DEMAND SIDE MANAGEMENT AT AN ELECTRICAL DISTRIBUTION UTILITY - METHODOLOGY, APPLICATIONS, RESULTS, EVALUATIONS AND PROJECTIONS

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SUMMARY

This paper presents a methodology for evaluation of Demand Side Management Programs (DSM), aiming at the application of Integrated Resources Planning (IRP) techniques. Data from "Companhia Energética de Brasília - CEB" are used to explain this methodology. Relevant results concerning Property of Appliances and Habits/Usage Researches, are presented. The results of some DSM pilot programs are also discussed with their effects analyzed. Fifteen DSM Programs are evaluated from four points of view: participants', non-participants', utility's and community's, with concurrent calculation of the impacts over energy and peak load. Six alternatives for market supply through the expansion of in energy offer, are compared to DSM programs. Finally, a multi criteria analysis is performed in order to have supply alternatives compared in importance to DSM alternatives.

METHODOLOGY

The proposed methodology for this study comprises the following steps [1]:

- Data gathering of energy market, demand and load information, scenarios and end uses;
- Evaluation of DSM Programs;
- Comparison between supply alternatives and DSM;
- Multi criteria analysis.

General Data for Methodology Application

Basis year for this work is 1996 and horizon year 2006 comprehending 10 years of inspection.

For load characterization and knowledge of electric energy end use, a daily load curve decomposition methodology was applied, with reference to the 13.8 kV feeder's load curves analysis, to get the participation percentage of the consumers' class [2]. This methodology was applied to the CEB system daily load curve as shown in figure 1.

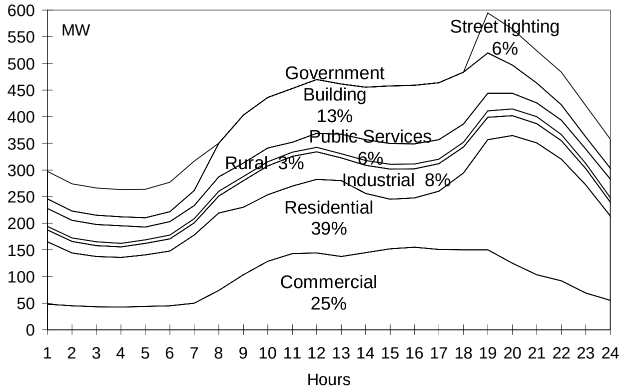

Fig. 1 - Load profile split in consumer' class

Supply Side Analysis

Six supply alternatives were considered: in the first one CEB buys from other utilities all energy that is needed at US$35/MWh, similar to present. In alternative 2 the cost is US$42/MWh and in alternative 3, US$50/MWh.

Alternative 4 considers CEB generating 20% of the energy demanded in the market. For the energy bought (80%) the adopted value was US$42/MWh; and for the own generation (20%), an investment of US$1350/kW for the hydro plant itself or an energy cost of US$32/MWh were considered. In alternative 5 an investment of US$1080/kW (hydro) was assumed or a cost of US$26/MWh for the 20% own generation, and US$42/MWh for the other 80% of bought energy. Alternative 6 was conceived considering CEB's participation in natural gas thermos generation business. The energy year horizon cost here is: 20% at US$50/MWh (thermos); and 80% at US$42/MWh (bought energy), considering an investment of US$1140/kW.

Demand Side Analysis

At CEB, residential, commercial, government buildings and street lighting consumers, represent all together more than 80% of the energy and of the peak load (figure 1). The DSM programs have, therefore, to be concentrated in those classes. Concerning the residentials CEB carried out in 1997 a survey on household electric equipment and consumption habits of residential consumers within conceded area. The research involved questionnaires in a sample by locality and consumes range of 6748 residences in a total of 401.992 consumer's units (March 1997).

Uniformity was observed in the localities when aspects such as familiar income, level of education and social class were verified. Concerning consumers' households it was possible to trace the ones with saturated acquisition and the ones with growing potential. Consumers' habit results showed the use of the main electric households.

Figure 2 shows, as an example, the distribution percentage of the use of the electric shower weekdays, for some of the researched localities. At the end of the research, estimation on the load curve composition by end use for the residentials was possible.

From figure 1, the residential load curve was extracted, which was obtained from CEB's system of global load curve measurements, and therefore without a relation to the end uses. This curve was then compared to one obtained by the addition of the main end uses. Obtained results are in figure 3. By calculating the corresponding energy to the end uses aggregated curve, 70% of the energy of the global curve was obtained.

Considering that only the main household equipment was evaluated, the conclusion was that the applied methodology was validated.

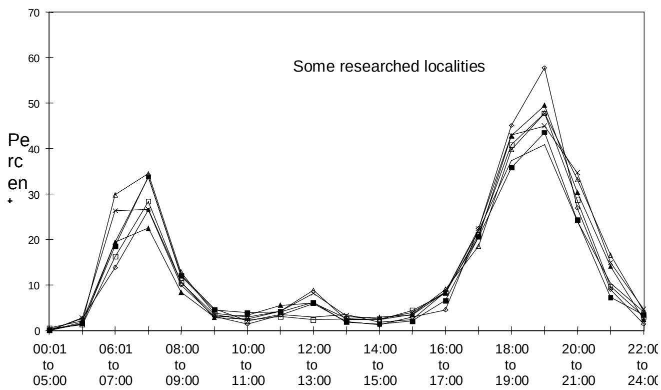

Fig. - 2 Time of use – electric shower- working days

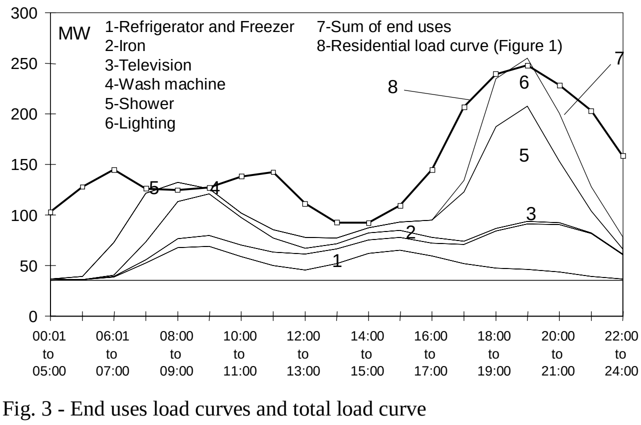

Fig. 3 - End uses load curves and total load curve

Some Experiences With DSM Programs

Lamps Substitution in The Residential Sector. 78 incandescent lamps were substituted by compact fluorescent in 37 residences in the same street aiming at checking their effect on the load curve, by measurements of the daily load curve. Figure 4 shows the results obtained in terms of the mean daily load curve and the standard deviation curve before and after lamp substitution. There was a reduction of 1.7 kW in the load peak (from 6.8 kW to 5.1 kW), for the 4.4 kW of lamp power replaced. This leads to a coincidence factor of 39% between replaced lamp power and the power reduction in the peak load.

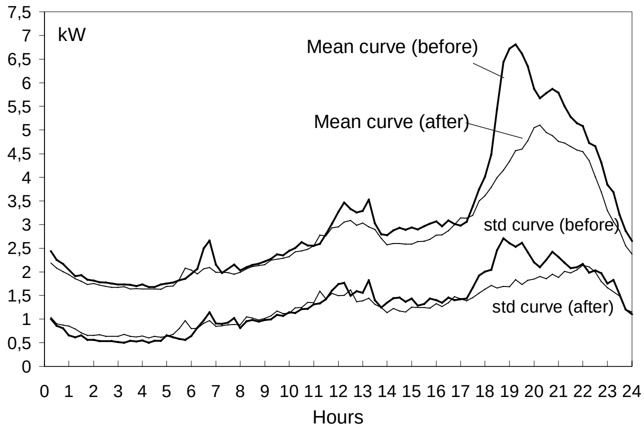

Fig. 4 - Effects of lamps substitution in residences

The DSM evaluation programs have to be done through cost benefit relations considering 4 points of view [1]: clients' participants in the programs, for the utility, non-participant clients and for the community.

$$\text{Participant test (PT)} = \frac{\text{Participant Bill Savings} + \text{Incentive Costs}}{\text{Participant Investment}} \quad (1)$$

$$\text{Utility test (UT)} = \frac{\text{Avoided Utility Capacity Costs} + \text{Avoided Utility Energy Costs}}{\text{Utility Administration Costs} + \text{Incentive Costs}} \quad (2)$$

$$\text{Ratepayer Impact Measure Test (RIM)} = \frac{\text{Avoided Utility Capacity Costs} + \text{Avoided Utility Energy Costs}}{\text{Utility Administration Costs} + \text{Incentive Costs} + \text{Decrease in Utility Revenue}} \quad (3)$$

$$\text{Total Resource Test (TRT)} = \frac{\text{Avoided Utility Capacity Costs} + \text{Avoided Utility Energy Costs}}{\text{Utility Administration Costs} + \text{Participant Investment}} \quad (4)$$

The way this program was conceived, the participant cost is zero. As consumers do not have costs but only benefits, the calculation of PT tends to infinite.

With program data, the calculation leads to: UT = 1.377, RIM = 0.706 and TRT = 5.794.

UT>1 means that the program is advantageous for the CEB.

As RIM<1 the program is not interesting concerning consumers not involved with DSM program.

The result TRT>1 shows that the program is advantageous, taking into consideration the total of benefits and costs involved.

Installation of Load Blocker in the Peak Load Period. Equipment were installed in 8 residences that restrict the load from 30A to 6A altering the power allowance of the residence for 2 hours during the load peak period. Figure 5 shows the results obtained for the mean and the standard deviation load curves for the street where the experiment was implanted. By observing this figure one can see a reduction and load move in the peak hour.

Based on this, for the analysis of this program impact, here and after, two situations for the energy consumption reduction was considered: without a reduction and with a 10% reduction.

When there is no decrease in the consumption, consequently the loss in the income of the utility is null, the UT and the RIM are the same. As there has been no investment from the consumers' side, the test under the point of view of the participant (PT) always tends to infinite. From figure 5 a load reduction of 2.6 kW is observed at 7:00 PM.

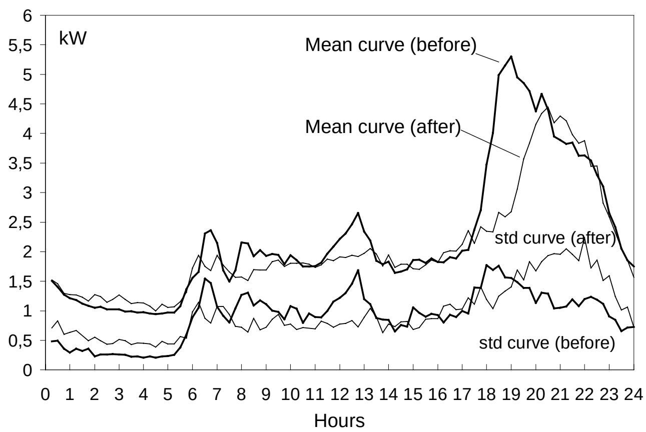

Fig. 5 - Effects of installation of load blocker

As there are eight blockers it means 0.325 kW per residence, so 0.3 kW and 0.5 kW were then considered reductions. The consumers get 30 % discount in their electricity bill, so two situations of monthly rebate had been simulated: US$ 3,00 and US$ 5,00. With the US$ 5,00 rebate all cases presented an UT< 1. With the US$ 3,00 rebate an UT > 1 was obtained only for the cases where the reduction in the peak load was of 0.5 kW. The only cases where RIM > 1 reunited a series of costs reduction conditioners for the utility and, therefore, positive for the non-participants (Rebate of US$ 3,00, without reduction in the energy and with a reduction in the demand of 0.5 kW).

All simulations presented TRT>1 showing that the analyzed DSM program is interesting from the global point of view.

Installation of Refrigerator Motor Blocker. Equipment that blocks the refrigerators from functioning for 60 minutes in the peak hour was also considered. The advantage offered for the consumer participants was a rebate of 5 % in the monthly bill. The first results have shown that there has been no significant reduction either in the consumption or in the peak load, as figure 6 shows.

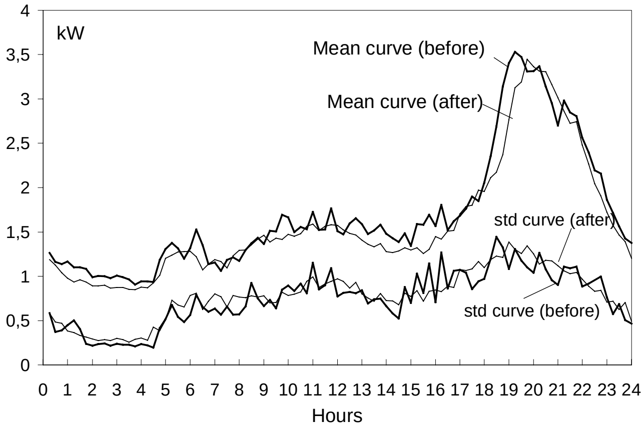

Fig. - 6 Effects of installation of Refrigerator motor blocker

Lamps Substitution in the Street Lighting System. A set of 2222 high pressure mercury vapor (HPM) lamps of 125W rating were replaced by high pressure sodium (HPS) lamps (70 W), out of a total of 4500 existing lamps in the target locality. In figure 7 the curves that represent the sum of feeders' loads of the locality before (August 96) and after (August 97), are shown. Within a year an increase in the load at the peak hour was observed. On the other hand there was a decrease in the night hours. Considering that the region is predominantly residential, the loads in the night hours are mainly from street lighting and from refrigerators in residences. Therefore, the conclusion was that there had been loads decrease due to the replacement and would be bigger (in the period after replacement) than verified in case there wasn't a DSM program.

DSM Programs Choice

Fifteen DSM measures were chosen to be analyzed, as described bellow and grouped by consumer's class

Residential. Replacement of incandescent lamps by compact fluorescent lamps; installation of load blockers during the peak load; implementation of an incentive program to the use of more efficient refrigerators in replacement to the conventional ones.

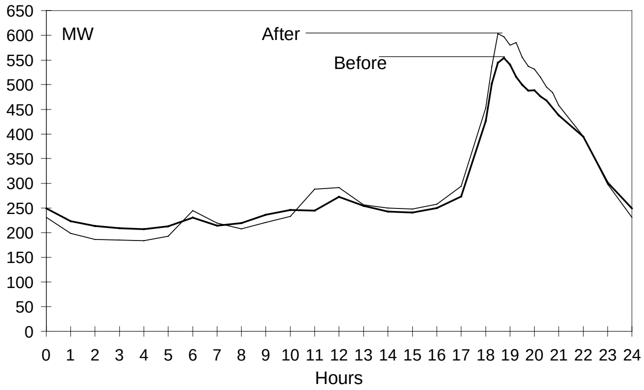

Fig. 7 - Street Lighting effects

Government Building. "Retrofit" appliance using efficient fluorescent lamps, altering the total power of the condition of 4 x 40 W (lamps) + 2 x 22 W (reactors) to 2 x 32 W (lamps) with electronic reactor; installation of circuit breakers to sectionalize lighting circuits that supply large quantity of lamps; change in the configuration of the illumination point with removal of lamps; installation of presence sensors in places that do not have a permanent occupation; installation of blockers for the air-conditioning systems.

Commercials. Programs similar to the ones chosen in the Government building had been selected having only some parameters referred to use, altered.

Street Lighting (SL). Replacement of 400 W HPM lamp (Hg 400) by 250 W HPS lamp (Na 250); replacement of HG 250 by Na 150; replacement of Hg 125 by Na 70.

Scenarios Construction

A basic scenario was established and its data projected in time. Two other (scenarios A and B) considering the effects of the DSM programs were also considered.

In Scenario A for the programs of SL a penetration of 50% was adopted, meaning 5 % a year during 10 years. For the other programs in the residential commercial and government building sectors had a penetration of 10 % adopted for the whole period comprising, therefore 1 % a year. Considering that the response to questionnaires indicated a much better acceptance than the assumed values in the calculation for the installation of blockers and for the use of efficient lamps, another scenario (B) where 30 % penetration were used instead of 10 % was established. In this alternative scenario the other DSM programs penetration were assumed 20 % instead of the 10%, keeping the 50 % for the SL programs.

Evaluation of DSM Programs

Once chosen the DSM programs to be studied, data from each of them is collected and the merit figures calculations are done. [3] to [8]. The merit figures are described bellow.

Cost of Saved Energy (CSE): relates the total annual cost caused by the implementation of the DSM program and the energy saved by this measure.

Conversation Load factor (CLF): is analogous to the load factor and relates the reduction in the average demand with the reduction in the peak demand.

Cost Effectiveness Index (CEI): measures the relation between the cost to save and the annual cost to generate 1kW, for a specific capacity factor.

The CSE, CLF and CEI will be applied later in the integration of DSM options with supply alternatives.

Table 1 shows the results of the tests: PT, UT, RIM and TRT, previously defined. In these calculations there has been applied an interest rate of 12% per year.

Table 1 - DSM programs tests

	PT	UT	RIM	TRT
Lighting residential	12,66	1,31	0,56	2,43
Refrigerator residential	6,46	0,35	0,22	1,39
Blocker residential	infinite	1,23	0,81	3,70
Retrofit commercial	80,61	6,57	0,04	2,42
Removal of lamps commercial	188,99	19,13	0,04	5,74
Circuit beakers commercial	1445,3	126,3	0,03	37,9
Sensor commercial	112,47	9,92	0,03	2,98
Retrofit government building	345,82	7,64	0,01	2,81
Removal of lamps gov. build.	812,11	22,24	0,01	6,67
Circuit beakers gov. building	9036,1	168,4	0,01	50,5
Sensor government building	698,16	13,23	0,01	3,97
Controllers air conditioning	1894,7	48,37	0,01	14,5
Hg 400 - Na 250	4,43	23,42	0,77	3,06
Hg 250 - Na 150	3,25	17,18	0,76	2,24
Hg 125 - Na 70	2,78	14,70	0,75	1,92

Changes in the Energy Consumption and in Peak Load

Once the number of appliance of the programs were projected, some figures of reduction for the horizon year were obtained and varied between 4,32% (Scenario A) and 8,78% (Scenario B) for the energy consumption, and between 8,29% (Scenario A) and 15,87% (Scenario B) for the load peak.

COMPARISON OF SUPPLY OPTIONS AND DSM

To compare the supply alternatives with DSM programs it should be plotted in the same graphic the alternatives that correspond to both forms. Figure 8 presents this comparison for the present case. In this figure supply options are presented by filed lines, while isolated points represent the DSM programs. For the supply options the ordinate y-axis contains the Total Annual Cost (US$/kW) and in the abscissa (x) axis the Capacity Factor. For the DSM programs the y-axis is the Annual Cost by kW Saved and the x-axis the Conservation Load Factor. [6] [8]

A DSM program is considered economically attractive if its respective point in the graphic is placed below the line corresponding to the supply options to which it's being compared. Figure 8 shows that all DSM programs have costs lower than 4,5 and 6 supply alternatives, being therefore interesting the implementations when compared to these options of expansion in the offer.

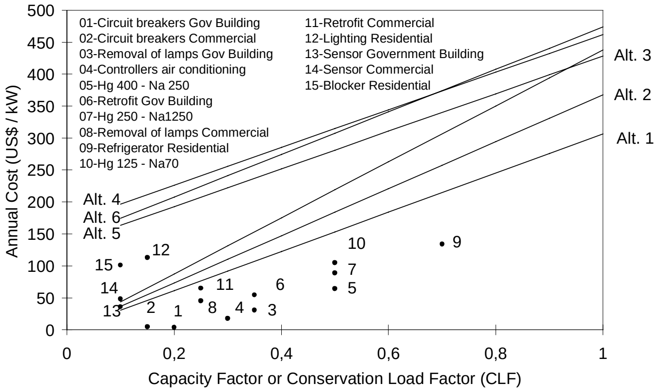

Fig. 8 - Comparison between supply alternatives and DSM

The residential lighting programs, installation of presence sensors in the commercial sector and load blocker, proved to be less economically attractive than supply alternatives 1 to 3.

For the presence sensors installation program in Government Building, a higher cost than alternative 1 was found, equivalent to the cost of alternative 2 and lower than supply options 3, 4, 5 and 6.

The next step is to check the best sequence of DSM implementation programs (Figure 9). They are organized in crescent order, according to the Cost Effectiveness Index (CEI) which is an index that relates the cost to save with supply cost, and therefore, take into account both involved cost.

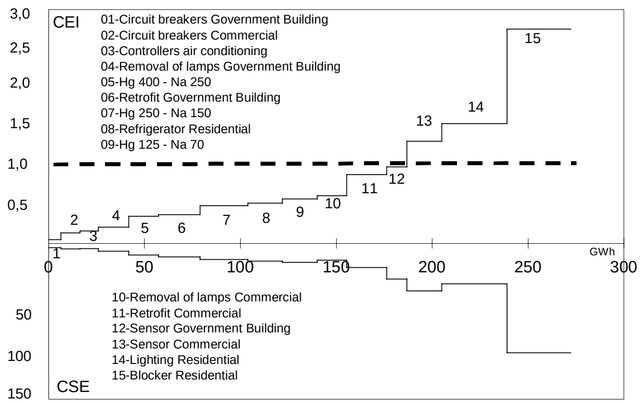

Fig. 9 - CEI and CES for energy saved

At the top part of figure 9 there is this ordering by the CEI for supply option 2. At the bottom part the CSE is represented according to the ordering of the programs at the top part. The last 3 programs (above broken line) show CEI>1 and wouldn't be implemented considering option 2.

MULTI CRITERIA USE IN INTEGRATION PROCESS

Once economic evaluations were concluded other aspects were considered to support the decision about the choice between offer expansion alternatives and DSM. The aspects are as follows: number of jobs permanently generated, impact to environment; risks of not supplying forecasted energy; components and set reliability; and technological development promotion. Adopted method for equalizing this analysis considering multiple criteria was the AHP-Analytic Hierarchy Process [9].

The aspects were compared, one to one using a scale index for the comparisons (values between 1 and 9). In this consideration 19 technicians at CEB were consulted, being 12 of them engineers with experience in planning and 7 professionals that do not work directly with electrical matters. The results are allocated in comparison matrix. The next calculation involves the steps: square the matrix and divide the sum of each line elements by the sum of all matrix elements. This proceeding is repeated till the difference between the two interactions is small enough (after the third decimal). The inconsistency index of the calculation is obtained to check answers coherence.

The level of the obtained inconsistency in this case was 0.08 and as it is lower than 0.10, it is considered acceptable. [9]

The following order of importance was obtained for the criteria: economic evaluation (38.1%) jobs generation (5.4%), environment (30%), risk (8.9%), reliability (13.9%) and technological development (3.6%).

Once this step is over, the comparison of the offer expansion alternatives versus the DSM action is done, considering, isolately, each of the criteria . Once again 19 technicians took part in this evaluation.

With a matricial processing similar to the previous one already explained, the result obtained is the levels of preference of each alternative within the criteria. For global valorization of each alternative the weighed sum of the indexes of importance related to the criteria with the levels of preference of the alternatives. It was obtained as final result: DSM programs (56.2%) and offer expansion (43.8%). Figure 10 presents the global alternatives performances considering each criterion.

After performing a sensibility analysis it was observed that for any variations in the importance indexes of the economic criteria, generating jobs and technological development, the DSM alternative always is better than the offer expansion alternative. For the environment criteria the DSM alternative predominates to the alternative of offer expansion for importance indexes related to this criteria above 16%.

Concerning risk and reliability risk criteria, the DSM surpass the expansion offer for the importance levels related to these criteria of 23% and 28% maximum, respectively.

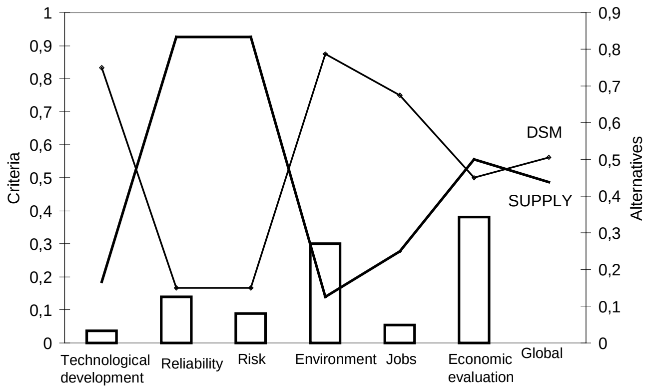

Fig. 10 - Alternatives performance considering each criterion

CONCLUSIONS

From the DSM pilot programs the conclusion is that for each kW reduced with the replacement of incandescent lamps by compact fluorescent lamps provokes a change of 0.39 kW in terms of load peak reduction. Another evidence observed was that the installation of a load blocker provokes a move in the load peak and a reduction of about 325W for each residence. Out of the 15 DSM programs evaluated and later compared to the offer expansion alternatives, all presented a positive result in the evaluation under the point of view of the community and participants customers. All of them, except for one (use of efficient refrigerators in the residential sector) showed a positive result under the point of view of the utility. None of the programs presented a positive result in the evaluation under non-participant consumers' point of view. All programs proved to be economically more interesting than supply alternatives 4, 5 and 6 and 3 programs (lighting residential, presence sensor in the commercial class and load blocker) presented less interesting results than the other 3 expansion offer options (alternatives 1, 2 and 3).

In the application of multi-criteria analysis for the comparison among the offer expansion alternatives and DSM, the following result was obtained: economic evaluation (38.1%), jobs (5.4%) employment (30%); risk (8.9%); reliability (13.9%); and technological development (3.6%).

For global valorization of alternatives 56.2% was obtained for the DSM programs and 43.8% for the expansion offers.

Acknowledgments

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