

DEPARTMENT FOR BUSINESS
ENTERPRISE & REGULATORY REFORM

DYNAMIC DEMAND

Government Response to Clause 18 of
the Climate Change and Sustainable
Energy Act

AUGUST 2007

Executive Summary

Section 18 of the Climate Change and Sustainable Energy Act (“the Act”) requires the Secretary of State to publish a report on the potential for dynamic demand technologies, which could assist in the management of the electricity grid, reduce emissions of greenhouse gases and facilitate the integration of renewable generation. The Act also requires the Secretary of State to state his view as to whether it is appropriate to take any steps to promote the use of dynamic demand technologies.

Having considered the information set out in this report – particularly the potential of dynamic demand technology to reduce greenhouse gas emissions – the Secretary of State supports the further development of the technology and work to fully quantify the extent to which it can contribute to the Government’s energy policy goals. However, the Secretary of State’s view is that it would not be appropriate to take any steps to promote the technology until such time as the results from this work have been concluded and evaluated. In forming this view, the Secretary of State has had regard to the matters in section 4 of this report, namely the potential barriers to the deployment of dynamic demand and possible support options to overcome these barriers, should the work currently underway confirm the technology’s potential.

1. Introduction

Dynamic demand control is a technology that can be incorporated into electrical appliances that enables them to provide important services to the electricity grid such as smoothing peaks in consumer demand and continuous second-to-second balancing of that demand and the output from power stations. The Climate Change and Sustainable Energy Act 2006 requires the Secretary of State to publish, within 12 months of the commencement of the relevant provision, a report outlining what potential he sees for dynamic demand technology and, if appropriate, what steps should be taken to promote it. On these points, section 18 of the Act states:

- (1)The Secretary of State must, not later than 12 months after this section comes into force, publish a report on the contribution that is capable of being made by dynamic demand technologies to reducing emissions of greenhouse gases in Great Britain.
- (2)The report must state the view of the Secretary of State as to whether it is appropriate to take any steps to promote the use of such technologies, and, if it is, what those steps are.
- (3)In forming the view mentioned in subsection (2) the Secretary of State must have regard, in particular, to any matters which would prohibit or inhibit the use of any dynamic demand technology in any circumstance in which its use could be expected to make a contribution to reducing

emissions of greenhouse gases in Great Britain; and the report must state the matters to which he has had regard.

This report relates to the above obligation on the Secretary of State to report on dynamic demand technology, its potential, barriers to its development and the appropriateness of support measures. Encouraging evidence of the potential of the technology to reduce carbon emissions is reported as are details of work currently underway to further quantify this potential. Specifically, this report provides:

- A summary of the current 'state of play' of dynamic demand technology;
- An assessment of the contribution that is capable of being made by dynamic demand technologies to reducing emissions of greenhouse gases;
- An outline of the barriers to adoption of the technology;
- Possible options to promote the use of dynamic demand technologies; and
- Details of further measures proposed to promote the use of this technology, including a summary of a Department of Business Enterprise and Regulatory Reform (BERR) - funded research project¹ currently underway.

In considering the potential for dynamic demand to play a role in carbon saving and facilitating the deployment of renewable intermittent energy, the Department of Business Enterprise and Regulatory Reform (BERR) has worked closely with the not-for-profit organisation, Dynamic Demand (founded in 2005), which, in turn, has liaised closely with key organisations likely to be involved in its adoption in Great Britain and, potentially, elsewhere. The content of this report draws on the valuable work in this area undertaken by the Dynamic Demand organisation.

2. Background

The concept behind dynamic demand control is not new. It involves fitting small electronic controllers to certain domestic and industrial appliances, such as fridges and freezers, so that they can participate in peak-demand management and the control of frequency on the electricity grid.

Early research carried out by the Centre for Renewable Energy Systems Technology (CREST) at Loughborough University and others, and reported in a recent IEEE paper², has shown that millions of such appliances fitted with dynamic demand control, acting together, could facilitate the balance between

¹ This research project involves the BERR Centre for Distributed Generation and Sustainable Electrical Energy and others. The BERR Centre provides fundamental research in support of the Government targets on renewables. The Centre is a joint academic activity between Imperial College, University of Manchester and Strathclyde University. The focus of the Centre is on the development of new technical, commercial and regulatory frameworks to support a cost effective integration of renewables in the GB electricity system, including the application of emerging technologies such as demand side management and storage

² "Stabilisation of Grid frequency Through Dynamic Demand Control" a paper by Joe A Short, David G Infield and Leon L Freris, published in the IEEE Transactions on Power Systems, Vol 22, No3, August 2007

supply and demand, improve the stability of the electricity grid, reduce the amount of “backup” generation needed and hence improve the efficiency of the grid, in addition to facilitating the deployment of variable-output renewable technologies such as wind generation. The domestic cold appliance market is around 3.5 million units per year (includes refrigerators, freezers and fridge freezers) and, even if dynamic demand appliances accounted for only a modest proportion of this annual market, the penetration of the technology could be rapid.

2.1 How is the electricity grid kept in balance?

At any instant, the amount of electricity being produced by generators (the ‘supply’) must be equal to the amount being consumed by customers (the ‘demand’). Any imbalance between supply and demand will cause a variation in system frequency. System frequency will fall if demand exceeds supply and will rise if supply exceeds demand.

The demand imposed on the electricity grid by customers changes continuously throughout the day as domestic, commercial and industrial appliances are switched on and off. Although this changing demand pattern can be predicted to an impressive extent, there is always an uncertainty. Demand can be thought of as consisting of a large predictable daily pattern with a smaller unpredictable and random (or “spiky”) variability added to it.

As well as continuous random changes in demand, the output of generation connected to the electricity grid will vary. In addition, occasional and unpredictable sudden large generation losses occur due to generator faults or losses of transmission lines. These large-scale generation losses result in large, sudden, falls in system frequency which can threaten the integrity of the electricity grid and could result in large losses of customer demand if preventative action is not taken.

To cater for unpredicted changes in demand and generation output, the Transmission System Operator, National Grid, ensures there is enough “spinning reserve” on the system at all times. Spinning reserve is simply extra generating capacity that can be called on at extremely short notice. It is provided by certain generators “pulling back” from maximum output in order to create spare “spinning” capacity and thereby creating a safety margin. These spinning reserve generators then operate in a ‘sensitive’ (called ‘frequency responsive’) mode where they continuously monitor system frequency and respond and alter their output to correct these imbalances in supply and demand.

As indicated above, imbalances in supply and demand result in changes in system frequency which can be measured from any standard electrical socket in the country. System frequency is effectively uniform across the country at any particular point in time and a dynamic demand appliance connected anywhere on the electricity grid will receive an identical input signal. The fact that any

appliance can easily measure and respond to this common signal is a crucial factor in the value of dynamic demand.

2.2 The cost of frequency response

The National Grid currently pays around £80 million each year to generators for operating in this 'sensitive' mode. The costs are high because the generators must be compensated for lost generating opportunity, and for wear-and-tear to the governor control systems and steam valves that control their output. It is also less efficient because generation equipment is designed to be most efficient when operating at full power, not when partly loaded. The precise impact of providing frequency response in terms of carbon emissions and operating efficiency will be considered as part of the on-going BERR-funded work programme to fully quantify the potential of dynamic demand technology.

2.3 The challenge of variable renewable energy

Some renewable energy sources, such as wind and solar, are variable. This means that their output changes according to a changing natural resource such as wind speed or direct sunlight. With more renewable energy connected, the challenge of balancing the electricity grid will be greater. When there is a high penetration of variable generation, the variability in supply would combine with the variability of the demand to make the system even more difficult and expensive to manage.

2.4 Dynamic demand control

The availability of low-cost microcontrollers makes it possible to design electrical appliances that are sensitive to the power imbalances on the electricity grid and able automatically to alter the timing of their demand requirements accordingly. Such techniques are becoming known as "dynamic demand control" because the appliance can change its demand dynamically according to the conditions on the grid. Dynamic demand appliances, acting together, could react extremely quickly. In principle, they could reduce demand more rapidly than a traditional "spinning reserve" generator could increase its supply.

There are many electrical appliances (such as refrigerators) which are not time-critical, in that they need energy but do not care precisely when that energy is delivered. Other 'time-flexible' appliances include air conditioners, water heaters and pumps. Early research shows that these appliances, taken together, provide the potential for a large "dynamic demand" which could act to reduce imbalances on the electricity grid – potentially providing a more carbon efficient solution than traditional spinning reserve and potentially providing additional stability that may be required when a large amount of variable-output renewable energy is connected. If developed successfully, dynamic demand presents a significant opportunity to reduce the costs of managing the electricity grid, particularly with the predicted growth in variable-output renewable generation, and at the same time reduce carbon emissions.

3. What are the potential benefits of dynamic demand technology?

In summary, the potential benefits of dynamic demand are considerable and include:

- A more efficient electricity grid;
- A more stable electricity grid;
- Removal of some of the barriers to a higher proportion of renewable energy;
- A reduction in the cost of integrating renewable energy;
- The creation of new sustainable businesses;
- Significantly reduced carbon-dioxide emissions from power generation.

3.1 Potential for significant carbon saving

Based on the research undertaken by CREST referred to earlier, and consultation with academics and others, it is estimated that a possible saving in the order of 2 million tonnes of carbon dioxide annually could be achieved by the deployment of dynamic demand technology in Great Britain. This saving comes from the reduced requirement for partly-loaded generating plant and does not include the additional possible benefits from aiding the integration of renewable energy, nor carbon savings associated with replacing some fast-acting, less efficient, generation with more efficient alternatives.

Although some work has been carried out to quantify the potential carbon saving, further work is required to determine the overall savings possible. It is one of the key aims of the on-going BERR-funded research project to authoritatively quantify the carbon emission savings that could be made by the implementation of dynamic demand.

3.2 Aiding the integration of variable renewable generation

The work undertaken by CREST to review the potential for dynamic demand to facilitate the integration of renewable energy referred to above concluded that, when operating with fluctuating wind power, dynamically controlled loads have the potential to offer considerable frequency smoothing and a significant reduction in governor activity of spinning reserve generators. Dynamic demand control has also been shown to have the potential to allow the system to “ride through” short-term drops in wind power, i.e. sufficiently reduce demand such that additional spinning reserve does not need to be engaged in order to maintain grid frequency.

3.3 Economic efficiency for National Grid management

Dynamic demand appliances have the potential to achieve substantial savings in the form of reduced payments for services provided by generators and used by National Grid in balancing demand and supply. As indicated earlier, National

Grid currently spends in excess of £80 million per year on frequency control alone and significantly more on other “ancillary services” that are associated maintaining a balance between generation and demand at all times. These services could, at least in part, be provided by the aggregated effect of millions of appliances (e.g. refrigerators and freezers) fitted with dynamic demand controllers and responding to changes in grid frequency. In view of this potential, National Grid has expressed an interest in dynamic demand technology and is a party to the BERR- funded work programme.

The extent to which dynamic demand could replace spinning reserves held on partly-loaded generation will depend on the ability of the technology to contribute to both security and quality of supply and the extent to which changes in the traditional response to variations in system frequency can be accepted. Simulations carried out by CREST at Loughborough University suggest that this amount could be of the order of the total size of the dynamically controlled loads connected; however this is a crucial issue to be addressed by the BERR-funded work now underway.

Discussions with component manufacturers suggest that the likely cost of dynamic demand controllers is around £3 or £4 per appliance. It is also estimated that the theoretical market value of the balancing services provided by a single dynamic demand appliance is of the order of £30 over its lifetime. This shows that there could be a very considerable net benefit, even before savings in carbon emissions are taken into account.

3.4 Contribution to grid stability and security

The aggregated response of a large number of dynamically controlled loads has the potential to provide significant added frequency stability to power networks, both at times of sudden increase in demand (or loss of generation) and during times of fluctuating wind power. Work carried out so far suggests that a large population of dynamic demand appliances would be able to provide a similar response to a sudden loss of 1,320MW of generation (equivalent to the largest credible loss National Grid currently plans for) as currently provided by generators acting in a part-loaded frequency-responsive mode.

3.5 Applicability to other power grid systems

Dynamic demand technologies promise benefits that are especially applicable to small and islanded networks such as in Great Britain that have special challenges in achieving stability and balancing frequency and have a comparatively wide system frequency band-width. The technology might also be similarly applicable in developing and transition economies in reducing difficulties with supply-side investment and maintaining an adequate supply-demand balance, which is often a particular issue for these economies. The development of the technology may therefore have the double benefit of creating an ‘export market’ for technology and expertise on dynamic demand, but also help some countries meet clean development objectives through creation of efficient electricity systems.

4. What are the barriers to implementation of dynamic demand technology?

Whilst there would be many beneficiaries from the introduction of dynamic demand technology, a clear route to market is required to ensure its development and deployment. For example, manufacturers of appliances suitable for delivering dynamic demand services have indicated that they cannot risk investing in the new technology until they are assured of a market for the services. Meanwhile, a market mechanism cannot be established until benefits of the technology in terms of reduced operating costs, security of supply and carbon savings have been quantified and verified, and the aggregated effect of appliances shown to be acceptable to National Grid as System Operator. No single organisation is in a position to undertake the necessary research, investment and product development to break the deadlock. The Secretary of State is therefore of the view that a broad approach needs to be taken to the further development of this technology.

4.1 Technical barriers that need to be addressed

The BERR-funded research project now underway has been commissioned to address the main technical barriers to dynamic demand, by answering the following questions:

- What is the potential of dynamic demand technology to reduce the requirement for the System Operator to commission expensive balancing services?
- What is dynamic demand's carbon-saving potential, both in current generation scenarios and in scenarios featuring greater integration of variable renewable energy generation?
- On a per-appliance basis, what are the carbon savings? Are these savings sufficiently large and can they be assessed precisely enough to merit support via demand-side policies such as the Government's household energy supplier obligation (the Carbon Emissions Reduction Target (CERT), which is to replace the Energy Efficiency Commitment over the period 2008 – 2011, or the post-2011 obligation?

The project will also deliver answers to the following secondary questions, which are necessary to ensure that dynamic demand can deliver balancing services on a cost-effective basis:

- Is dynamic demand an economically viable approach?
- Could appliances possibly become synchronised and cause undesired effects?
- To what extent could the provision and use of 'peaking' plant be avoided, with further possible savings in carbon emissions?
- Will there be conflicts with existing control from governor-controlled plant?
- What other 'emergent' properties could an aggregation possibly have and how costly could this be in practice?
- What are the design and manufacturing issues?

Successfully addressing the above technical questions will allow a suitable standard for dynamic demand appliances to be established, which will in turn facilitate the development of appropriate incentive mechanisms and market drivers (see below).

4.2 Other barriers to be overcome

Once the technical questions listed above have been answered, we believe that the remaining barriers to implementation of dynamic demand can be addressed. These barriers can be summarised as follows:

- There is as yet no incentive mechanism to reward dynamic demand service providers (e.g. electrical appliance manufacturers) for enabling system benefits and carbon savings.
- Potential dynamic demand service providers have no assurance that an incentive mechanism will be established.
- There is as yet no universal and publicly agreed standard of compliance for a dynamic demand appliance to deliver reliable and quantifiable system benefits and carbon savings.
- There is no process or roadmap in place for overcoming these barriers and no means for key stakeholders to have their say in shaping the process.

5. What support mechanisms have so far been suggested?

A number of possible support mechanisms that have been suggested by key stakeholders are summarised below

5.1 The Carbon Emissions Reduction Target (CERT), previously known as the third phase of the Energy Efficiency Commitment, or EEC3

A policy measure suggested by a number of stakeholders is to include dynamic demand appliances as a valid carbon saving measure under the Carbon Emissions Reduction Target (CERT), which will replace the Energy Efficiency Commitment (EEC) from 2008 to 2011, or the post-2011 obligation. This could create additional demand for such appliances, leading to increased sales for those manufacturers who adopt the technology. If dynamic demand could be accredited under future carbon saving schemes, the technology could represent an attractive option for those wanting to obtain credit under those schemes, given its simplicity and low-cost.

However, there is significant doubt as to whether dynamic demand would be an acceptable measure under CERT, given that the savings are gained at system-level rather than at a consumer level. This issue and the accreditation of dynamic demand under future carbon savings schemes will be discussed with both Defra and Ofgem over the coming months. The availability of an authoritative per-appliance figure for carbon savings and the establishment of an agreed standard for compliant dynamic demand appliances will be key inputs to these discussions.

These are key objectives of the BERR supported research project currently underway.

5.2 Consumer-led

One of the key challenges for dynamic demand is that it does not yield direct energy savings for the consumers using the domestic appliances. Instead, the potentially considerable energy savings are achieved at a system-level. For this reason, it seems unlikely that relying on consumer demand will provide an adequate market driver to ensure sufficient uptake of the technology to provide system-level benefits. Dynamic demand appliances do not use less electricity overall, they simply use it at times that increase system-level efficiency. There is the potential for a “green” motivation to purchase a dynamic demand appliance in order for consumers to “do their bit”. However, this seems unlikely to deliver rapid and widespread adoption of the technology to the level that would provide system benefits. However if dynamic demand could be given incentives under future carbon savings schemes, such as CERT or its replacement for 2011 and beyond, a combination of green marketing and deployment via carbon saving targets placed on Suppliers can be conceived, which could lead to uptake of the technology driven by a mutually reinforcing process of manufacturer or energy company promotions and consumer demand. It is notable that media coverage so far (including reports on Channel 4 News, Radio 4’s Today programme and in New Scientist) have been extremely positive and supportive, with the idea treated as a simple, innovative and welcome device for helping people take small steps to reduce their carbon emissions while, at the same time, contributing to the secure and efficient operation of the electricity grid.

5.3 Direct legislation

Some have also suggested that if dynamic demand were shown to be a very low-cost carbon-saving measure with no adverse effect on appliance quality, it could simply be made a legal requirement for all suitable appliances. However, single market issues notwithstanding, which for instance would prevent Member States from imposing unilateral restrictions on traded goods, there is concern that such an approach could lose the good-will and enthusiasm of private sector partners. The development of dynamic demand has succeeded to date largely because of genuine environmental concern from companies and commitment to investigating options for increasing generating efficiency, thereby contributing to the reduction of carbon emissions. Compulsion might threaten this good will and enthusiasm. In any event, a market-based approach to the development of the technology is much to be preferred to direct legislation.

5.4 Industry funded: by grid operators, electricity suppliers or generators

In principle, dynamic demand technologies could considerably reduce the cost of balancing services and could also reduce supply-side investment costs for generation capacity. This has led some to ask whether the System Operator or users of the system (e.g. electricity suppliers and generators) could provide the necessary market driver, say by funding an incentive scheme. Currently, balancing service costs are managed by National Grid and the potential for

dynamic demand to reduce the need for services to be purchased from conventional generation could open up a commercial route for the deployment of the technology. Suppliers or others could encourage the take-up of the technology by leasing or discounting dynamic demand appliances and selling the aggregated response of those appliances to system frequency as a balancing service to National Grid as System Operator.

5.5 Commercially led by “vertically integrated” suppliers

Dynamic demand is part of a wider category of demand-response methods currently being discussed. Demand-response as a whole could be of interest to suppliers, particularly those with renewable generation interests. Such companies are exposed to charges via the Balancing Market for errors in predicting their supply or demand for any particular half-hour. It has been suggested that dynamic demand, by smoothing out short-term fluctuations, could help improve predictability and that the financial gains from this could provide an incentive to the update of the technology. At present it is not clear what financial gains might be possible through increased predictability and there is concern that this approach may require the technology to be remotely controlled (which would increase costs and complexity, potentially increasing the risk of failure). It might be that this approach could remove the inherent simplicity of dynamic demand and make the technology indistinguishable from other demand side technologies.

5.6 Establishment of a dynamic demand standard

Inherent to all of the options outlined above is the need for an agreed standard for dynamic demand appliances that would define which behaviours of a modified appliance should qualify for the status of a ‘dynamic demand appliance’. The standard would also allow for an authoritative statement of carbon saving per rated watt for each appliance or set of appliances, which in turn will facilitate the assessment and payment of the chosen incentive mechanism. A legally defined and universally recognised and applicable standard, established through full public and technical consultation, is essential to ensure system security and to achieve the possible system benefits and carbon savings. However, as appliances that would incorporate dynamic demand technology are internationally traded goods, there would be need to work internationally to agree an appropriate standard and to notify that standard to the European Commission under the Technical Standards and Regulations Directive 98/34/EC.

6. Conclusions and proposals for a way forward.

This report identifies encouraging evidence as to the potential of dynamic demand to increase the efficient operation of generation, reduce the costs of operating the electricity grid and reduce the emissions of greenhouse gasses. The report considers potential barriers to the uptake of the technology and reviews possible support measures. The Secretary of State therefore supports the development of dynamic control technology in principle, subject to conformation of the technology’s potential by the comprehensive analysis currently in hand.

However, the Secretary of State is of the view that it would not be appropriate to take any steps to promote the technology until such time as the results of this analysis are available and have been evaluated.

The Secretary of State intends to publish a further report, not later than August 2008, which will report on the outcome of this analysis. However, given the encouraging evidence already available as to the potential of the technology and to ensure that time is not wasted, it is proposed to embark on a programme of work which would inform the debate as to which, if any, support mechanism could be adopted, assuming that the technology's potential is confirmed. This would include the commissioning of work to investigate the possibility of utilising future carbon emissions savings schemes as a possible incentive mechanism for stimulating implementation of dynamic demand, and would address the following issues

- Assuming that a per-appliance carbon saving is attributable, could dynamic demand be included as a valid energy efficiency measure under future carbon emissions saving schemes?
- What would assessors need to know about dynamic demand in order to make a proper assessment in relation to future incentive mechanisms?
- How likely is it that participants in carbon emission savings schemes will choose dynamic demand out of the range of options available, and will this be a sufficient driver for take-up of the technology? If not, what could help overcome this?

In addition, we will continue to discuss policy and incentive options with interested parties. These discussions will mesh with, and be informed by, the analytical analysis currently in hand via the BERR -funded research programme.

URN 07/1329