THE TECHNOLOGY ASSESSMENT OF DEMAND SIDE BIDDING IN THE SOUTH AFRICAN CONTEXT*

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ABSTRACT

South Africa is currently in the grip of a severe power supply capacity constraint. January 2007 saw blackouts throughout the country, and worse was expected in the months to come. As a measure of immediate remedy Eskom has turned to demand side bidding (DSB), a methodology whereby the demand side has an opportunity to sell back flexible load to the supply side. This paper assesses DSB with the aim of evaluating and gauging the current and potential future standing of DSB as a technology product within the South African context.

OPSOMMING

Suid-Afrika ervaar tans ’n ernstige vraagstuk in elektrisiteitsvoorsiening. Vanaf Januarie 2007 kom gereelde kragonderbrekings voor, en volgens alle aanduidings lê die ergste nog voor. As ’n korttermynmaatreël beoog ESKOM ’n strategie van aanvraagbestuur en spesifiek aanvraag-bie, ’n metodologie waarvolgens verbruikers die geleentheid kry om elektrisiteit aan die verskaffer terug te verkoop. Hierdie artikel assesseer die metodologie ten einde die huidige en toekomstige gebruikers-moontlikhede daarvan as ’n tegnologieproduk binne Suid-Afrikaanse konteks te bepaal.

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1. INTRODUCTION – THE SOUTH AFRICAN CONTEXT

South Africa is viewed by the world as a young democracy with great potential, and as a leader for the African continent, leading the way in many sectors including electrical power generation. “South Africa exists both in the developed and developing world; on one hand it is the economic power house of Africa, and on the other, it is beset by developmental challenges such as unemployment, poverty and severe inequalities, largely along the lines of race – a legacy of Apartheid – and location” [1].

South Africa has always been an energy-driven economy, with the mining industry – the backbone of the economy – laying a solid foundation for the development of a firm electricity infrastructure. Eskom was formed in 1921 to provide for a power-hungry economy [2]. Currently Eskom has a total installed capacity of just less than 40,000 MW that is produced by 24 power plants dispersed throughout the country; of these, fossil fuel [coal] fired power plants are the most used (www.eskom.co.za). “Eskom is among the five largest utilities, as well as being one of the lowest cost producers of electricity [dollar equivalent R/kWh], in the world… The utility generates and supplies more than half of the total electricity consumed on the African continent” [2].

Despite such a great record, Eskom is faced with a looming crisis: the rate at which the present demand for electricity is growing is putting considerable strain on the supply capacity. Indeed, the demand for electricity was due to surpass Eskom’s installed peak load capacity by the year 2007 [3], [4] and base load capacity by 2010 [5]. This was confirmed by Tsholo Matlala, Eskom’s DSM manager [6].

As a contingency measure to contain the crisis, the government is spending billions of Rands on returning to service three mothballed power stations that were decommissioned in the 1980s. These are the Camden, Grootvlei, and Komati power stations. The new capacity was expected to be connected to the grid between 2005 and 2014 [7]. However, that might not be enough to mitigate the peak capacity shortage problem which is currently taking place.

On the demand side, Eskom has successfully introduced DSM as a tool to restrain the ever-growing demand for electricity.

2. WHAT IS DSM?

The term ‘demand side management’ (DSM) and its concept were coined by Clark Gellings in the early 1980s. The concept can be summarised as the planning and implementation of those utility activities designed to influence the customer to use electricity in ways that will produce desired changes in the utility’s load shape [8].

DSM activities include [9]:

- **Peak clipping**: reduction of peak demand
- **Valley filling**: building load during off-peak periods (used with in conjunction peak clipping)
- **Load shedding**: strategic transfer of load from peak to off-peak periods

- **Strategic conservation**: direct influence on load shape to alter end usage
- **Strategic load growth**: initiated by the utility to increase sales
- **Flexible reliability**: incentive-driven usage flexibility

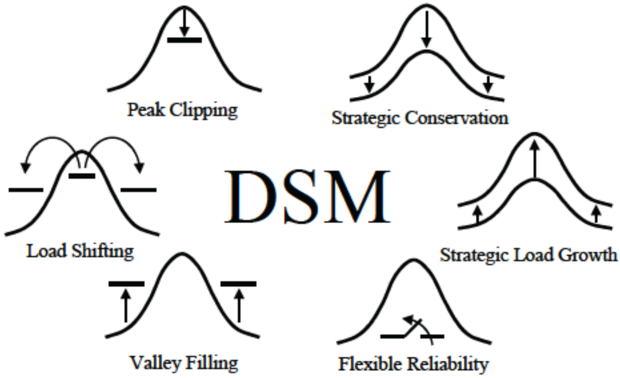

Figure 1: The six DSM activities [9]

2.1 DSM in South Africa

In the South African scenario, the two primary activities being implemented by Eskom DSM are (1) energy efficiency or strategic conservation - specifically targeting base load capacity constraints, and (2) load control (an amalgamation of load shedding, valley filling, and peak clipping strategies) - specifically targeting peak load capacity problems.

Eskom has set its 'DSM targets' as "total load reduction of 4255 MW over 20 years (2025)" [10].

Another demand side activity Eskom is seriously considering is DSB - demand side bidding.

3. WHAT IS DSB?

DSB is generically the next generation of DSM, suited for use in dynamic electricity markets. "Demand side bidding (DSB) is the mechanism that encourages consumers to offer to undertake changes in their usual pattern of consumption in return for financial reward" [11].

"By rescheduling load or agreeing to load reductions, consumers help to maintain a balance between electricity supply and demand and to ensure quality and surety of supply" [12]. "DSB starts from the proposition that it would be worthwhile paying some customers to shed their electricity load; where the cost of doing so is offset by a consequent reduction in the price of generation.... in other words it is a way to use voluntary non-essential load reduction to reduce electricity demand" [rather than producing more generation capacity] [13].

DSB has short- and long-term benefits. In the short term, it avoids the need to call on expensive reserve generators, thus reducing overall market costs. In the long term, it reduces both the size of networks and the number of generators required, and so may reduce costs and emissions [13].

4. DSB IN ESKOM'S ELECTRICITY MARKETS

The Eskom electricity markets where DSB participation takes place are segregated into two main market segments: the energy market and the reserve market [5].

A. The energy market

The energy market caters for power capacity constraints that are predictable for the next day. In the energy market, DSB participants make bids for the next day and dedicate single-hour time slots for that day.

B. The reserve market

In the reserve market the demand side participants are committed to make load instantly available at different times of notification, thus standing by to shed load as reserve capacity. This is the fundamental difference between the *energy* and *reserve* markets: the delivery of load shed is either day-ahead or instantaneous. The reserve market is further sub-divided into three markets segments (shown in Figure 2).

1) The instantaneous reserve market

Given the notification, within an action period of 10 seconds the demand side participant is to shed load, and keep it off for at least 10 minutes.

This instantaneous reserve is ideally suited for system stability – that is, when there is a sudden drop in supply levels, the demand levels can be instantly brought down to maintain stability.

2) Ten-minute reserve market

Here, once given notice, the customer needs to shed load within 10 minutes and keep the load off for at least 2 hours.

3) Supplementary reserve market

On notification, the demand side is to shed load within 2 hours, and keep the load off for a minimum of 24 hours.

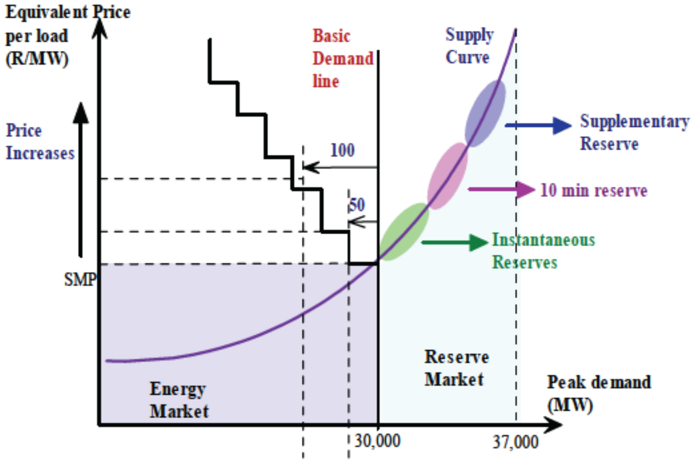

Figure 2: The Eskom DSM markets, showing a 50 MW DSB participant in the energy market (SMP = System Marginal Price)

5. THE PROPOSED APPROACH: TECHNOLOGY ASSESSMENT OF DSB IN THE SOUTH AFRICAN CONTEXT

So far in this paper DSM and DSB have been described. Now, in assessing DSB, the following approach is proposed:

- **The present**: First, the current stance of DSB in the South African context will be fully assessed. Here the technology balance sheet will be developed.
- **The past**: Here the technology roadmap will be developed to determine the timely evolution of DSB in the Eskom environment.
- **The future**: Here, using the scenarios approach, the potential future of DSB will be gauged.

6. THE TECHNOLOGY BALANCE SHEET

The technology balance sheet is a graphical representation of the inter-relationships, inter-dependence and reliance between technology, processes, products, and markets (Figure 3 below) [14].

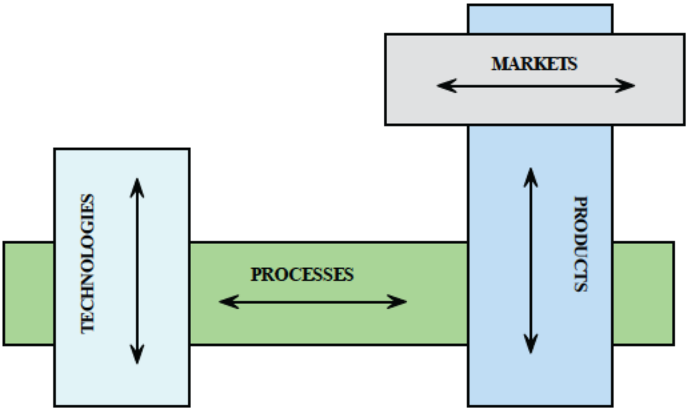

Figure 3: A typical technology balance sheet showing the various matrices of the complete technology balance sheet

1) Defining the markets

For the purpose of developing the balance sheet, the markets will be defined as the four market segments described previously: the energy market, and the three reserve markets - instantaneous reserve, 10-minute reserve, and supplementary reserve.

2) Defining the products

From an analysis of the six DSM activities of Figure 1, *peak clipping* and *load shifting* may be utilized in immediately shedding load for DSB participation. *Flexible reliability* may also be considered as a DSB product where the user receives benefits for allowing a reduced quality of supply. *Strategic conservation* looks at a complete load reduction over a longer period (compared with peak clipping and load shifting). Therefore these will be defined as the four DSB products.

3) Defining processes and technologies

The processes will be defined herein as those activities that allow DSB participation to take place within the above-defined markets: load scheduling, thermal load storage, load management, energy management, and real-time load monitoring.

Technologies will be regarded as those tools, knowledge, and people to be utilised in producing the DSB products through the processes.

4) Bringing it all together: The graphical representation

To enhance the visual appeal of the technology balance sheet, symbols will be used to measure the degree of applicability, which will be done in three phases: high, medium, and low applicability.

Figure 4 reflects this technology balance sheet.

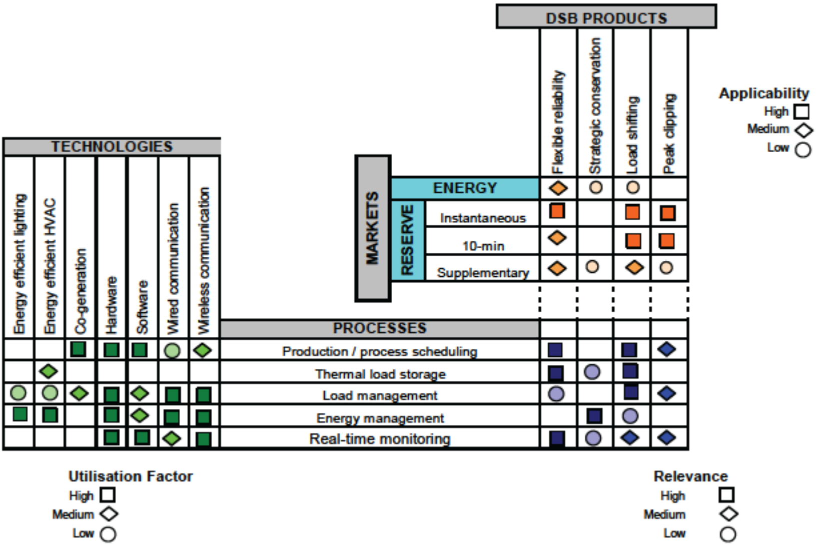

Figure 4: The complete technology balance sheet

7. THE TECHNOLOGY ROADMAP

Technology roadmapping provides a structured means for exploring and communicating the relationships between evolving and developing markets, products, and technologies over time [15].

The generic roadmap can be described as a time-based chart, comprising a number of layers that typically include both commercial and technological perspectives [15]. "The roadmap enables the evolution of markets, products and technologies to be explored, together with the linkages and discontinuities between the various perspectives" [15].

A. Roadmap vs balance sheet

The single, clear distinction between the balance sheet and the roadmap is in the 'time' variable: the balance sheet is a snapshot at one particular time, showing the specific interrelations between the technologies, products, processes, and markets at that time.

On the other hand, the technology roadmap shows the sequential time-dependent development of the specific parameters. This provides the technologist with an insight into the developments and evolution of the various parameters associated with the specific technology.

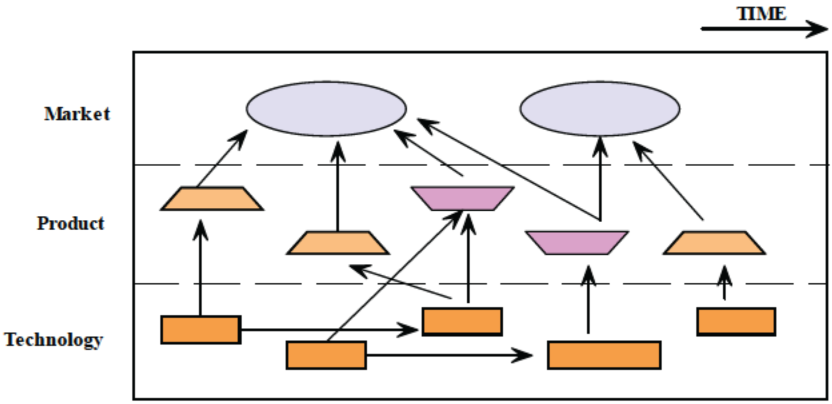

Figure 5: A typical technology roadmap, showing the graphical inter-linkages between the various technologies, products, and markets

B. Customising for the South African context

The scenario in which DSM and DSB were introduced into South Africa is drastically different from the western world. In the USA, DSM was first introduced in the 1970s as a corrective measure after the Arab oil embargo, whereas in South Africa, DSM was introduced in the late 1990s as a corrective measure for the continually constrained supply capacity of Eskom.

The most significant dates in the South African scenarios are 2007 (expected peak load capacity shortage) and 2010 (expected base load capacity shortage). Therefore, for the focus of the technology roadmap, the development shall be within a 20-year timeframe, from 1990 through to 2010, thus leading up to the above two significant dates. Within this timeframe, all the major developments surrounding DSB and those that later evolved into DSB will be highlighted.

C. The significant South African parameters

The following are the significant parameters that, for the purpose of developing the technology roadmap, consist of the technology products associated with DSB. These parameters are either directly related to DSB or have further evolved to form the crux of the concept of DSB [10] & [5].

- TOU (Time of Use) tariff: Introduced in the early 1990s, and still being successfully implemented.
- Real-time pricing (RTP): Introduced in 1996/7 and successfully implemented

until 2004.

- ELI (Efficient Lighting Initiative): Initiative by Eskom to introduce energy efficient lighting (2001).
- DSM Load Control: Introduced in 2001 as a measure to contain the growing peak capacity shortage.
- DSB: Introduced into the Eskom environment in 2003, and being successfully implemented.

D. Drawing from the balance sheet

As was the case with the balance sheet, 'real-time monitoring' – using both IT and communication technologies – is linked with the processes of 'load management' and 'process / production scheduling'. Co-generation technologies are also linked with the processes of 'load management' and 'process / production scheduling'. Here co-generation is considered as a technology. One might argue, however, that co-generation is not a technology but an *incentive*, based on the use of on-site generation technologies to save electricity costs.

The author will argue that technology may be considered as a combination of knowledge, tools and people [16]. Therefore co-generation technologies involve applying the **knowledge** of varying electricity tariffs (with RTP, TOU tariff periods, and DSB signals) and using the **tools** of on-site generation stations (obviously driven by **people**). Thus one implements the processes of 'load management' and 'process / production scheduling', which in turn contribute to DSM and DSB savings. Therefore co-generation should be considered as a technology within the scope of this article.

This brings us to the final technology roadmap, Figure 6.

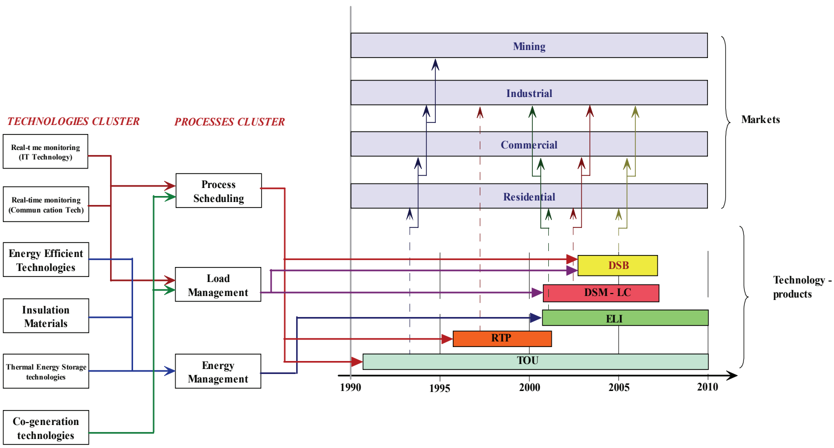

Figure 6: The complete technology roadmap

8. THE TECHNOLOGY FORECAST

"Most planners and futurists reject the idea that planning should be conducted against one single 'most likely' or 'most wanted' image of the future. *Rather, sets of scenarios should be used in planning*" [17].

"Scenarios neither predict the future, nor prevent the unexpected from happening" [18] & [19]. Therefore, in essence a scenario-logic approach looks at various possible outcomes that have a probability of occurrence.

A. Scenarios in the South African context

As can be discerned from the discussion leading up to the technology assessment of DSB, there are various possible scenarios one could consider: Eskom runs short of supply capacity (either peak or base-load); or the supply side successfully reinstates the three mothballed power stations, thus avoiding possible capacity shortages. These three possible occurrences present three distinct scenarios, as shown in Table 1.

Event	Details
Scenario 1	Severe peak capacity shortage
Scenario 2	Severe base-load capacity shortage
Scenario 3	Successful restoration of surplus supply capacity

Table 1: The three scenarios considered

The approach taken here will be to present scenarios (projections into the future) and analyse how the present should change to meet that future. The present is represented in this paper by the technology balance sheet; therefore the investigation will look into how the balance sheet is altered through the scenario. However, owing to space constraints, only the products-markets matrix of the balance sheet will be shown here.

1) Scenario 1: Severe peak capacity shortage

Eskom has given an official account of the January 2007 blackouts by stating that more than 8 generation stations were "experiencing technical problems", and as a result there was a capacity shortage... However, demand was also 1,000 MW higher than predicted (www.engineeringnews.co.za). The projection that there would be a peak capacity shortage in 2007 has materialised. What is to be expected by 2010?

Given that during January 2007 (summer season), the demand side experienced blackouts as a result of higher-than-expected demand, the likelihood of a severe peak capacity shortage can be ranked as *high*.

This rating can be further substantiated by considering that the annual, national peak demand is highest in the winter season (June-August), compared to the summer season. More outages can thus be expected in the winter seasons.

a) Net effect on the technology balance sheet

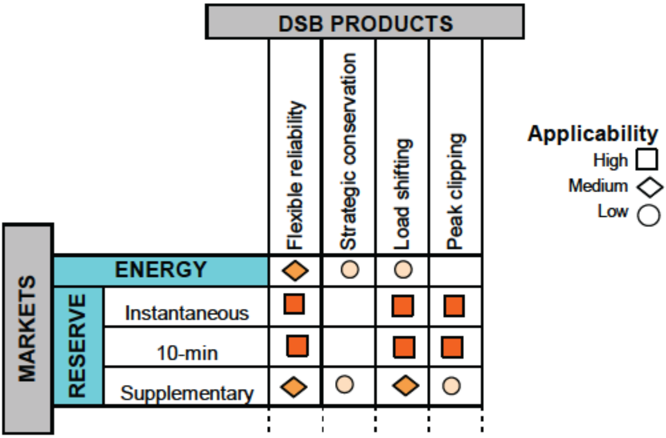

Figure 7: Net effect on the products-markets matrix of Scenario 1

Note that in Figure 7 the instantaneous and 10-minute reserve markets have the highest participation of all DSB products. This is because Scenario 1 calls for maximum (instantaneous) load reduction activities. This would see all priority shifting to DSB products in the first two reserve markets (instantaneous and 10-minute), and applicability ratings would shift to *high*.

2) Scenario 2: Severe base-load capacity shortage

Eskom CEO Thulani Gcabashe expressed his concern in a report regarding base-load capacity: "...Eskom would remain in a tight supply position until the first 750-MW base-load capacity [begins] coming on-stream in 2010/11... In fact the reserve margins, which had fallen from 25% in 2000 to between 8-10% could deteriorate further over the next few years as growth in demand matched Eskom megawatt for megawatt" [20].

Considering also that the three mothballed power plants are only expected to be fully-operational in the grid by 2014, the rating of likelihood would be considered *high*.

Scenario 2 has seen drastic alterations to the DSB compared with Scenario 1. Despite this, Scenario 2 would be a greater threat to DSB as a technology product, because the shifted load would still need to be recovered. This would invariably require capacity - the constraint in Scenario 2.

"Demand side bidding redistributes load, not reducing overall energy consumption, therefore, if the load recovery periods (which follow load reduction periods) are not considered, then DSB's effectiveness is not authentic" [21].

a) *Net effect on the technology balance sheet*

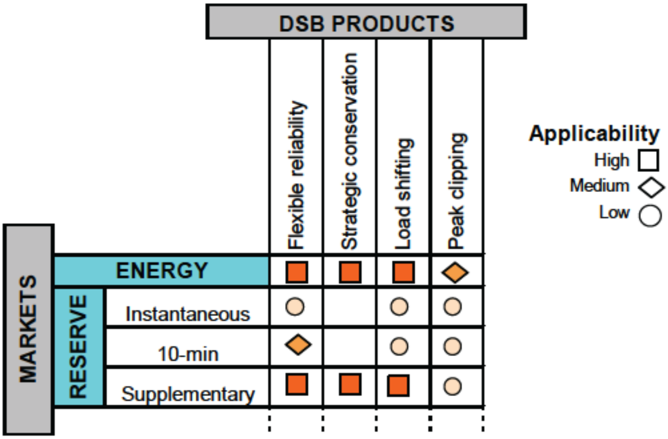

Figure 8: Net effect on the products-markets matrix of Scenario 2

3) Scenario 3: Successful restoration of supply capacity

Scenario 3 considers the event where the three mothballed power plants are successfully put back into full operation, as well as other successful supply side initiatives being implemented by 2010, so that the grid sustains sufficient supply capacity, thus nullifying the possibility of the first two scenarios even occurring.

The likelihood of such an event taking place will be considered as *low*.

This can be further supported by [20]: "Eskom would remain in a tight supply position until the first 750-MW base-load capacity [begins] coming on-stream in 2010/11."

Note that Scenario 3 has produced the lowest applicable rating in the energy and supplementary reserve markets. Surplus capacity would mean there would be minimal need to participate in day-ahead demand-supply balancing activities - hence the low ratings in the energy and supplementary reserve markets.

The rating of the remaining two reserve markets has been set up in such a manner as to keep DSB as the complete back-up reserve in case of a sudden unplanned power outage. Note, therefore, the high applicability rating of load shifting and peak clipping in the instantaneous and 10-min reserve market.

a) Net effect on the technology balance sheet

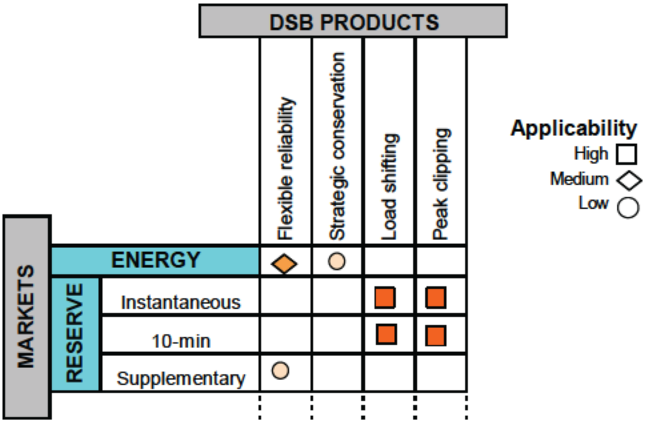

Figure 9: Net effect on the products-markets matrix of Scenario 3

In Scenario 3, DSB has been converted to a full back-up reserve activity where DSB will be utilised only when there is an unplanned power interruption.

9. CONCLUSION

As a technology product, DSB has evolved from DSM and RTP, introduced in the South African context in 2004. DSB is currently being utilised as a tool to mitigate peak capacity constraints. However, the recent blackouts in South Africa have increased pressure on the supply side to restrain the growing demand. In such a situation DSB participation would see a sharp rise.

The *status quo* is riddled with the uncertainties of the future. This paper has selected three specific scenarios covering possible future occurrences. The high-likelihood scenarios (1 & 2) pose the greatest threat to DSB. Considering the uncertain future, the following recommendations are made.

10. RECOMMENDATIONS

A. Further segregate the energy market

Market segmentation is proposed with the consideration of base-load capacity constraint. This segmentation would allow further tweaking of specific DSB products to their precise requirements; from this refinement more manageable market and DSB product chunks would be created. The proposal is based on creating two sub-market segments:

- Predicted (day ahead) base-load capacity constraints market. This market will allow for **planned** day ahead base load shortages to be matched with willing DSB participant load.

For example: if planned maintenance were to take place tomorrow at a base-load serving power plant, this would be an ideal instance where willing DSB participants could be called in to balance demand with lowered supply. For this, flexible reliability or even load shifting would be ideal. Here the supply side can cycle load shedding between DSB participants for the duration of the planned maintenance. Once the power plant is back online, the day's market will close.

- Real-time DSB participation market. This market segment allows for the **unplanned** situations to be catered for. If there is a sudden base load reduction, DSB participation can be called in.

The participants in this energy market would not be the same as the reserve market participants. First, the situation would call for load shedding for a longer duration (which reserve market participants do not do). Second, these customers should be paid an extra availability fee, as the load disruptions would be unplanned.

Another difference between this energy market segment and the reserve market segments would be that participants here would be large single-load customers (for easier manageability), whereas in the reserve market – because the load interruption is required for a short period – the customers could also be small aggregated loads (which are managed more complicatedly).

Segmenting the energy market would allow for greater flexibility in approaching base load capacity constraint situations in both planned and unplanned scenarios.

B. Invest in the supply side rather than DSB

Base-load capacity constraints cannot be mitigated or deferred for too long using DSB, because whatever load is shifted needs to be reinstated; and with a limited supply, this situation could be disastrous.

Therefore the final and most important recommendation arising from the evaluation of DSB in the South African scenario is that more investment should be made in the supply side to bring back as much supply capacity as possible. DSB can provide a short-term solution to a short-term problem, but for long-term problems, DSB is not a viable solution.

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