreement on the price and quantity of electricity made between two parties. Such agreements are often made between suppliers and generators, but large consumers will also enter into such agreements directly with generators.

A supplier with a bilateral contract may, if he has suitable customers who are able to reschedule loads or interrupt processes, be able to sell other DSB products such as Ancillary Services and Balancing Market products, or bid rescheduled demands directly into the Spot Market.

Conversely, a generator with a bilateral contract may be able to use it, with the co-operation of the supplier and his customers, to meet his contractual agreements elsewhere, when he would otherwise have insufficient capacity to do so.

Supply Contracts
The objective of a DSB Supply Contract is to enable an electricity supplier to have some control over the quantity and time of a customer's electricity consumption. The actual level of control is usually defined in an 'interruptible tariff', which states the electrical loads that can be interrupted, the number of permissible interruptions in a year and the maximum length of any one interruption. A more sophisticated version would be to actively reschedule customers loads (with their agreement) to avoid periods of high cost production.

This type of DSB product gives a supplier some flexibility in equating the company's total electricity supply and demand and reduces the possibility of being out of balance.

It also gives the supplier the control to be able to offer DSB products (such as Ancillary Services), or bid directly into balancing and spot markets.

4.6 Summary

The following Table highlights the differences between each of the four DSB categories used for Bids involving changes in demand.

Table Key:

SO	System Operator
MO	Market Operator
Su	Supplier (or any third party agent)
Co	Consumers
Ge	Generators
DC	Distribution Company
Ag	Aggregator
Tr	Trader

Table 5. Scheduling ahead of the day of consumption

Category	Function	Scheduling Time	Seller(s)	Buyer(s)
Maintaining quality of supply	Assist SO in maintaining quality and security of supply	Close to point of delivery	Co, Su, Ag	SO
Balancing Market	As a means of equating supply and demand	Within day	Co, Su, Ag	SO, MO
Network Constraints	Assist a Network operator to overcome capacity constraints	Within day	Co, Su, Ag	DC, SO
Access to market prices	Improve market efficiency	Day ahead	Su, Co, Ag, Tr	MO, Su, Co, Tr, Ge

5 Generic requirements for Demand Side Bidding

The following schematic diagrams show, in very general terms, the major steps that need to be taken in order to participate in those categories of DSB that require changes in electricity demand.

Figure 2 refers to the category "DSB for access to market prices" – that is products involving scheduling ahead of the day of consumption. Figure 3 relates to the DSB categories that involve changes in demand during the day of consumption. These can either be near to delivery ("DSB to maintain quality of supply") or rescheduling within a few hours of delivery ("DSB to solve network constraints" and "DSB for electricity balancing").

The schematics are divided into events that take place ahead of the day of consumption, events that take place during the day and events that take place after delivery. In order to participate in DSB, a consumer must have the appropriate form of control, monitoring, and communication equipment for the particular DSB product they wish to trade, so that these events all take place.

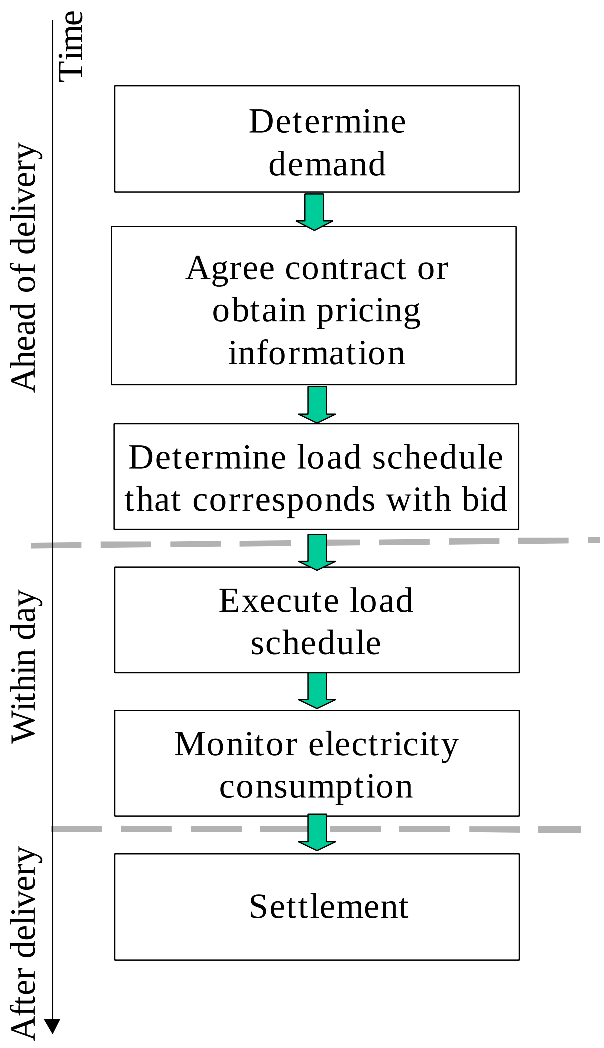


Figure 2. DSB for access to market prices

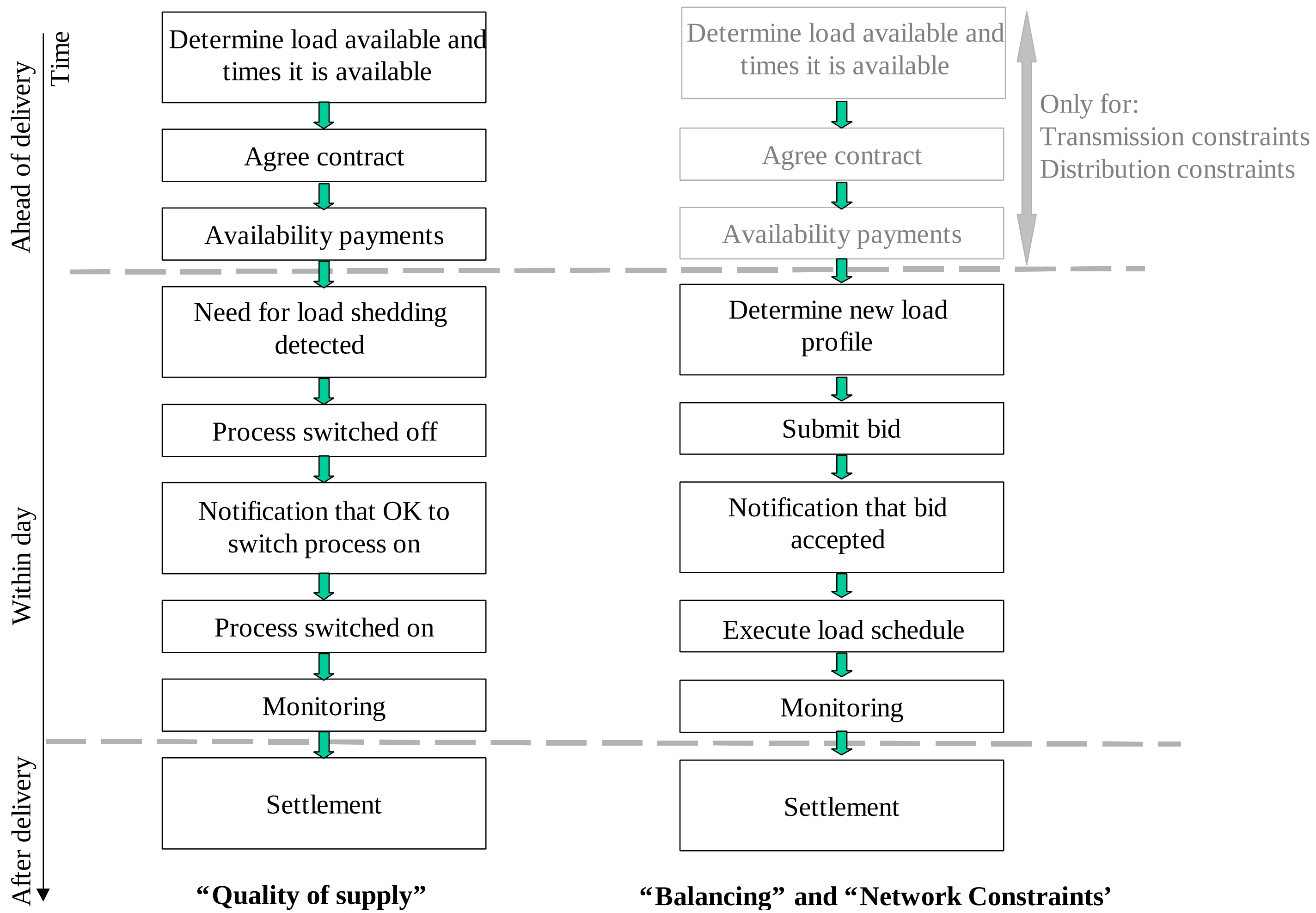


Figure 3. DSB requiring within the day notification of demand changes

The generic types of control, monitoring and communications technology necessary to make the DSB process work will now be discussed, leading into a category by category analysis.

5.1 Control equipment

The function of the control equipment is to effect the necessary change in electricity consumption. Thus, the control equipment should be able to switch on and off the relevant electrical load, whether this is to execute an agreed load schedule, or to make rapid changes in response to some predetermined signal. Thus one major difference in control between the various DSB products relates to the speed or notice required for switching and whether the control is manual or automatic.

In the category of "DSB to maintain quality of supply" load reduction must be rapid, and consequently control is usually automatic. For example, for frequency control, load is switched off when an automatic frequency relay detects a change in frequency of a fixed amount. Control to switch the process back on may also be automatic, or may be manual, on delivery of notification that the process can be restored.

In many of the other DSB products, the process control must also determine the required schedule of loads that will deliver the agreed load reduction and still give satisfactory performance of the process. It must then execute that schedule. Again control is often automatic.

5.2 Monitoring equipment

In terms of monitoring, or metering, the equipment must be able to verify that a consumer has fulfilled their contractual obligations and switched off the necessary load for the required duration i.e. it is necessary to monitor 'non-consumption'. However, this is not necessarily straightforward.

Most consumers buy electricity through a supply contract. Here the consumer is able to consume as much electricity as desired at the price specified in the contract. That is, a consumer is not obliged to consume the same amount of electricity as their historic load profile suggests. Consequently, it is difficult to prove that a consumer has delivered a particular DSB product unless their actual load profile is examined after the bid has been executed. That is, a consumer must be able to demonstrate 'non-consumption' by showing that, had it not engaged in DSB, it would have been consuming a particular quantity of electricity higher than the amount shown by the profile. This suggests that any consumer who wishes to undertake DSB must have an approved 'normal' load profile that can be compared with an actual load profile. In monitoring terms, this implies that a consumer must have time of day metering (usually with meter readings recorded every half-hour).

The actual monitoring equipment that is required is also dependent on what information is required for (financial) settlement purposes. That is, monitoring requirements will be dependent on whether the consumer is paid per interruption or according to the quantity of load that is shed over a specific period of time. These factors will clearly differ between DSB products.

In the case of DSB products requiring rapid load shedding by a single consumer, the monitoring also has the function of giving the buyer confidence that the offered load is available when required. It will, therefore, often be an essential requirement of the buyer (generally the System Operator) that monitoring is in place which can allow him to determine how much load is available at any given time. (Such monitoring is not required when a large number of aggregated consumers are involved, as the buyer can use statistical techniques to determine how much load should be available.)

5.3 Communication equipment

With some DSB products, such as the balancing market, communication technologies can be a major factor at each stage in the process. In others, such as ancillary frequency control, communication technologies may not be required at all.

In general, events that happen well ahead of the day of consumption can be dealt with through normal contract negotiation procedures and there is no need for sophisticated communications technology.

As the day of consumption approaches, communication of information between participants becomes more technology dependant. In many products, a point is reached where the consumer’s load schedule for the day of consumption needs to be determined, based on price information from the market or the supplier. In the case of a group of small customers this will be transmitted or broadcast automatically, whilst if the communication is to / from a large or medium, single consumer, then it may be cost effective to install a dedicated communications system.

Methods available for communicating within or just ahead of the day of consumption include:

- Telephone (PSTN or cellular)
- Internet dialling / E-mail
- Radio broadcast
- Power Line Carrier
- Fibre / coax cable
- Radio / microwave

During the day of consumption, communication technology will often be required within the consumers’ premises to effect the agreed load schedule. Dedicated process and energy management equipment will be used in most cases. In smaller premises mains signalling may be used.

After the day of consumption, the settlement process requires communication of both consumption and the agreed ‘non-consumption’ of electricity. Automatic meter reading may be required.

Detailed discussion of the types and uses of communication technologies may be found in another IEA project within the DSM Implementing Agreement - Task II Communication Technologies for Demand Side Management.

5.4 Control, monitoring and communication for DSB products

5.4.1 DSB to maintain quality of supply - Ancillary services

Control	DSB Frequency and Voltage Ancillary Services involve instantaneous load shedding. Therefore, the control mechanism must be in the form of an automatic switch that turns off the load to a particular circuit when the voltage or frequency reaches specific limits. For most industrial processes, it is possible that switching the load back on must be done manually due to start-up procedures. In which case, it is not necessary for the control mechanism to be able to switch on the load, but it should include some form of notification mechanism that informs a consumer when they can switch the load on. DSB for reserve may be given a few minutes notice, although control may still be automatic.
Settlement & Monitoring	It is highly likely that a consumer will be paid an ‘availability’ fee for the times when they are available to provide DSB Ancillary Services. This implies that no metering is required under such a payment mechanism. However, monitoring may be required to prove that load was available for shedding, and that it was shed in the agreed manner.
Communication	Not applicable

5.4.2 DSB to solve network constraints

Control	DSB Network Constraint contracts are most likely to be called upon in the day of actual bid delivery, usually in the few hours ahead of the relevant trading period. Nevertheless, there is likely to be sufficient time for a consumer to plan the necessary load switching that is associated with an accepted bid. This suggests that manual control of the relevant electrical circuit may be sufficient, although some form of automatic control mechanism is probably preferable. An automatic controller may take the form of a programmable devise that ensures no load is taken on the relevant electrical circuit during the time a particular bid is ‘active’.
Settlement & Monitoring	It is possible that a consumer may be paid an availability fee for times when they are available to provide DSB Network Constraint services. This represents an attractive approach because it would be simple to administer. However, the Network Operator (Distribution or Transmission company) may not favour this payment mechanism because a predicted constraint will not always turn out to be an actual constraint. Thus, according to this method a company would be paying for a service they do not actually require in some time periods. Therefore, it may be more appropriate to pay a consumer for each interruption. If this approached is implemented only a simple form of monitoring is required that registers the number of interruptions within a specific time period. However, if a consumer is paid according to the length of each interruption then a more complex metering solution may be necessary.
Communication	Notification of the need to call upon a network restriction contract, and the subsequent ending of the restriction, may be given by any of the methods listed in Section 5.3 for within the day communication.

5.4.3 DSB for Electricity Balancing

Control	DSB Balancing Market contracts are most likely to be traded a few hours ahead of the relevant trading period. Nevertheless, there is likely to be sufficient time for a consumer to plan the necessary load switching that is associated with an accepted bid. This suggests that manual control of the relevant electrical circuit may be sufficient, although some form of automatic control mechanism is probably preferable. An automatic controller may take the form of a programmable device that ensures no load is taken on the relevant electrical circuit during the time a particular bid is ‘active’.
Settlement & Monitoring	A consumer is likely to be paid according to the quantity of load they do not consume, perhaps as a price per kilowatt-hour. Therefore, in order to ensure a consumer fulfils their contractual commitments some form of ‘avoided’ consumption monitoring is necessary. In addition, a means of proving that the consumer would normally have taken that load during the time in which the bid is ‘active’ is also required. The appropriate metering solution for this task may vary depending on the size of the consumer, but it is likely to be either time of day or half hourly metering.
Communication	Notification that a bid has been accepted for balancing purposes may be given by any of the methods listed in Section 5.3 for within the day communication.

5.4.4 DSB for access to market prices

Control	DSB Spot Market contracts are most likely to be traded ahead of the day of actual bid delivery. Therefore, there is sufficient time for a consumer to plan the necessary load switching that is associated with an accepted bid. This suggests that manual control of the relevant electrical circuit may be sufficient, although some form of automatic control mechanism is probably preferable. An automatic controller may take the form of a programmable device that defines the required load profile on the relevant electrical circuit during the day of actual trading.
Settlement & Monitoring	Usually time of day metering will be required (e.g. half-hourly)
Communication	The customer will receive details of the agreed pricing information just ahead of the day of consumption, by any of the methods listed in Section 5.3. Communication within the customers premises (e.g. main signalling or dedicate control wiring) is likely to be required to effect the calculated load profiles.

6 Examples of Demand Side Bidding

6.1 Regulating Power Market in Norway

Categories: DSB to maintain quality of supply

Unlike most other tradable commodities, the supply and demand of electricity needs to be kept in balance at all times. Operational disturbances and deviations from the forecasts are normally covered by fast response, adjustable power reserves – that is generators that are capable of increasing their output at short notice. One important function of DSB is to give the system operator an alternative to relying solely on generators to provide this reserve capacity, which should reduce prices and avoid or reduce the need for less efficient power plant to be held in a state of readiness.

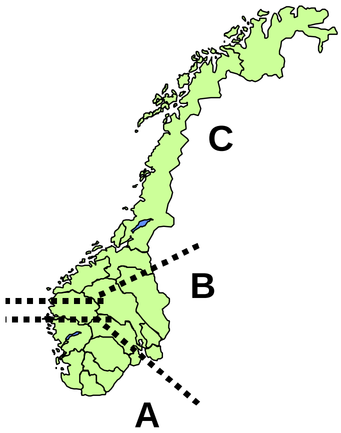
In Norway, such imbalances are dealt with on the Regulating Power Market. This operates on the day of consumption of electricity, and is separate from the price setting market that operates ahead of the day of consumption. Norway has only limited spare generator capacity at present, and demand is forecast to continue to rise in the future. Thus there was an added incentive for the system operator to encourage active participation of the demand side in the Regulating Power market.

The market is open for both generators and heavy industrial consumers. The participants are paid an availability payment in order to secure necessary reserves during peak load periods. When the System Operator takes advantage of this “option” and asks the participants for Regulating Power bids, the participants are allowed to define the cost of activation on the same basis as other players bidding into this market. Thus the price obtained for providing the service to the system operator, is made up of a fixed cost (the option payment), which is paid regardless of whether the service is called upon, and a price for the units of electricity made available – i.e. the non-consumption in the case of the industrial customers. The price for the units of electricity made available is set by bidding into the Regulating Power Market with bids on volume and price.

The terms of availability are laid down by the System Operator. Currently they are:

- Minimum volume is 25 MW
- There are two types of contracts: 3 months - and one year contracts
- The capacity must be available between 06:00 and 22:00 Monday to Friday
- The capacity must be possible to activate within 15 minutes
- The capacity must be available for at least 1 hour continuously
- The capacity must be available for at least 10 hours per week except public holidays
- There may be a “resting period” of maximum 8 hours between each activating of the disconnection (only for demand)

Price and quantity is determined in a bidding process for three different areas of Norway. The availability (“option”) payment depends upon which of these three areas is being served, Figure 4.



Area payments

Area A: 30 000 NOK/MW
Area B: 25 000 NOK/MW
Area C: 20 000 NOK/MW

Figure 4. Area payments for the Regulating Power Market in Norway (November 2000)

The notice period, given by the system operator, to inform the consumer that the change in demand is required (i.e. to activate the option) is 15 minutes. Notification is delivered by e-mail. General information from the spot market is also sent to market participants via e-mail and posted on the Internet. The end of activation is notified in the same way (i.e. via e-mail, with 15 minutes notice.)

The large customers involved in the Regulating Power Market all have hourly metering, which is collected once a week. However, this is not, currently, used to prove that the agreed non-consumption / reduced-consumption actually took place.

Consumers offering to reduce demand in this way must take into account their commitments in the regulating power market when they are making bids in other markets e.g. the day ahead price setting market (spot market). If the consumer reduces his energy demand due to the prices in the spot market, his obligations to the regulating power market may be reduced proportionally. The system operator must be notified as soon as possible, but there is no penalty in terms of reduced compensation.

If there are other reasons for a general reduction in demand, such as changes in the consumer’s plant or organisation, the System Operator must be notified of the expected duration of the change, and the ‘option’ payment will be reduced proportionally.

If there are other reasons why the reduction has not been activated when called upon, and the system operator has not received notification, the compensation is reduced by a factor of 25 times the capacity that not was available, compared to the contracted amount.

In November 2000 there were agreements for 1274 MW of reserve capacity on three-month contracts, with 582 MW of this being offered as load reductions by consumers.

The prices for these options vary from 20 000 to 30 000 NOK/MW[1] between the three geographical areas defined in Norway.

The one-year agreements amounted to 471 MW of reserve capacity, with 88 MW coming from consumers. The price paid for this option is NOK 20 000 per MW.

6.2 Frequency response in the UK

Category – DSB to maintain quality of supply

In the UK, the System Operator, the National Grid Company (NGC), has the statutory obligation of maintaining supply at a frequency of 50Hz (+/- 1%). A fall in supply frequency must be corrected instantly. Traditionally this has been achieved by having reserve generators in a state of readiness. However, consumers capable of instantaneous shutdown can also provide the same frequency correction.

The conditions laid down by NGC for purchase of this service is that the load available must be > 3 MW and that control must be instantaneous. Availability can be specified for any period of the year.

Acting as an agent or Demand Side Aggregator, Yorkshire Electricity Special Markets have placed contracts with a number of large sites to automatically disconnect loads for periods of up to 30 minutes. Because frequency can fall so rapidly, the load reduction is controlled by frequency sensitive relays, which operate in microseconds. These are connected to circuit breakers of the piece of plant that the customer has agreed to allow to be tripped. Customers can decide how often they want to be tripped and can control the trigger set point of the relay. For example, at 49.7Hz there will be around 20 interruptions per year, at 49.6Hz only one. Sites receive payments for making themselves available for tripping.

Yorkshire Electricity Special Markets currently manage this service for a number of large industries in the UK, including all of the major cement producers and some of the major steelworks. In all cases, it has been shown that immediate shut-downs in processes can be coped with, without damaging equipment or adversely affecting products.

Cement production is an ideal process for frequency response. It consumes large, predictable and steady loads, and the process of crushing and milling can easily be interrupted and restarted. Yorkshire Electricity now have contracts with, in total, thirteen sites, offering a maximum instantaneous load reduction of 110MW.

Individual steel works are less attractive as providers of frequency response services. For example, arc furnaces have very high, but irregular, patterns of electricity usage, fluctuating from zero demand to over 50 MW 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 (see Figure 5), can provide a suitable load for frequency response. Yorkshire Electricity have grouped together a number of arc furnaces in this way, and are able to guarantee to the System Operator (NGC) that a firm load of around 100 MW is almost always available for interruption.

[1] 1 NOK ≈ 0.12 Euros

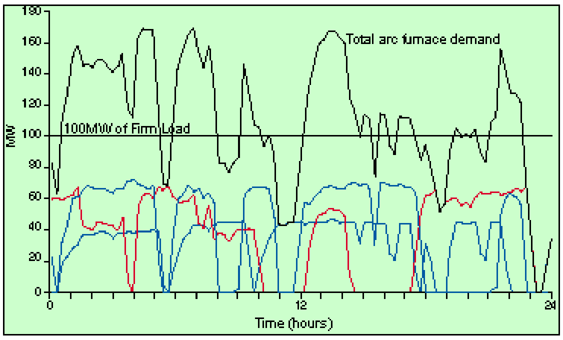


Figure 5. Aggregated loads from several arc furnaces

In total, Yorkshire Electricity manage approximately 300 MW of load for frequency control, from a control room at their headquarters.

Consumers notify Yorkshire Electricity of their load schedules, for those processes available for frequency control. These offers of availability are totalled together and relayed to NGC by mid-morning of Tuesday, for the week beginning the following Monday. Offers can be refined a day ahead of consumption, for example to cover production problems at the plant.

Actual availability is monitored continuously. The control room is in constant communication with both the consumers and NGC, via dedicated telephone lines (a leasing charge is paid for the lines to the phone company, rather than a call time based charge). Pulses from a power meter at each process are relayed to the control centre. These are converted into MW and summed to give the total availability. An additional calculation is included to account for the variability in demand from the arc furnace.

Supply frequency is also constantly monitored, so that Yorkshire Electricity are constantly aware of the likelihood of frequency control being activated.

Great efforts are taken to reassure consumers that DSB availability will have as little impact on their business as possible. For example, consumers can automatically undeclare their availability at any time, by pushing a button at their plant. Similarly, during a disconnection, consumers can manually over-ride the frequency trip if process demands dictate.

The frequency trips are automatically reset after a given time period – 30 minutes in the case of cement works and 15 in the case of steel. Processes are then restarted manually.

Currently sites are only paid for availability - there are no payments to reflect length of load management period or relay setting. The aim is that as agent / aggregator, Yorkshire Electricity will rotate the relay settings so all sites are exposed to a similar number of interruptions in a year. Sites receive an availability payment of around £1.64/MWh[2] for any half-hour where they make themselves available.

[2] £1 ≈ 1.6 Euros

6.3 Supply contracts for domestic customers in Finland, the UK and Norway

Categories: *DSB to maintain quality of supply*
DSB for access to market prices

Small houses in Finland are often heated by electricity, and direct resistance heating is quite common. About 600,000 small houses have electric heating. They usually have time-of-use tariffs with lower electricity prices during night and/or summer times. Domestic hot water is usually produced during the night-time and stored in the hot water tank. Space of the house is often heated through direct resistance heating.

Many customers will have a supply contract, which allows the supplier to interrupt the supply to the heating circuits for short periods. Despite the absence of any storage element to the heating system, these short term interruptions have little effect on comfort. This kind of direct load control contract has traditionally been offered by several utilities. Numbers are of the order of 30,000 to 50,000, offered by tens of utilities.

The main characteristics of the product are:

- The main reason for the product has been the structure of whole-sale tariffs with very high penalties if the pre-ordered demand is exceeded
- The product is offered by local suppliers to reduce their own peak loads
- Long-term contract time (usually continuous)
- Supplier can interrupt the load directly without any notice
- Interruption can last usually 0.5...2 hours depending on the type of the house
- The number of interruptions is usually limited to 1 to 2 per day and certain time between successive interruptions is required. In some contracts also the maximum number of interruptions per year is defined
- The availability fee is usually 50 % reduction from the fixed charge corresponding usually 300...500 FIM/year[3]. No extra trigger fees are paid
- Supplier has usually one-way communication system to customer (ripple control or distribution-line carrier system)

Thus the supply contract is used to enable the supplier to manage his loads – particularly his exposure to high prices during periods of peak demand, and to assist the System Operator maintain quality of supply. The benefits are shared with the customer through a reduced fixed charge.

Ironically, with the introduction of a liberalised electricity market in Finland, this type of product is becoming less popular. There are several reasons for this:

- Whole-sale tariff system is no more defining marginal price of electricity, and marginal price defined by spot market has been quite low and therefore doesn't give incentives for the supplier to offer the product
- Customers did not usually remember or understand this kind of contract and complained about the interruptions
- Separation of supply business from network business has caused organisational problems because the technical system (ripple control of switching) is usually

[3] 1 FIM ≈ 0.2 Euros

owned by the monopoly part of the infrastructure, whilst the suppliers may also need the system

However, it is clear that such contracts can give benefits in a liberalised electricity market. Similar ideas could be used in other fields (commercial buildings, industrial process heating) to allow the supplier to take more advantage of market prices or to offer other DSB products to the System Operator.

A similar product is also available in the UK for use with domestic storage heating. Here the customer sees no effect of disconnection, despite charging of the heaters being largely under the control of the supply company. The storage element makes it possible to take fuller advantage of market prices.

In Norway, experiments are currently being undertaken to look at the feasibility of load interruptions in homes. In one experiment loads for space heating were controlled via TV / Internet, to give slight reductions in space temperatures during part of the day. Most customers found the system attractive or very attractive.

6.4 Fuel substitution in Sweden and Norway

Category: DSB for access to market prices

Most electricity generation in Sweden and Norway is from hydro power. In addition there is some municipal and industrial CHP, and a growing amount of wind power. The integrated Nordic Electricity market (which includes Sweden, Norway and Finland) has been in operation since 1996. Market prices for electricity are often low, with the availability from hydro power exceeding demand for much of the year (apart from 1996, which was a dry year and consequently the availability of hydro was low). The low prices mean that producers have closed down some of the peak load capacity so that the production margin has decreased substantially.

A large proportion of cities are heated by district heating systems. These systems can often use many different energy sources in different boilers. Bio-fuelled boilers are becoming increasingly common - taking care of the base load during winter. In addition, they often have both oil fired and electric boilers. Duel fuel boilers (oil and electric) are also used by large industrial / commercial customers.

Traditionally, electric boilers were mostly used during the summer, when only domestic hot water is required and there is a surplus of electricity at low cost. Special rules applied to the use of electric boilers and they got a low price. One part of the rules were the right of the supplier to shut off the supply in times of scarcity.

Since the electricity market was liberalised in 1996, many boiler owners have been able to negotiate contracts that make it possible to use these boilers economically at all times of year, not just in the summer.

The shrinking capacity margins for electricity generation have, however, made it interesting for suppliers to have some influence over the running of these boilers, as they are a simple way to shed load. So there is a new tendency to run these boilers such that the hourly spot price for electricity is compared to the cost of running the oil boiler instead. When the spot price exceeds a certain limit, a signal is sent so that the electric boiler is switched off and an oil boiler can be switched on. This means that the oil fired boilers are used during periods of peak electricity demand, when electricity prices are high. Exposing the electric boilers to electricity spot market prices has allowed the owners to take full advantage of fuel substitution, by using oil whenever the cost of so doing falls below the cost of using electricity.

There are several solutions to controlling the electric boilers. Many big boilers are owned by large energy companies. They often run the boilers from the control room according to the hour-to-hour spot price that is fixed at 3.00 PM for the next day. Spot prices are published on the Internet by the market operator, Nord Pool. Another solution is that the company that owns the boiler buys electricity from a supplier at a price that follows the spot market price, hour by hour. In both cases, settlement is via hourly metering.

The boilers can also be run to aid system balancing (DSB to maintain quality of supply). In some cases this is through supplementary agreements to the contract with the supplier, that make it possible to switch off the boiler during peak load. No availability payment is made, but attractive tariffs are offered to consumers providing this service.

6.5 Standing reserve in the UK

Category: DSB to maintain quality of supply

In the UK, it is the responsibility of the System Operator, the National Grid Company (NGC), to maintain a careful balance at all times between the supply and demand for electricity. Traditionally this has been achieved by holding generator plant in reserve as a contingency against unforeseen events. However consumers can play a part by reducing demand or starting up their own standby generators.

Standing Reserve is required to "take over" from frequency recovery services (see example 6.2) , and is needed within 20 minutes from instruction, for example following the loss of a generator. The service should be capable of being maintained for at least 2 hours.

The requirement for Standing Reserve varies according to the system electricity demand profile, and so NGC seeks to specify service needs in terms of seasonal requirements across working and non-working days. At certain times of the day, generating units may be only partially loaded. Reserve provided by part-loaded generation is paid for via the arrangement through the electricity pool. At other times, particularly across demand peaks when generation tends to be fully loaded, there will be relatively little synchronous (spinning) reserve available and so the requirement for Standing Reserve will be much higher. These requirements are specified in terms of "windows" of service, for which there are two or three each day, as indicated in Figure 6 below.

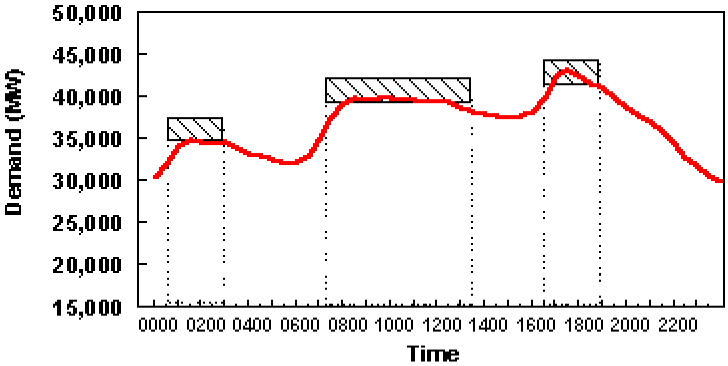


Figure 6. Typical times in the day when standing reserve is required

In order to facilitate the provision of a DSB standing reserve service, NGC require that an electronic interface is in place. This automatically checks on availability, sends the notification to reduce load or start up standby generators and monitors transactions. An element of the cost of this interface (which is sourced by NGC) is factored into the economic viability of any offer to provide this DSB service. This overhead means that it is unlikely (although not impossible) that service providers less than 3MW can supply an economic service. Payments are made for service availability and when NGC uses the service i.e. when the service is "called-off".

Generally services that are likely to be used frequently have low call-off / high availability prices: services that are used infrequently vice versa. The service provider (consumer or DSB aggregator) tenders in prices, availability, call-off information (which includes certain minimum and maximum criteria), indicating for which periods and for which service they wish to be considered.

Both load reductions and the start-up of standby generation are used for this service. For example, one UK water company has aggregated a number of small standby generators together to provide 15 MW of useful reserve capacity.

Notification is through the electronic interface. Monitoring starts at the beginning of the 20 minute warning period, and continues throughout the period of the contracted load change. The end of the load change period is also notified through the interface. This often comes sooner than the contracted period. Currently load changes of around 60 minutes are the norm, compared to contract periods of typically 2 hours.

Load reductions are generally undertaken manually - the 20 minute warning period being adequate for processes to be switched off. At present in the UK, those large customers who can load reduce automatically will offer DSB for frequency control, rather than for standing reserve, as this gives the higher income.

Standby generators are started automatically, and are brought on line gradually over the 20 minute notification period.

6.6 Load management of refrigerated warehouses in New Zealand

Category: *DSB for access to market prices*
DSB for electricity balancing

As part of the food supply and distribution chain, most countries will have large refrigerated warehouses for the storage of frozen and chilled produce. Such warehouses represent sizeable electricity loads, predominantly from the refrigeration plant.

Normally, the refrigeration plant is controlled to maintain a set temperature within the warehouse at all times – typically -18°C for frozen food and 0 to +5°C for chilled produce. However, the produce represents a significant thermal buffer and often the refrigeration supply can be interrupted for quite long periods, without storage conditions becoming unacceptable. This is particularly so of frozen produce, where the storage conditions are less critical - most produce only being required to be kept at below a certain temperature (rather than within a narrow band of temperatures as is the case with chilled produce).

A number of frozen food warehouses around the world have practised load management in recent years. This has tended to be in response to simple two or three rate tariffs for electricity. Very simple, timer-based, strategies were followed, using off peak electricity as much as possible to over-cool the produce, and then avoiding consumption during the higher cost day rate periods.

In 2000, a trial was conducted in a frozen food storage warehouse in New Zealand of a more sophisticated load management system. At the heart of this system is a model based predictive controller. It was used successfully to demonstrate the cost saving potential of using market based prices. Electricity prices are sent to the controller by email just ahead of the day of consumption. The model then calculates at what times, during the following day, the refrigeration plant should be run in order to achieve the lowest cost, whilst meeting product quality constraints. The calculation takes account of the expected loads on the warehouse, covering factors such as weather conditions and movement of produce to and from the warehouse. It also takes account of the efficiency of the plant, making best use of the highest efficiency operating conditions. The controller then produces a schedule of set points which are loaded into the refrigeration management system, to effect the calculated operating sequence.

The model is based on a standard personal computer, and could in the future be integrated into the refrigeration management system. Parameters for the predicted model are automatically learnt from data fed back to the controller. Price settlement would be by normal half-hourly metering.

As markets change throughout the world this could be an application where other DSB products could become of interest. For example, those networks that have ‘balancing markets’ could use the system to do relatively short term load manipulations – say over a time scale of three or four hours. Loads would be rescheduled during the day of consumption to help suppliers maintain a balance between their agreed purchase levels and the demand from their other consumers – thus avoiding expensive purchases from the balancing market.

6.7 Use of Generators for peak price avoidance in the UK

Category: *DSB for access to market prices*

Many commercial and industrial consumers will have standby generator plant available as a safeguard against interruptions to the supply from the network. Typical of such customers will be:

- supermarkets and cold storage depots, where a loss of supply would cause frozen and chilled produce to quickly deteriorate
- hospitals where essential services must be maintained at all time
- water companies
- air ports

Although the primary purpose of the generator is to maintain continuity of supply, they can also be used to manage the need for mains electricity, provided the primary purpose is not compromised.

At least one large frozen food distribution depot in the UK already use their standby generators in this way. Under the pre April 2001 pool arrangement in the UK, the company buys electricity directly from the pool. Pool prices are faxed to the energy manager every weekday morning to arrive on his desk at 8:30. He then simply decides when during the day it is cheaper to run the generator rather than import electricity from the network, based on his known cost of oil and the generators' efficiency. Typically this will be periods where the pool price exceed 5.5 p/kWh. (Pool prices are generally well below this for the period midnight to 08:30, so there is no loss of potential savings by only looking at the pool prices when they are already several hours old).

Times of start up are programmed into the generators by the operational personnel. Start up is automatic, with the generators brought up to synchronous speed and run in parallel to the mains. The 2 MW sets typically use 1 MW within the depot and export the remaining 1 MW to the network.

Costs are settled with the pool against half-hourly metering, with both the import and export prices being set at the pool price.

After April 2001, the electricity trading arrangements in the UK will alter, with the pre-existing pool trading arrangement disappearing. The depot will then negotiate a supply contract with a supplier to meet its electricity needs. The energy manager hopes to negotiate a tariff that will reflect the through-the-day variations in price, rather than a simple fixed or two rate cost. He will then still be able to use the standby generators in this way, reducing his overall electricity bill by only buying from the supplier when the price is low. Export to the supplier, may also be of benefit, as it could be used to help the supplier with his commitment to balance his supply and demand at all times. This may need improved communications between the supplier and the depot, but simple email or internet based communication is all that will be required.

7 Conclusions

This report has been written from the point of view of electricity consumers and suppliers, and provides a practical guide to the characteristics and benefits of Demand Side Bidding.

Five different categories are used to define DSB in relation to the length of notification provided before the demand bid is executed, i.e. the length of time given for a demand side bidder to manipulate their load in the agreed manner. The role of each of these five categories of DSB product within the electricity supply chain is discussed. For each category, definitions are provided for the purpose of the product, the buyers and sellers, and the alternatives available if the demand side do not or cannot participate. A brief description is also provided, for each category, of the control, monitoring, settlement and communications technologies required.

Seven practical examples are presented, which provide consumers and suppliers with an insight into how DSB can be implemented.

The first of these examples describes how very large consumers in Norway can offer load reductions to effectively provide reserve capacity, through the mechanism of a 'Regulating Power Market'. Currently over 500 MW of load reduction is available through this mechanism.

The second example demonstrates one of the ways in which DSB has operated successfully in the UK in recent years. A number of large consumers allow their plant to be switched off automatically in response to a fall in system frequency, thus assisting the System Operator to maintaining the quality of supply. In the example, over 100 MW of load reduction is available from 13 cement production facilities which are able to cope with immediate shut-down to their crushing and milling processes. In return, the cement producers are able to earn an availability payment for this service.

Although DSB is currently used most successful for the provision of ancillary services (such as frequency response and reserve capacity) by large consumers, smaller consumers can also participate as indicated by the third example. This shows how domestic consumers can participate by allowing interruptions to their electric space and hot water heating. In return for providing their electricity supplier with flexibility, they are rewarded with reduced standing charges for their electricity.

Fuel substitution is an alternative method that allows consumers to make short, discrete changes to their load profile, thus allowing participation in DSB. The fourth example describes how fuel substitution is used in large Swedish and Norwegian district heating schemes during periods of high electricity demand.

Many commercial and industrial consumers have standby generator plant available as a safeguard against interruptions to the supply from the network. The fifth example shows one of the ways in which such generators can be used as a DSB tool. Here, a UK consumer, with a number of large standby generators, makes them available to the System Operator to use as reserve capacity. This provides the System operator with an alternative to relying solely on larger network generators.

Some consumers have processes which allow them to change the times at which they use electricity from day to day. This flexibility can be used to good advantage, by scheduling loads for periods of low electricity cost. The sixth example shows how modern control systems are able to help the operator of a cold storage facility, to schedule the running of his refrigeration plant - thus minimising his electricity cost each day. Consumers with such flexibility can be of great value to their suppliers, by helping the supplier maintain a balance between his agreed purchase levels and the demand from their other customers.

The final example shows another use of standby generators as a DSB tool. Here the consumer has negotiated an electricity tariff which follows the spot market (pool) price. He then schedules his standby generators to run whenever the cost of so doing is less than the cost of importing electricity from the network.

These practical examples demonstrate a variety of ways in which DSB can be of benefit to the consumer. There will, of course, be many other types of consumer who could also benefit. Appendix C provides a wider list of consumer processes which may be suitable for DSB.

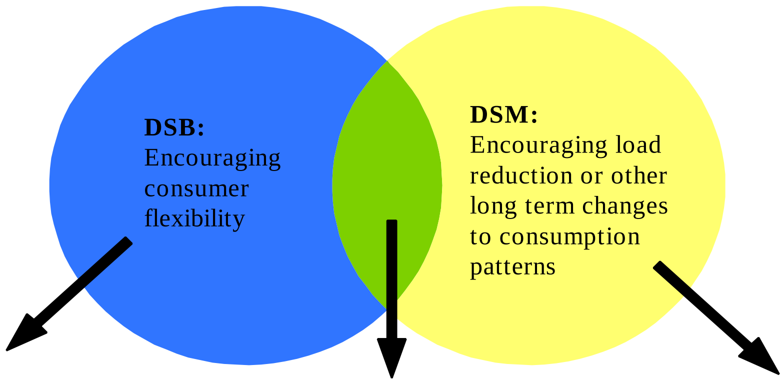
The examples also demonstrate that the control, monitoring and communications technology required to implement DSB already exists. Thus the major barriers to the wider uptake of DSB are economic rather than technical.

The economic case will vary from country to country and from one type of consumer to another. However, in many cases, consumers should be encouraged to think about how they might be more flexible in their use of electricity, in order to take full advantage of market conditions.

Consumers are already participating in DSB in a number of different countries, but wider opportunities will be found as a better understanding of the role of DSB within liberalised electricity markets becomes established.

Appendix A Demand Side Bidding and Demand Side Management

It is evident that there are some similarities between demand side bidding and demand side management. Therefore, in order to avoid confusion, the similarities and difference are clearly summarised in the following diagram.



DSB

- Market driven
- Involves short term, discrete actions by the consumer
- Improves market efficiency resulting in both short and long term benefits
- Consumers given the opportunity to earn money in the energy markets
- Potential energy efficiency and environmental benefits

Overlap

- Shared control, monitoring and communication technologies
- Cross fertilisation of ideas and opportunities

DSM

- Mostly regulatory driven
- Involves sustainable and permanent changes to demand profile
- Results in long term benefits for the environment, for utilities, and for consumers
- Cost savings for consumers

Appendix B DSB for price setting in wholesale electricity markets

Trading in any electricity market can be simplified into two basic types of process: the bulk purchase of electricity (i.e. bids for total demand) and system balancing (i.e. bids for a change in demand) which ensures that demand exactly matches generation at any given time. In addition the System Operator has responsibilities for maintaining the quality and stability of supply. Quality of supply and system balancing were dealt with in section 3 of the main report. Here, a brief outline of how markets are used to set the price for the bulk purchase of electricity, is presented.

Three types of demand side participation are important here:
1. Spot Markets
2. Bilateral contracts
3. Supply contracts

1 Spot Markets

At first sight, there is very little elasticity of demand with price in the consumption of electricity (the demand for electricity per day, say, will be the same irrespective of price - at least in the short term before steps can be taken to reduce consumption if costs are high). However, electricity consumption, and with it the price of generation, varies throughout the day. Many end users can schedule their use of electricity to avoid high cost periods and use lower cost periods - and thus there can be considerable elasticity of demand with price during each day.

The aim of demand side participation in the bulk purchase of electricity is to utilise this elasticity of demand to lower the overall cost of electricity supply. A major use of Demand Side Bidding therefore arises from consumers (or suppliers on behalf of consumers) who are able and willing to schedule load to take advantage of lower costs.

All electricity markets work on the basis of predictions for the demand of electricity. However, there are differences in how the predictions are made, depending on whether it is a single sided market or a two-sided market.

1.1 One-sided markets:

Only the generators participate in single sided markets (such as the UK electricity pool - pre April 2001). In this type of market, the System Operator predicts both the demand and the elasticity of the demand with price. The generators provide bids for the amount of generation they will supply at a given price, and the system marginal price is then set at the intersection of the predicted demand with the offers from the generators.

Most, if not all, one-sided markets set the system marginal price for electricity before the time of delivery (ex-ante), thus allowing the demand side the opportunity to react to the price of electricity.

1.2 Two-sided markets:

In a two-sided market, in which both the generators and the demand side participate, the prediction for demand comes in the form of bids, from the demand side, to consume a given quantity of electricity at a particular price. The bids come either from individual consumers or from suppliers (of groups of consumers).

The demand side bids are submitted in the form of price-demand curves, for each period of the day (usually every half-hour). Figure B1 below shows what a price-demand curve might look like for an individual consumer.

Figure B1. Inelastic demand-price curve bid for a consumer.

Some consumers will have a relatively inelastic price-demand curve, in as much that their demand will be largely unaffected by price. However, as price increases there will be a point above which a consumer will respond by reducing their demand .

Some consumers, however, will be much more sensitive to price, and may have a more elastic price demand curve, as indicated in Figure B2 below.

Figure B2. Elastic demand-price curve bid for a consumer.

The price is then set by the intersection of the price-demand curve from the consumers / suppliers and price-generation curve from the generators. This greater involvement by the demand side is widely seen as an advantage, giving greater market responsiveness leading to lower prices.

The way that a consumer reacts once it has submitted its bid depends upon the type of market, and particularly on whether or not the bids are regarded as firm or non-firm. If the bids are firm, the consumer must respond to the market price according to its bid, or face imbalance charges.

2 Bilateral contracts

In some electricity markets, electricity consumers (or suppliers acting on behalf of a group of consumers) are able to agree contracts for the bulk purchase of electricity directly with generators, without going through the spot market or pool (known as trading outside the pool). These contracts can be agreed several months ahead of the time of delivery, and are therefore only a viable option for those able to predict their demand with confidence, maybe even up to a year ahead of the time of delivery. This type of contract, therefore, is more suitable for meeting base load requirements which do not vary significantly day by day and are generally unaffected by ambient weather conditions.

Usually such contracts are placed with generators with a portfolio of generation plant. The ability of the consumer (or supplier) to schedule their demand may be important to avoiding the use of the more expensive plant, in much the same way as for trading within the spot market or pool.

3 Supply Contracts

Supply contracts offered by Suppliers to their customers are a relatively simple way of allowing consumers to participate in the electricity market. The contract typically takes the form of an interruptible tariff, whereby consumers are offered a favourable rate for their electricity in return for allowing an interruption their electricity supply. The interruption could apply to the whole load of the consumer, but is more likely to apply to part of the load, for example electric hot water heating or space heating. Such contracts usually include a clause to restrict the number of times that interruptions will take place. These types of contracts are reasonably widespread within the participating countries, and are offered to small and large consumers alike.

Another variation on the supply contract offers the consumer a favourable off-peak tariff, but the period of availability of the off peak electricity is determined by the supplier on a day by day basis.

Both of these types of contract help the supplier to manage the demand of their customers, and thus meet any contractual obligations they may have with the electricity markets or generators.

Appendix C Other DSB opportunities

There is a wide range of possible opportunities for consumers to participate in DSB. These methods include:

Thermal Storage:	hot e.g. water / storage heaters cold e.g. water / ice
Material storage:	energy used to stockpile a resource/ component/ subassembly for use in a later process
Scheduling:	processes where energy must be used, but the time of use is not critical
Gas pressure:	increase storage pressure for a short period to allow for a short interruption later
Turning things off or down:	often good practice from an energy efficiency point of view
Electrical storage:	e.g. flywheels, batteries
Standby power generation:	many premises install standby generators to provide standby power in the event of a supply failure from the distribution system
Alternative fuels:	e.g. dual fuel, renewables

C.1 Industrial Applications

The dominant cost in many industries is the capital cost of the plant. Maximising its use is therefore the prime objective.

C.1.1 Chemical industry

Thermal storage:	primarily hot water production molten salts
Material storage:	pumping and recycling of process water
Scheduling:	batch drying / processing regeneration of absorbers and catalysts preheating (or cooling) of process plant
Gas pressure:	compressed air is widely used (e.g. pneumatic valve control) and the use of buffer pressure vessels can allow load shifting

Most of these applications would require little in the way of modifications to the plant – apart from alterations in the control or scheduling routines – and hence are well worth considering further. Compressed air storage would require very large high-pressure storage vessels, plus a new high-pressure booster compressor, and so is less likely to offer a feasible DSB opportunity.

C.1.2 Agriculture

Thermal storage:	milk cooling - ice storage used to smooth refrigeration load - both on farms and at the dairy hot water production
Material storage:	abstraction of water
Scheduling:	slow batch drying - grain drying / storage potato storage (temperature / humidity controlled but close to ambient and not critical) horticultural lighting irrigation washing, blanching and pre treatment infra red heating scheduling for animal heating
Standby power generation:	often available on farms for emergency use

Most of the loads here will be quite small, and maybe would not normally justify the cost and complexity of including DSB products. However, the rural locations may make them good targets for Distribution Constraint DSB products.

C.1.3 Food manufacture and storage

Thermal storage:	food refrigeration & coldstores – precooling large cold store warehouses are ideal for some load shifting (large thermal lag of store – typically long time constants, use of upper and lower temperature limits for food) hot water production - lots of applications with storage possibilities
Material storage:	abstraction and recycling of water for breweries
Scheduling:	ovens – particularly warm up

C.1.4 Manufacturing & assembly

Thermal Storage:	hot water
Material storage:	product storage - possibly batch operations subassemblies surface finishes - hot dipping, painting bulk liquids – galvanising anodising solvents ovens
Scheduling:	large number of small loads warming up – extruders, injectors
Gas pressure:	compressed air is again widely used (see 6.1.1 Chemicals)

C.1.5 Textiles, paper & wallpaper

Thermal Storage:	hot water – dyeing, bleaching and domestic use
Scheduling:	effluent treatment clean plant between print runs
Gas pressure:	compressed air is again widely used (see 6.1.1 Chemicals)

C.1.6 Gas (natural gas supply)

Gas pressure:	ground pressurisation general pumping - use of network as pressure vessel

Pressurisation of the ground would involve either creating new storage caverns (old salt mine perhaps) or pumping gas from one natural gas reserve to another. Investment costs would be significant. The use of the network as a pressure vessel might lead to increased gas leakage.

C.1.7 Water

C.1.7.1 Clean water

Material storage:	pumping from one reservoir to another
Scheduling:	borehole extraction water treatment local generation and storage of Chlorine

C.1.7.2 Sewage

Scheduling:	pumping sewage heating site based industrial effluent treatment but not aeration (trend is towards continuous which is less suitable)
Gas pressure:	methane gas storage
Standby power generation:	power generation including from local methane

C.1.8 Metals (including ceramics and glass)

C.1.8.1 Large businesses

Large industrial consumers are likely to have some form of load management already, for example:-

Thermal Storage:	hot water
Scheduling:	furnaces melting (as above)
Turning things off or down:	fans – fume extraction (large loads here MW)

C.1.8.2 Middle & Small (~2500 ~40kW plus foundries)

Lots of opportunities here. More small batch working with scope for process interruption.

Thermal Storage:	hot water
Material storage:	40 - 60 kW loads & resistance furnaces - hot metal storage (holding at reduced loads of say from 40 to 10kW), alteration of preheat cycle of furnaces may be possible depending on time delay and tariff variations
Scheduling:	production scheduling and process integration
	glass industries (much lower loads, normally gas or resistance furnaces - batch oriented)
	ceramics, glasses and metals, drying/ heat treatment (e.g. 500^{o}C for eight hours)
Turning things off or down:	fans - fume extraction- energy saving opportunities but fans must work when they are needed in the production cycle, hence scheduling required

C.1.9 Forestry

C.1.10 Fishing

Thermal Storage:	water heating
	ice making and storage
Scheduling:	infra red and UV (fish farms both fish growth and bacteria control)

C.1.11 Construction

C.1.12 Mining & quarrying

Scheduling:	crushing and grinding equipment

C.2 Commercial

C.2.1 Offices

C.2.1.1 Small offices – non-air-conditioned (200m2)

Thermal Storage:	electric heating control – CELECT direct acting heating - controls / setbacks

C.2.1.2 Large offices with air conditioning

Thermal Storage:	bulk ice storage fabric storage hot water storage
Turning things off or down:	smart windows - ventilation and shading lighting control, daylight, and occupancy sensors
Electrical:	battery backup on computers (often short term - less than 1 minute) d.c. plus battery operation of p.c.
Standby power generation:	computer suites

C.2.2 Leisure

C.2.2.1 Sports halls

Thermal Storage:	shower hot water

C.2.2.2 Pools

Thermal Storage:	pool water storage for scheduling chp hot water storage
Scheduling:	dehumidifiers / ventilation (shifting set points for short periods)

C.2.2.3 Others

Thermal Storage:	under soil heating of pitches

C.2.3 Hospitals

Thermal Storage:	hot water
Standby power generation:	perhaps the best opportunity in hospitals

C.2.4 Local authorities and education

Perhaps a good overall target area. Opportunities as per 6.2.1 & 6.2.2

C.2.5 Wholesale/retail

C.2.5.1 Supermarkets

Thermal Storage:	ideal addition to secondary refrigeration systems ice storage option possible for primary refrigeration systems (but difficult) refrigeration cabinet temperature modulation (retailers are not keen) ice store for air conditioning with ice generated by spare refrigeration capacity overnight
Turning things off or down:	night blinds on refrigerated display cabinets

Standby power generation: potentially attractive use

C.2.5.2 Department stores

Thermal Storage: ice storage for air conditioning

restaurant – hot water storage

C.2.5.3 Small retail

Thermal Storage: CELECT electric heating

C.2.6 Hotels/restaurants

Thermal Storage: hot water storage

pool - control of CHP for optimum generation

ice or fabric storage for air conditioning

CELECT management of electric heating (e.g. Travelodges)

C.3 Transport and communications

C.3.1 Transport

Scheduling: battery charging - stacker trucks, milk floats

canal pumping

pumping out of tunnels

ventilation systems

street lighting

C.3.2 Communications

Scheduling: battery charging

C.4 General

Electrical:	in principle, direct electric energy storage (batteries, flywheels, super-capacitors) can be used anywhere electricity is required
Standby power generation:	all critical loads generally have backup generators, examples include hospitals, airports, and supermarkets