Demand Side Management (DSM) as a Strategy to Alleviate Power Shortages

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ABSTRACT

The dwindling fossil fuel reserves and unfavourable high initial costs of alternative energy sources in Zimbabwe requires that the potential of DSM be investigated as a strategy to alleviate power shortages at household level and reduce investment in energy infrastructure, networks and/or power plants which are thermal and hydro. Today Zimbabwe energy service industry struggle to balance the competing needs of increasing energy usage and supply constraints. Electric utility industry planned their supply to meet the needs of customers with little regard to how or when customers use energy. The demand for energy has sharply increased due to population growth in urban centres. Current generation cannot meet this demand, as is the case in many developing countries, because generating infrastructure is old and inadequate to meet end user demand. An energy demand survey on randomly selected households to determine the end uses and estimate potential savings in energy is investigated. The data collected included the type of equipment, energy consumption and the duration of operation per day. The data obtained indicating the energy consumption patterns for the areas under study were presented graphically from tabulated usage matrix. Results from graphs were analysed to identify end use applications that could potentially be targeted to reduce peak demand. Graphs with DSM were redrawn. Findings indicated a saving of 8% and 7% by switching from incandescent bulbs to LEDs and CFLs respectively for a single household and a 15% reduction in load for the selected residential sector.

Introduction

According to Bonnville E.[1] :Demand Side Management (DSM) is the implementation of policies and measures which serve to control, influence and generally reduce electricity demand. DSM aims to improve final electricity-using systems, reduce consumption, while preserving the same level of service and comfort. Table 1 shows that residential sector consumes the most of the available energy in Zimbabwe and even competing with productive industry on a world scale.

From this table it can be deduced that if DSM strategies are implemented in the residential sector, there is the most potential to reduce power consumption and demand.

Table 1. Energy Consumption by Sector, 1999 (in GJ of energy)

	Zimbabwe	World
Industry	51 046	97 819 661
Transportation	37 885	80 226 578
Agriculture	37 382	7 599 316
Commercial & public services	11 836	23 378 064
Residential	243 672	84 338 207
Non-energy uses and "other" consumption	12 019	15 262 932
Total final energy consumption	**393 843**	**308 624 713**

Source: Earth Trends[2]

Zimbabwe Situation

In general the power generation capacity in Zimbabwe is too small to meet demand from the industry and private households. Import of electricity from surrounding countries has eased the situation somewhat, but load shedding is used on a routine basis. Zimbabwe's difficult economic situation causes part of the problems, as coal for power stations may at times not be produced in sufficient amounts.

Situation for the power stations leaves a lot to be desired.[7] ZESA owns Kariba hydropower station together with its Zambian counterpart, ZESCO. The station is part of the Kariba Dam project, damming the Zambezi river. The Zimbabwean-owned capacity is said to be around 750 MW. ZESA also owns four thermal power stations, of which Hwange Thermal Power Station in the extreme west of the country is by far the largest with a theoretical capacity of about 920 MW. The other three at Harare, Bulawayo and Munyati have a nominal capacity of 270 MW together. In the last years the thermal power stations have only been producing part or no electricity due to coal shortages and maintenance neglect. Theoretical installed capacity is 1190MW against a demand of 2800MW.

There are projected stations such as Gokwe North power plant, near the Sengwa coal fields, Batoka Gorge Hydroelectric Power Project situated between Victoria Falls and Lake Kariba, a joint venture with Zambia in addition to plans to upgrade both the Hwange plant and the Kariba dam facility, however funding is not secured.

DSM in Zimbabwe

Zimbabwe imports up to 35% of its requirements from the Southern African Power Pool. The government has been considering a number of options to increase internal power generation. Such projects will require major capital investments thus the attractive option of energy efficiency and Demand Side Management. Studies done has shown that Zimbabwe has a potential to save over 20% of current energy consumption as energy is not being used in an efficient manner. This translates to 700MW of power; most of the energy is being lost through inefficient lighting systems, electricity water heaters and other poor energy management practices. [8]

The Ministry of Energy and Power Development strongly believes the national demand can be reduced through the consented efforts of each and very citizen of Zimbabwe. A National Energy Efficiency and DSM Steering Committee comprising various stakeholders is in place and has the following sub committees: Awareness, Lighting, Water Heating, Energy management in industry and commerce and Finance.

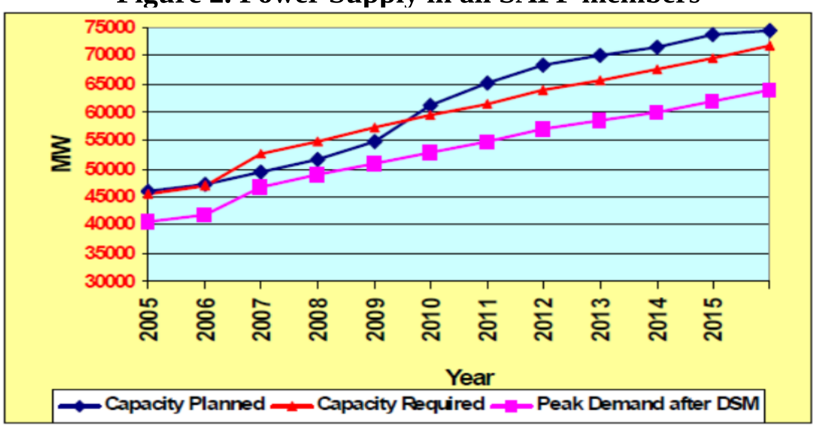
The mandate of these committees is to provide strategies that will be used to meet the DSM objective of saving 20 % of the total national energy consumption. Bankable project proposals on specific energy-efficiency and demand reduction measures have been identified, with the assistance of the Finance Sub-Committee and are currently awaiting funding. This indicates that there is no functional DSM programme in Zimbabwe.

Power Supply in Southern Africa

The power supply crisis in Southern Africa is deepening. Figure 2. According to the Southern Africa Power Pool (SAPP), the reasons for the current crisis vary: [9]

- Economic growth of more than 5% in most of the SADC countries and with South Africa at almost 6%. Because South Africa is a big economy, 6% translated into 4.6% in electrical demand which was higher than had previously been predicted at 3%.
- No tangible investments in generation capacity in the last twenty years. The last generator in Southern Africa was commissioned in 1982 in the DRC and Zimbabwe. Since then, there have been no massive investment in generation capacity.
- The 2010 World Cup that was hosted by South Africa attracted a lot of companies into building new infrastructure including stadiums, roads, hotels, shopping complex and others. This has resulted in additional stress to the SAPP grid.

Figure 2. Power Supply in all SAPP members



Source:http://www.Background_paper_Power_Supply_situation_in-Africa_FINAL.pdf

There is inadequate electrification policy and weak commitment of governments to allocate sufficient means for increasing the access to electricity have been major challenges. There is now a clear awareness of the problem and a aggressive electrification programs have started e.g. Ethiopia, Kenya and Rwanda.

Infrastructure and Policies on Energy in SADCC

Investment in additional generation and transmission in capacity is imperative given the dropping supply power generation capacity as predicted by Southern African Power Pool (SAPP) that generation capacity would fall by 2007[9]. However, SADCC has not succeeded in developing financing mechanisms for regional infrastructure development. [5]. 31000MW of new generating capacity is required in SAPP region by 2015, an increase of 70%, a distant hope for SADCC.[6] The cost impact of expanding electrification would amount to $0.9 billion per year in SAPP for development of transmission and distribution networks. [6] With regard to policy the SADCC secretariat has neither legal borrowing authority nor creditworthiness enabling it to borrow from domestic or international markets.

Background

The year 2007 saw Zimbabwe experiencing an electricity shortage as predicted by Southern African Power Pool (SAPP)[9]. The effects of this crisis were rippling throughout the Southern African Development Community (SADC) region (countries found in Southern Africa). On the other end Zimbabwe Electricity Supply Authority (ZESA) was confronted with the prospect of growing demand and tight supply due to aging coal-fired power plants. This shortage set the platform to seek alternate strategies such as working towards optimising demand side management.

As Zimbabwe needs energy to raise productivity and to improve the living standards, increase in energy demand would entail greater investment costs to the company and perhaps increased air pollution from coal powered generating plants. Historically the country's energy needs have been met by expanding the supply base with little attention to the efficiency of energy use. However this approach is raising serious financial, household and environmental problems. The magnitude of these problems underlines the need for devising strategies for improving the efficiency with which energy is currently produced and used.

Pertaining to the above mentioned problems, this research draws discussions on the technical and economical feasibilities of applying DSM as a strategy to alleviate power shortages. DSM has been thought of as a proven method of meeting economic goals in an environmentally sustainable way and is a fast and effective way to address power shortages. In view of the fact that energy, like capital and labour, is a key input to production processes, the objective of the strategy developed in this research is not to pursue energy efficiency as an end in itself, but as a means to an end where the end includes minimising the utility costs as a general focus.

In order to accomplish the solution to power shortage at household level the objectives of this research were to:

- To generate estimate profiles without DSM and when DSM strategies have been applied.
- To evaluate the potential energy savings from DSM programmes.

Hence this led to carrying out an energy demand survey in the year 2010 on randomly selected households and collecting data concerning all end use home inventory electrical equipment pertaining type of equipment, energy consumption and the duration of operation per day.

Methodology

The study used a physical survey method of research. This included observing and personal interviews. This involved carrying out an energy demand survey on an urban low density residential area with 600 units. This was selected because high energy consumption items are found in this area. Of the 600 units, four hundred randomly selected households were visited and data concerning all end use electrical equipment was collected via self report. The data collected on home inventory included the type of equipment, energy consumption and the duration of use per day. The tenants of households were asked to provide the information on the time in which they used the equipment. The survey helped to address the following questions:

- How much electricity was being used and at what time of the day? Can the use be reduced through changed operations?
- How much would be the reduction? Can the reduction result in the adoption of DSM.

Using the collected data a usage matrix was created. The usage matrix is a versatile tool for analysing load variations. By merely looking at the matrix at a glance, one can easily visualise the times with low or high demand. The usage matrix is 24 x N_A matrix, meaning there were 24 rows and N_A number of columns, where the rows represent the 24 hour period of the day and N_A is the number of appliances. This matrix uses binary language 0 and 1. 0 indicates OFF- time when the equipment was not in use and 1 indicates ON- time when the equipment was in use. To be able to fill in the data for the usage matrix, one needs to have a load matrix as shown in Table 2 below. This is then translated to the usage matrix as shown in Table 3 below.

Table 2. Load Matrix of Residential Home Inventory

Code No.	Appliance	Number	Total Power KW
1	Refrigerators	396	110
2	Deep freezers	244	60
3	Air Conditioners	102	204
4	Microwave ovens	88	176
5	Stoves with both oven & cook top	267	801
6	Stoves with separate cook top	310	620
7	Washing machines	91	180
8	Fans	421	280
9	Lighting	2864	226
10	Coffee maker	62	720
11	Rechargeable portable tools & appliances	1134	388
12	Other appliances (disc sanders, drilling machines, water pumps, electric shavers, vacuum cleaners, blowers, clothes dryers, consumer electronics)	667	1120
13	TV's	588	120
14	Hot Water Devices	372	404

Table 3. Usage Matrix

	Appliance in use													
Time	1	2	3	4	5	6	7	8	9	10	11	12	13	14
01:00	1	1	1	0	0	0	0	0	1	0	0	0	0	1
02:00	1	1	1	0	0	0	0	0	1	0	0	0	0	1
03:00	1	1	1	0	0	0	0	0	1	0	0	0	0	1
04:00	1	1	0	0	0	1	0	0	1	0	0	0	0	1
05:00	1	1	0	0	1	1	0	0	1	0	1	0	1	1
06:00	1	1	0	1	1	1	1	0	1	1	1	0	1	1
07:00	1	1	0	1	1	1	1	0	0	1	1	1	1	1
08:00	1	1	0	0	1	1	0	0	0	0	1	1	0	1
09:00	1	1	0	0	0	0	0	0	0	0	1	1	0	1
10:00	1	1	0	0	0	0	0	0	0	0	1	1	0	1
11:00	1	1	0	0	0	0	0	0	0	0	1	1	0	1
12:00	1	1	0	1	1	1	0	0	0	0	1	1	0	1
13:00	1	1	0	1	1	1	0	1	0	0	1	0	0	1
14:00	1	1	0	1	0	1	1	1	0	0	1	0	0	1
15:00	1	1	0	0	0	0	1	1	0	0	1	0	0	1
16:00	1	1	0	0	0	0	0	1	0	1	1	0	0	1
17:00	1	1	0	0	0	0	0	1	0	1	1	0	1	1
18:00	1	1	1	1	1	1	0	1	0	0	1	0	1	1
19:00	1	1	1	1	1	1	0	1	1	0	0	0	1	1
20:00	1	1	1	1	1	1	0	1	1	0	0	0	1	1
21:00	1	1	1	0	0	0	0	0	1	1	0	0	1	1
22:00	1	1	1	0	0	0	0	0	1	0	0	0	1	1
23:00	1	1	1	0	0	0	0	0	1	0	0	0	0	1
00:00	1	1	1	0	0	0	0	0	1	0	0	0	0	1

Taking the total power column as an N_A x 1 (kW) and multiplying it by the usage matrix (hours), a 24 x N_A matrix; and using laws of matrices, when multiplied in the correct order it will give the total power consumed (kWh/day), as a 24 x 1 matrix. Hence the data obtained and the times were used to draw graphs which indicated the energy consumption patterns for the households combined.

DSM Strategies

1. Use of Alternative Lighting

From the data collected, it was noted that lighting used in most households was incandescent lamps and compact fluorescent lamps (CFLSs). Day lighting was also included, that is switch off lights during the day as a potential strategy. Occupancy sensors were also considered for lighting, heating and cooling systems. Light emitting diodes (LEDs) can be used throughout a building as an accent.

Table 4. Investment Cost and Potential Benefit

Variable	LED	INCANDESCENT	CFL
Lifespan	50 000 hours	1200 hours	8000 hours
Power used	6- 8 W	60W	13- 15W
kW electricity used per 30 incandescent bulbs/yr	329kWh	3285 kWh	767 kWh
Annual operating costs/ 30 Incandescent bulbs	$46.06	$459.90	$107.38
Cost of electricity @ 0.14/kWh	(50*0.14*8)=$56.00	$420.00	$105.00
Bulbs needed for 50k hours of use	1	42	5
Cost of unit bulb	$42.00	$1.25	$5.00
Equivalent 50k hours bulb expense	$42.00	(42*1.25)= $52.50	$25.00
Total Cost	$56+ $42= $98.00	$472.50	$130.00
Total cost for 10 bulbs	10* $98= $980.00	$4725.00	$1300.00
Saving by switching from incandescent bulbs	**$3745.00**	0	**$3425.00**
% Saving per household	**8%**		**7%**

NB: Bulb breakage and replacement costs have not been factored into this comparison chart. Incandescent and CFLs are easily broken than LEDs. From the Table 4 it can be seen than economically there is a huge potential to save money by implementing DSM programmes.

2. Peak Load Reduction or Conservation

This would be applied to all hot water systems. The action was either to switch off hot water systems when not in use or to replace all with solar hot water systems.

3. Efficient Building Envelope

The concept of efficient building envelope can result in the drop of perimeter heating and cooling. The building envelope includes walls, windows, roof and floor. Putting emphasis on selecting the right insulation, type of windows, shadings and other techniques can lead to substantial energy savings. Investments in improvements of building envelope should be evaluated on the basis of life cycle costs. There are number of considerations for evaluation of windows, skylights, doors, vestibules, overhead doors, foundations and floors, roof and ceiling, infiltration, exhilaration, and building pressure. While evaluating windows the consideration includes: Single/double glazing, frame type, operable window, day lighting, glazing orientation and cooling zones, glazing coatings, cracked or broken panes, alignment of operable windows. While evaluating roofs and ceilings for adequate insulation , consideration includes: Type, thickness, and location of the existing insulation, age and condition of the roof, damaged or wet insulation, insulation voids, proper attic ventilation, space available for additional insulation, colour of roof membrane.

4. Evaporative Cooler in Combination with Exhaust Fans

Existing windows can be used to install exhaust fans in each bedroom and a cooler in the lounge. The exhaust fans can be made reversible so that when the outside air has lower temperature than inside temperature, the exhaust fan can supply fresh air to the building. When the inside temperature is lower than the outside temperature, the exhaust fan can be used to remove hot air from the building. The cooler can send fresh cool air to each exhaust fan. The combination of cooler and exhaust fan can result in achieving the average of outdoor and indoor temperature. Due to evaporative cooling, very comfortable conditions are achieved.

5. Other Technologies

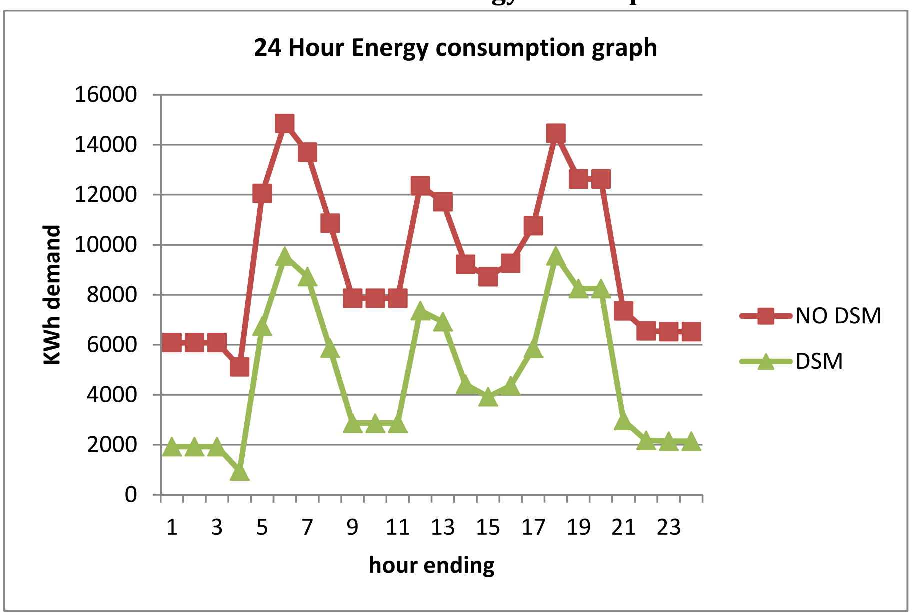
For refrigerators and washing machines, the strategy would be to use Energy Star appliances and replace old model appliances with more efficient ones. This would greatly reduce the power consumption.

After applying the potential DSM strategies, the load matrix and usage matrix was tabulated and graph drawn to check on the consumption pattern.

Discussion

Table 5 below shows a comparison of the load profiles for the households combined, with and without DSM as modelled using the survey and home inventory data.

Table 5. 24 Hour Energy Consumption



The graphs show that there are three peaks to total electric demand: early morning during the hours 4a.m to 9a.m., mid-day from 11a.m to 2pm and in the early evening from 18:00 to 20:00.. The primary loads contributing to these peaks are the cooling loads, the stoves and the hot water heating. When DSM is to be applied, with all incandescent lamps replaced with CFLs, all electric hot water heaters removed from the grid and replaced with solar units and all inefficient refrigeration appliances replaced with more efficient models there would be a reduction in load demand. The shape of the load profile is maintained. The main contributing factor to this shape of demand is because of the DSM strategies applied, which are energy efficiency and load conservation. There was no load shifting or load building strategies applied during times of peak demand which would otherwise alter the shape of the load profile and possibly raise the average during times of low demand.

The reduction in energy demand as shown by the graph may have been contributed by the fact that DSM remains underutilised in Zimbabwe because there are powerful barriers to customer and utility investment in energy efficiency. In addition to well known barriers such as capital, lack of information about DSM potential and benefits, and prices that do not reflect the full direct and indirect costs of power, Zimbabwe has its unique barriers among them the following;

- Zimbabwe lacks the legal basis to adopt effective DSM policies. There are no government driven programmes on DSM.
- Zimbabwe lacks an adequate and stable DSM funding mechanism. International experience shows that public and/or utility funding for DSM is critical to DSM success.
- Shortage of talented DSM professionals. Talented people play a pivotal role in DSM. They are needed to develop DSM policy, programs and finances, develop technology, launch publicity and conduct surveys. Currently specialised DSM staff does not exist to implement broad scale DSM programs in Zimbabwe.
- Availability of high quality energy efficient products. Zimbabwe does not have manufacturing plants for energy saving products. The ones sold on the market have quality problems. For example, energy saving CFLs of both good and bad quality are available in the market place and consumers have no way of knowing the difference. Poor quality deprives the consumer of any economic benefit and injures the reputation of energy saving lamps and appliances.
- NO incentive mechanisms for energy saving.

Annualized Potential Energy Savings for the Sample

1. No DSM applied
Energy cost/ kWh = $0.14
Energy demand per day = 4689.72 kWh
Assuming 365 days of use per year
Annualised energy cost = 365 x $0.14 x 4689.72
= **$239 644.69**
2. DSM Applied
Energy demand per day = 3992.3 kWh
Assuming 365 days of use per year
Annualised energy cost = 365 x $0.14 x 3992.3
= **$204 006.53**
Annual energy cost savings = $239 644.69 – 204 006.53
= **35 638.16**
% saving per annum = 35 638.16/239 644.69 x 100% = **15%**

Conclusion

When the impact of DSM was modelled, the energy demand profile reduced, albeit the same utility. The results show potential economic saving of $3745.00 by switching to LEDs and $3425.00 by switching to CFLs which translates to 8% and 7% respectively of money saved per household for the lifespan of a bulb. The study also revealed potential energy saving of $35 638.16 , which translates to 15% of total sampled residential cost of power could be realised by applying DSM strategies. Hence the impact of energy efficiency is to free scarce resources which would be applied elsewhere thus DSM should not be viewed separately from other energy supply options.

Recommendations

Worldwide, nations are beginning to face up to the challenge of sustainable energy production/ supplies. In other words altering the way that energy is utilised so that social, environmental and economic aims of sustainable development are supported. The following recommendations arise from the study:

- From Table 4 it is feasible that there is potential in the use of LEDs and CFLs to save energy. Hence a DSM strategy of switching to LEDs and CFLs is recommended.
- There is need for extensive publicity and to enlist the support of all households on the benefits of DSM. This can be done through media publicity and exhibitions of energy efficient devices to showcase their applicability and potential energy savings. The development of an information strategy for energy efficiency is therefore an immediate short teem priority.

References

[1]. Bonneville, E. 2006. Demand Side Management for residential and commercial end-users: AERE.

[2]. http://earthtrends.wri.org, Earth Trends,2003, Country profiles, Energy and resources, Zimbabwe.

[3] "Demand Management." Office of Energy. Government of Western Australia, n.d. Web. 30 Nov 2010.[6] Sustainable Energy Regulation and Policymaking Training Manual for Africa, Module 14 Demand Side Management, UNIDO

[4] Chiwaya, A. 2000. Reforming the power sector in Africa, Zed Books Ltd, New York, USA

[5] ITRUST, Southern Africa Trust. 2008. How can Infrastructuer Development Sterngthen Regional Integration to Overcome Poverty in Southern Africa. http://www-southernafricatrust.org/docs/policy_brief.pdf . South Africa.

[6] Orvica Rosner and Hanko Vennemo, 2008. Africa Infrastructure Country Diagnostic. http://www.eu-africa-infrastructure-tf.net/attachments/library/aicd-background-paper-5-power-invest-summary-en.pdf. ECON Poyri, UK Department of International Development.

[7] Zimbabwe Electricity Supply Authority. 2011. http://en.wikipedia.org/wiki/Zimbabwe_Electricity_Supply_Authority. Harare Zimbabwe.

[8]Ministry of Energy and Power Development. 2009. Energy Efficiency and Demand Side Management. http://www.energy.gov.zw/index.php/conservation . Harare Zimbabwe. [ref 11

[9]Dube I, Dewha S. 2006. Opportunity of Demand Side Management in Integrated Energy Resource Planning and Development in Power Sector: The Case for Zimbabwe. http://ieeexplore.ieee.org/xpl/login.jsp?tp=&arnumber=1611820&url=http%3A%2F%2Fieeexplore.ieee.org%2Fiel5%2F10730%2F33853%2F01611820.pdf%3Farnumber%3D1611820. Durban South Africa.