ECONOMIC VALUATION OF THE POWER OUTAGES IN ARGENTINA

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ABSTRACT

It is of the essence to know the value of power interruptions by appraising Energy Non supplied (NSE) when it comes to providing guidance for investments geared towards the development of electric grids, both at the level of National Economy as well as for Electric Energy Distributors.

In the first case, in order to develop investment plans in Generation and Transmission based on the damage inflicted upon society as a whole if faced by a lack of supply, and upon Distributors within a scenario of restricted rates as is currently taking place in Argentina, it is preemptive to be able to prioritize works that will expand facilities based on genuine needs and requirements of users.

Taking into consideration the variety of applications and demand levels for consumers of electric energy, a first segmentation was carried out of all clients dividing them into different categories:

Residential, Industrial, Commercial and Services

Unlike what happens with Industrial and Commercial Customers, who are quite precisely aware of the cost the lack of energy has in their economic equation, for Residential consumers a specific method of surveys was resorted to where all the answers needed in order to appraise non supplied KWh were obtained by means of an indirect questionnaire.

Even though the cost in U$S as well as non supplied energy are both strictly non measurable variables because they refer to the confrontation between a first situation in which electric feeding is regular and a second one in which the feeding is interrupted, for which reason it was not possible for them to co-exist simultaneously, the methodology used allows us to obtain a value in U$S per non supplied KWh which can be perfectly utilized when prioritizing investments

INTRODUCTION

It is of paramount importance to know the cost of failures, expressed in monetary terms, which the economy of the country has to bear in case of an electric power outage so as to optimize the investment needed to be made in order to expand and strengthen the electric system.

This cost can be evaluated according to three different criteria:

1º.-From a GLOBAL point of view, through macroeconomic methods: for example, based on the ratio between the Gross Domestic Product (GDP) and the total electric power consumption.

2º.-From the point of view of electric power SUPPLIERS, based on lower incomes due to the lack of sales of electric power.

3º.-From the point of view of CLIENTS or USERS, based on the cost of the "trouble" or "discomfort" that they have to put up with.

Whereas the first two criteria can be applied starting from the data made public by the National Institute of Statistics and Census and internal statistics provided by Distributors, the methodology most widely used for the application of the 3rd criterion is in the form of interviews or surveys in order to obtain data and the knowledge required to evaluate the cost of failures.

The present study focuses on the evaluation of the cost of failures from the point of view of clients, based on the results of a data gathering campaign carried out in Argentina, taking into account a sample of more than 1000 clients.

The data gathering methodology and organization were developed by a group made up of specialists from the Distributing Companies in Argentina together with the ENEL (Ente Nazionale per l´ Energía Elettrica).

The surveys corresponding to residential clients were conducted by a Market Research agency.

METHODOLOGY

The typology of clients is very varied, both from the point of view of the size and the uses that each client gives to electric power, which has allowed for segmentation into five main categories:

- Residential clients
- Large industrial clients
- Small industrial clients
- Clients from the service sector
- Other clients

A subdivision between large and small industrial clients was made taking into account the fact that larger companies have enough information about the economic and technical variables related to their own production processes to allow for the direct determination of the resulting failure cost while, for smaller companies, said data is obtained on an indirect basis. The criterion used for the subdivision was the power supply capacity and the capacity limit was set at 200kW.

For each of the first four categories of clients before mentioned, a market research study was conducted aimed at determining the cost born by clients in case of a power supply failure.

<u>Sampling Method</u>

A stochastic sample of clients was examined for each category of clients considered, that is to say, a sample where each of the clients had a chance of being included in the known sample before being removed so that the

data could be projected from that sample to the whole category. A total study was conducted only in the case of large clients with consumption over 50 GWh/ year, that is, of each and every client from that category.

Failure cost

In general terms, the cost that an electric power supply outage creates to clients refers to the power that this interruption has prevented from being supplied. This is expressed in US$/ non-supplied kWh.

It is worth noting that both the cost in US$ and the non-supplied power are strictly non-measurable variables. They refer to the comparison between a first situation in which the electric power supply is regular and a second situation in which the supply is interrupted. These situations cannot coexist simultaneously and, therefore, they can actually never be compared on a perfect basis. From another point of view, it can be said that the loss in currency can never be deducted from an accounting entry and that the non-supplied power can never be measured by means of an instrument.

In order to add up the failure cost for all the clients in the sample and obtain the total cost of the failure, D, it will be necessary to multiply the specific cost, di, in US$/ kWh related to the client, i, by the power that has not been supplied to this client, Ei.

$$D = \sum_i di\ Ei$$

The specific average failure cost related to all the clients would be

$$d = D / E$$

where E is the non-supplied power to all the clients: $E = \sum_i Ei$.

That is to say: $$d = \sum_i di \frac{Ei}{E}$$

As regards the non-supplied power Ei, it is common to assume that the kWh that have not been supplied should be proportional to the electric power consumption, for outages of the same duration and same time period. If the failure ratio is not related to the cost per kWh corresponding to each client, this hypothesis will not cause any distortion to the calculation of the average failure cost for all the clients. In addition, this hypothesis is almost forced since it is quite difficult and costly to obtain estimations of the amount of non-supplied power for each client.

The proportionality hypothesis mentioned above results in:

$$d = \sum_i di \frac{Ei}{E} = \sum_i di \frac{Wi}{W}$$

where Wi is the consumption of the client i, and

$W = \sum_i Wi$ is the total consumption.

Based on this formula, the average failure cost can be calculated without being necessary to know the amount of non-supplied power.

In order to evaluate the failure cost in monetary terms which, as it has already been said, cannot be strictly measured, there are several methods depending on the client sector.

Apart from the implicit error in the evaluation, there is also a large variability in the variable considered: we know that the failure cost can vary depending on:

- Day and time at which the outage took place;
- The duration of the outage;
- The fact that the power interruption may or may not have been previously announced by the electric power company.

The specific failure cost, that is to say, the cost related to the power that has not been consumed, is a value which, as it has been said, varies with time since it is a relationship between two variables, both varying at the same time. It seems to be appropriate to take into consideration only the cost that the average failure produces to each client for a one-hour cut occurring at any time point during the year and its average hourly consumption. In this way, the need to know the load curve of the client being considered has been avoided.

However, the need to know average annual value of the failure cost remains, taking into consideration the hypothesis that the outage producing the cost may occur at random at any moment.

This average time value was obtained by means of different methods according to the type of clients being considered.

For residential clients, a special question was used to check with each client the relative importance of interruptions occurring during several periods of time in a day.

For industrial clients, since the verification of the level of activity during the different times of the day for each facility was considered excessively difficult, an approximate formula was used. However, this formula works in such a way that the calculation is exact in those cases in which the facility practically ceases its activities between shifts, or works at a constant rate during three shifts (most industries being included into these two cases).

In general terms, the failure cost faced by the facility depends on the moment at which the outage occurs. As a result, the annual failure cost is:

$$Da = \int a(t)\, dt$$

where a (t) is the failure cost at t time.

It can be immediately noticed that if “a“ has a constant D value during L time (the facility´s working hours) and is null for the rest of the time, the result is:

$$Da = D\ L\ ;$$

And it can be inferred that this formula is obviously also valid in the case in which L extends for the whole year.

RESIDENTIAL CLIENTS

The failure cost born by residential clients was estimated in monetary terms based on data gathered by means of a sample survey conducted in that group of clients.

Those clients with power consumption under 1000 kWh/year were left out of the sample since the questions included in the questionnaire were considered inappropriate for clients with very low consumption. However, the results of the survey were extended to all residential clients, by assigning the same failure cost per kWh determined for clients with consumption right over the limit, that is between 1000 and 1500 kWh/year, to clients with an annual consumption below 1000 kWh. The resulting error cannot be but of a small value since those clients with a total consumption under 1000 kWh/year account for a small percentage of the consumption recorded for the whole residential sector.

It should also be considered that residential clients´ consumption also includes the consumption of the

electric power supply that feeds the electric applications used by a group of families, such as elevators, stairway lighting, water pumps, heating systems, etc. The failure cost/kWh related to these supplies has been considered as equal to the cost estimated for the supplies to each one.

Sampling

A sample of 600 clients was selected from the files of the main Distributors in the country. Two conditions were taken into consideration in order to assign the number of clients to each of the Companies:

* the assignment of sample clients should be proportional to the number of clients of the company, and
* a minimum of 80 interviews

The questionnaire used to gather data included questions for each client on:

- the division of the working day into six periods according to the main family activities: beginning of the day and breakfast, rest of the morning, lunch, afternoon, dinner and family gathering, nigh rest;
- the level of importance an outage may have for each of the periods mentioned above;
- if the last time that all the members of the family went out together, they went to the movies or to eat out, and the corresponding cost of that activity;
- the existence of household appliances;
- the number of family members and their professional activity;
- the tendency to give up their free time to perform an extraordinary job;
- the number of rooms in the house;
- the education level of the head of the family;
- family´s monthly income.

In addition, the interviewer evaluated the socio-economic level of the family being surveyed and the Distributors contributed with data on the electric power consumption of each client of the sample.

Alternative activity method

This method allows assuming that the failure cost should be equal to the cost of the alternative activity that the client would perform in order to obtain the same satisfaction level that would have been obtained with the activity that the client was unable to perform as a result of the electric power interruption.

As it was very difficult to identify the alternative activity of the client through a direct question, an indirect question was made to find out what activity the client and his family usually performed, when they went out for pleasure, and the cost related to that activity. Taking into account that the most usual activities carried out were "visiting relatives and friends", "going to the movies", "eating out" and "doing sports", the question made to the client in the final questionnaire only made reference to these four activities.

The failure cost/hour born by the client was estimated according to the following formula:

$$C_{haa} = h \times (c_{alt}/2) \times P$$ where:

C_{haa} = failure cost/hour according to the alternative activity method;

h = 1 if the activity indicated was going to the movies,

= 0.5 if it was going to a restaurant;

In fact, in this case, non-incurred costs of a meal at home: food supplies, beverages, time to cook and doing the washing up, detergent, hot water, etc. are deducted.

c_{alt} = cost born by the client for the alternative activity. This value is subdivided into two because the alternative activity has been considered to last an average of 2 hours, while the formula refers to the cost per hour.

P = weighting coefficient which takes into consideration the relative importance of each hour of the day on which the power outage occurs.

Method to the non-operation of household appliances

This method is used to estimate the failure cost faced by clients in terms of the cost of the services that have not been rendered (such as the washing machine) or the loss in the value of goods as a result of the non-operation of household appliances (such as the supplies in the refrigerator).

The cost of failure per hour born by residential clients was estimated for the following equipment: refrigerator, freezer, TV set, washing machine, air conditioning, "lighting and others".

The hourly failure cost born by each respondent was estimated by adding up the hourly failure cost of each type of appliance existing in the house.

The average value of all the residential clients was taken as the cost, considering the different durations of the power cuts and the different times of the day at which they occurred.

The average failure cost per hour and per person was estimated based on a family of four people and a two-hour power cut.

In the case of the refrigerator, the assumption was that its content was to lose half of its value in the case of a 24-hour power cut, since it must be consumed or cooked quickly before it starts going bad.

By assuming that the failure cost variable is proportional to the duration of the power outage, the average hourly failure cost related to the non-operation of the refrigerator was estimated at US$0.05 per person. For the freezer, following the same reasoning, the cost was set at US$0.16 per person.

Based on a research study carried out in Italy, the use of the TV set was estimated at 5 hours a day, with a resulting hourly failure cost of US$0.06 per person.

According to Italian data, the washing machine is used an average of 3.5 washes per week. In addition, an average spending of US$0.90 per person was estimated when washing outside the home.

Therefore, the corresponding average hourly cost was US$0.02 per person. An air conditioner in average Argentine weather conditions is used for approximately two months a year, being assumed it works for 8 hs/ day.

According to this assumption, estimations resulted in an hourly failure cost of US$0.06 a week.

As regards lighting and small home appliances not considered above, their wide range does not allow for an analytical evaluation of their failure cost.

It was considered that the average failure cost which results from the home appliances examined in full detail above, which account for two thirds of domestic consumption, can also be extended to "lighting and other appliances", which account for one third of the overall domestic consumption of electric power.

This resulted in an hourly failure cost of US$0.02 per person.

Family income method

By applying this method, the failure cost per working

hour is considered as equal to the income per working hour earned by the family as a whole. This method is based on the hypothesis that each worker accepts to give up his/her free time in exchange for the hourly salary for each working hour. In the same way, one hour of electric power interruption prevents the worker from enjoying that free time. When applying this method, consideration is naturally given to the fact that the value of the electric power failure cost varies during the different hours of the day. A quantitative estimation of this situation was made by using the coefficient that has already been determined for the alternative activity.

The failure cost per hour born by a client was estimated using the following formula:

Chif = Ih x P x a , where:

Chif = cost of failure per hour according to the family income method;

Ih = family hourly income estimated as the ratio between the monthly income and the average number of monthly working hours;

P = weighting coefficient taking into account the relative importance of each hour of the day at which the power outage occurs.

a = coefficient that evaluates the importance that each person gives to free time. This coefficient was estimated based on how prone the person is to perform an extraordinary job.

Determination of the average failure cost

The failure cost per kWh was estimated for each of the three methods described, determining a ratio between the failure cost per hour and the average consumption of electric power per hour. The average of these three values was taken as the failure cost per kWh.

Results

The range of the sample allows for the projection of the results obtained to the whole universe with an acceptable margin of sampling error.

The cost per kWh of a one-hour power interruption was US$2.70 for residential clients. When analyzing the following tables, it can be noted that the three methods described used for the evaluation of this cost have given analogous results:

One-hour electric power outage

Method	Interviews	Failure cost
Alternative activity	406	3,30
Non- use of appliances	586	2,64
Family income	586	2,31
Total	**586**	**2,70**

The analysis of the annual consumption of electric power shows a trend indicating that the cost per kWh is reduced when consumption increases.

One-hour electric power outage

Annual consumption (kWh)	Interviews	Failure cost
Up to 1500	166	3.48
1501-2 000	195	3.18
2001-3 000	155	2.44
3001-4 000	48	2.04
over 4 000	22	1.70
Total	**586**	**2.70**

Regarding information about the troubles caused by an electric power outage, the results obtained showed that 60% of the clients consider that four half-hour power cuts on different days are less serious than a single two-hour cut. In both cases, reference was made to outages that occur with no prior notice during the part of the day in which these interruptions caused the maximum failure cost for clients.

LARGE INDUSTRIAL CLIENTS

A "Large industry" is defined as the set of industrial clients with a contracted power over 200 kW.

The failure cost for the large industry was evaluated by means of a sample survey.

Methodology

Two methods were used to evaluate the failure cost for clients in monetary terms:

Loss of production cost method

By applying this method, it is assumed that the failure cost for the Company is equal to the cost it would bear due to the lack of production or the cost of recovery of that production when it can be carried out during extraordinary hours.

Added value method

By applying this method, it is assumed that the failure cost for the Company is equal to the added value that has not been produced as a result of the outage.

Results

The number of 62 interviews allows projecting the results to the whole universe with a yet acceptable margin of sampling error.

The failure cost per kWh in a one-hour cut for the large industry is equal to US$2.72. From the analysis of the following table, it can be observed that the added value method showed significantly lower values than the Loss of production cost method:

One-hour electric power outage

Method	Interviews	Failure cost
Loss of production	62	2.80
Added value	23	1.18
Total	**62**	**2.72**

The failure cost per kWh obtained by applying the loss of production cost method was also estimated for outages of different duration with and without prior notice:

DurationFailure	No prior notice	With prior notice
5 min.	9.72	-----
30 min.	3.36	3.06
1 hour	2.80	2.60
2 hours	2.48	2.30
4 hours	2.26	2.02

SMALL INDUSTRIAL CLIENTS

Small industrial clients are those with a contracted power below 200 kW.

Data gathering

The electric power failure cost born by Companies was estimated in monetary terms by the application of the direct data gathering method carried out at the domicile of the client, finding out about the costs resulting from those failures.

Since small industrial clients do not usually have analytical data about industrial costs, it was necessary to simplify data gathering as much as possible. The information gathered from each client was:

- if, in case of a power cut without prior notice, with a duration of fifteen minutes and four hours, the client can make up for the production lost and the methods for that recovery, at regular hours or during extra hours;
- if, when the electric power supply is restored, it is

necessary to perform preliminary operations in order to restart the production activity and the duration of the possible startup process;
- the number of company personnel;
- the number of annual working hours;
- the number of average vacation weeks;
- the possible number of weeks during the year when the company closes;
- the ISIC code (International Standard Industrial Classification of All Economic Activities).

Results

The range of the sample (194 clients) allows for the projection of the results obtained to the whole universe with an acceptable margin of sampling error.

The cost per kWh of a one-hour power interruption in the small industry was **US$ 3.62**. This cost obviously changes according to the duration of the outage:

Outage duration	Cost per kWh
1 quarter hour	5.22
1 hour	3.62
4 hours	3.22

THE SERVICE SECTOR

In the service sector, which mainly consists of commercial or service-rendering activities, the failure cost is made up of two elements:

- the cost born by the company using the electric power, which will probably be forced to interrupt or reduce its own activities;
- the cost born by the people, clients of the company, who cannot make use of the service.

It is easy to confirm that, for almost the whole service sector, the second aspect of the cost, that is to say, the one that is born by the clients who cannot make use of the service, bears much more importance than the cost born by the companies that have to interrupt or reduce their own level of activity.

The survey was divided into two phases, which were carried out simultaneously.

The first phase consisted of interviews to a sample of businesses/stores in order to know the level of dependence, sales activity, and continuity of the power supply for each type of business.

The second phase consisted of interviews to a sample of clients of those businesses in order to know how often each person goes to a type of store and how much time he/she loses if the store cannot carry out its own activity.

The time lost was estimated for each individual in the sample by combining the data obtained. The time was assessed by means of the average work income per capita.

Survey on stores

The survey consisted of a sample of 200 stores: 50 stores for each of the four categories involved (bakery, butcher´s, convenience store, and coffee store).

The information surveyed for each store in the sample included:

- Type of business;
- Store´s opening hours;
- Level of dependency on the sales activity, that is to say, what are the limitations, if there are any, for the sales activity to be maintained during the power supply outage;
- Power supply identification data (such as, contract holder and power meter number).

In addition, data was obtained from the Distributors´ files on the electric power consumption during the last 12 months for each client in the sample.

Survey on clients

This survey was aimed at estimating how much time a person loses if, when going to the stores considered, he/she cannot be assisted.

The time lost, evaluated based on the average hourly salary and divided by the annual electric power consumption of the stores under study, gives the average failure cost per kWh as a result of the power outage.

The survey was conducted on a sample of 200 people chosen at random.

In order to reduce the cost of the interviews, but without invalidating the survey results, the clients to be interviewed were selected considering neighboring houses close to those that had already been chosen for the residential client survey sample.

A special questionnaire was used to obtain data of each "client" about:

- Number of times (a week or a month) they go to the surveyed stores;
- The time required to go to each store;
- Some demographic characteristics (gender and age of the respondent)

Results

The failure cost born by clients, based on the time lost to go to a store and not being able to make use of the service it provides, was **US$ 2.74/kWh**

CONCLUSIONS

For all clients, the failure cost was **US$ 2.82 /kWh** that accounts for the average value of a one-hour power outage which might occur at any time during the year.

The main sectors of clients account for similar failure cost/kWh values in spite of the large variety of electric power uses in the sector and the diversity of methods to obtain the cost:

Type of client	**Failure cost**
Residential clients	**2.70**
Large industrial clients	**2.72**
Small industrial clients	**3.62**
Clients from the service sector	**2.74**

This apparent uniformity in the average failure cost values does not mean that the failure cost is the same for each client: specific analysis shows significant differences between values related to each client.

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