Energy Efficiency in Dairy milk farms. Implementation of 500 standardized energy audits

Mag. Eng.. Ernesto Elenter, Eng. Gabriel Oleggini, Phd. Eng. Pablo Darscht, Eng. Federico Arismendi, German Perez, Martín Bentancor

Project "Improvement of energy efficiency in small and medium dairy farms"
Conaprole-IDB/FOMIN agreement ATN-ME-13114-UR
New York 1648, Montevideo, Uruguay
Phone: +5982 9247171 int 2801
E-mail: eelenter@gmail.com
Website: sustentable.eleche.com.uy

1. Abstract

This paper presents the main results obtained by the project during its execution (October 2013 to March 2017).
The validation of a low-cost, standardized Energy Audit scheme is highlighted, since 540 Energy Audits were successfully performed in dairy farms located in different locations in rural areas of Uruguay.
According to the data collected by the program, an average dairy farm consumes 3.426 kWh/month, which referred to its production is equivalent to 43 kWh/1000 liters of milk produced. This means an energy cost of USD 621/month for the owner of the farm on average. The mean potential savings found is 651 kWh/month, or 19% of the consumption, but in economic terms the potential for cost reductions amounts to USD 236/month or 38% of the electricity cost for an average dairy farm.
From the energy audits, a total of 2952 suggestions were made to the producers, and the final impact survey, showed that 88% of the participants implemented at least one of the recommendations. This leads to the conclusion that the program has proved to be useful, innovative and due to its structure, could be replicated in other countries or even in other sectors of activity.

2. Introduction

The Project "ATN-ME-13114-UR", funded by CONAPROLE[1] and supported by UTE[2], is being implemented by the Inter-American Development Bank (IDB) Multilateral Investment Fund (FOMIN)[3], whose goal is the implantation of energy efficiency plans In a group of at least 500 dairy producers of the milk cooperative. The overall objective of the project is to help dairy farms to save energy, so the project focused on obtaining concrete results of savings, taking advantage of all the opportunities that are cost-effective and that are therefore attractive for the owners of the farms.

3. Methodology, Results and Impact Evaluation

3.1. Methodology

A standardized methodology has been developed for performing energy audits in dairy farms, so that they are low-cost and therefore could be carried out in small dairy farms. Following a preparatory stage, energy audits were started in October 2013. Once the program was completed, 540 energy audits were carried out in dairy establishments of various sizes and throughout the country.

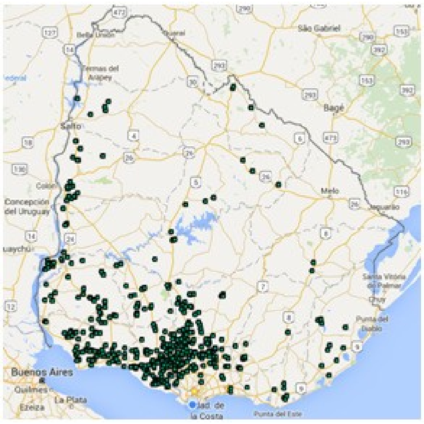

Figure 1: Energy audits carried out by the program.

For each site, an auditor performs a survey, then a report is prepared with recommendations, evaluating the payback period of each of the proposed investments. Finally, each producer is monitored in order to contribute to the implementation of the suggested recommendations. The cost of the audit transferred to the producers was USD 100 for small establishments, USD 150 for big or medium-sized farms. This price was independent of the geographic location of each establishment, which, together with program co-financing, made it possible to break down the barrier of the high cost of energy audits for small and medium-sized enterprises in the rural sector.
These methodological characteristics and the low costs towards the producers have allowed their rapid diffusion and the large volume of energy audits carried out in the 3 and a half years of work.

[1] National Cooperative Association of Milk Producers (www.conaprole.com.uy)
[2] The National Administration of Power Plants and Electric Transmissions (UTE) is a Uruguayan state-owned utility. (www.ute.com.uy)
[3] http://www.fomin.org/es-es/

The project co-finances the value of audits. 66% is contributed by Conaprole and FOMIN, while the producer only pays 34% of the total cost. Thus the standardized method of performing these energy audits allowed them to be made at a total cost of USD 450, of which the producer paid USD 100 in the case of small and USD 150 for medium and big producers.

3.2. Main results

As a base line of energy efficiency, dairy establishments have been characterized based on the Energy Performance Indicator kWh per 1000 liters delivered (EPI). This indicator is strongly related to the scale of establishments, so the indicator has been disaggregated based on this criterion. The delivery ranges used to determine the strata were:

a.- Small <1000 liters per day (equals a quantity of 50 cows aprox.).
b.- Medium, between 1000 and 3000 liters per day (between 50 and 150 cows).
c.- Big > 3000 liters per day (greater than 150 cows).

The following graph shows the distribution by scale of the participating establishments:

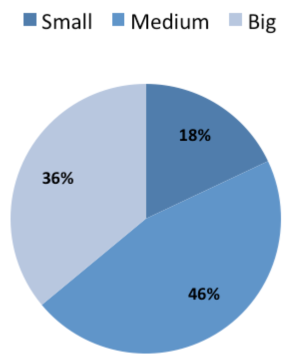

Figure 2: Distribution of establishments per size

From the previous distribution it is clear that mainly medium and large dairies have used the tool. This can be interpreted as a problem since small establishments are more vulnerable to the variation of energy costs.
In Table 1 we can see the EPI´s and the energy cost per 1000 liters of milk delivered in the 3 sizes.

Size	USD/kWh	USD/1000l	kWh/1000l
Small	0,22	16,56	74
Medium	0,20	9,68	48
Big	0,19	7,36	38
Average	0,21	11	54

Table 1: Energy intensity and electricity costs per 1000 liters of milk produced.

If we observe the energy intensity in function of the daily milk delivered as in figure 3, we can see the influence of the scale on this indicator.

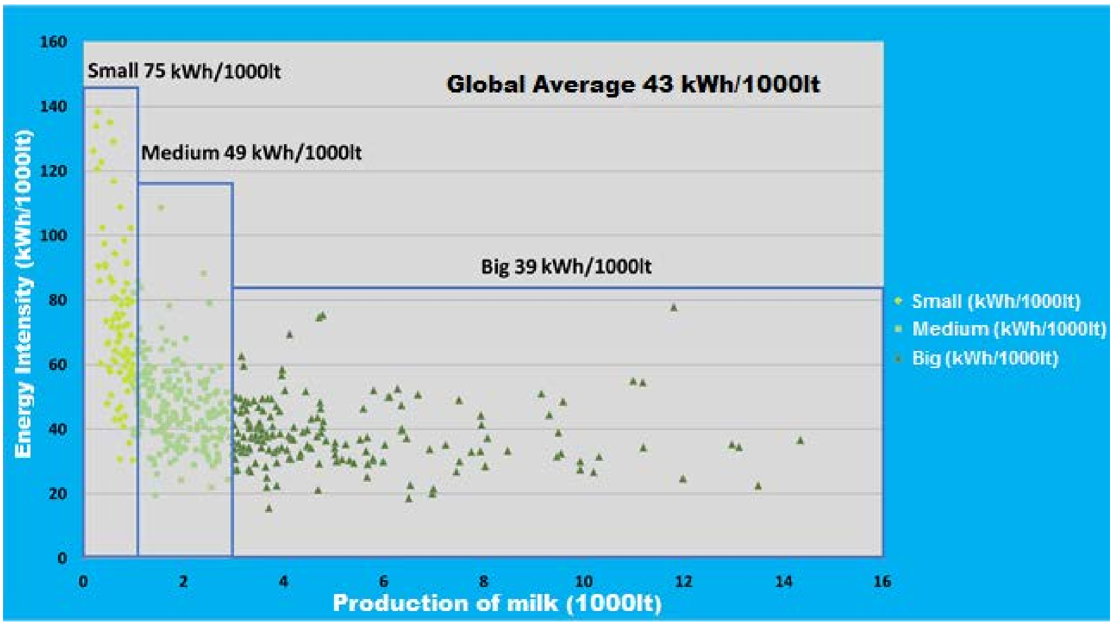

Figure 3: Energy intensity vs. daily milk production.

Some aspects to emphasize:

1.- There are small producers that achieve very good results, surpassing even large dairies, although in great majority they require a greater amount of energy to harvest the milk in relative terms. In this category the dispersion is very large with values between 30 and 138 kWh/1000 lt. Another effect that makes a difference with small farms is that energy consumption in the households of producers is usually included in the same electricity supply (same meter), so they home energy use is also included in the energy intensity indicator.

2.- The dispersion between the Big and the Medium is not so wide, practically the dairy farms that produce more than 2000 liters per day reach similar intensities to those achieved by large dairies.

3. In all the scales, the project found very dissimilar cases in terms of energy intensity. This is due, among other explanations, to the different productive dynamics of each establishment.

Based on a study carried out in May 2013 by the Center for Clean Production of the University of Montevideo[4], which analyzed the energy consumption of a pilot group of 32 dairies, a criterion was developed in order to establish a guide for comparisons between them from the point of view of electric consumption. The goal was to assign to each farm, an energy label in which the level of energy efficiency could be observed according to its scale. Using this benchmark was

[4] University of Montevideo, http://www.um.edu.uy/

possible to identify easily the improvement margin of each establishment. The parameter used for the labeling is the EPI already mentioned.
Since the incidence of the scale is very important, three different criteria were established according to the scale. It can be seen in Table 2, values are expressed in kWh/1000lt.

Category	Small	Medium	Big
A	<20	<20	<20
B	20-59	20-39	20-29
C	60-99	40-59	30-39
D	100-140	60-80	40-60
E	>140	>80	>60

Table 2: Criteria for the classification of establishments according to their energy intensity

Table 3 shows the percentage of dairies within each category. As expected, most are in the intermediate category (Cat C). One important clarification is that the label given to each establishment was determined at the time of the audit, ie it does not take into account savings from subsequent implementations.

Category	Small (%)	Medium (%)	Big (%)	Total (%)
A	0	1	1	1
B	31	31	17	26
C	59	56	45	52
D	10	10	34	19
E	0	2	3	2

Table 3: Distribution of the farms according to their Energy Intensity

In order to evaluate the impact of belonging to one or another category, an example of two dairy farms is shown below, in which the impact of being in different scales can be appreciated.

Farm	Daily production (lt)	Category	USD/1000lt	Annual Difference (USD)
I	1449	A	4,3	-
II	1556 (+7,4)	E	18	7948

Table 4: Example of the impact of the energy cost on 2 farms of the same scale.

The establishments exposed in table 4 are real cases of farms that were audited by the project. The idea is to present an example of farms whose daily production is similar (7,4% in this case) and to observe the impact of belonging to one category or another, in this example, Farm II pays USD 7,948 annually more than the Farm I (+350%). This difference expressed in terms of liters of milk, is equivalent to saying that 2 days per month the production of Farm II is only used to cover its energy inefficiencies. Now, if one looks at the effect of energy inefficiency from the point of view of profitability, which is on average 7% and considering that the price per liter of milk in April 2016 was 260 USD/1000lt, the producer gets USD 18/1000lt as the net profitability of its production. The difference in costs between dairies is 13,7 USD/1000lt, so the impact of energy inefficiency on profitability is 76%.

Measures to improve energy efficiency

The measures to contribute to the improvement of energy efficiency can be divided into 2 groups, on the one hand are the measures that impact on the reduction of the unitary cost of energy, that is, that reduce the cost per kWh consumed. Usually they consist of low investment cost.
On the other hand are the Energy Conservation Measures (ECM). These measures contribute to the reduction of energy consumption per se.

Reduction of the unitary cost of energy

Table 5 shows the main measures aimed at reducing the unitary cost of energy. The table shows the average values of monthly savings and investment costs of the audited dairy farms

Measure	Savings (USD/mo.)	Investment (USD)	Payback (years)
Reactive	188	156	0,83
Rate	333	310	0,42
Demand	62	583	1,7

Table 5: Measures for the reduction of energy costs.

Brief description of the measures:

1. Reactive: Incorporation of capacitors to compensate reactive energy (power factor improvement).

2. Rate: Contracting the electric tariff (rate) that best suits the establishment energy usage. Generally this depends on the volume of energy consumed and the time schedules in which the milk is harvested.

3. Demand: Adequacy of the contracted demand with the utility company.

Measures for the conservation of energy (ECM)

Measure	Savings (kWh/mo.)	Savings (USD/yr)	Investment (USD)	Payback (yrs)
PHE	391	652	2319	3,3
VSD	415	1009	2399	3
HRT	440	767	2755	3,6
SC	114	225	2543	4,8
Timer	73	154	10	0,1

Table 6: Energy Conservation Measures

Brief description of the measures:

1. PHE: Plate Heat Exchanger, Pre-cooling of the milk performing a thermal exchange with water.

2. VSD: Variable Speed Drives in vacuum pumps of milking machines.

3. HRT: Heat Recovery Tanks, consists of a device that takes advantage of the heat removed from the milk. This heat is used water heating.

4. SC: Solar Collector, incorporation of a solar collector for the use of hot water (solar energy instead of electricity).

5. Timer: Installation of an electronic device that controls the ON/OFF of the water heater.

The number of recommendations as February 2017 is 2.952, this number of recommendations refers only to those aimed at reducing both the cost and consumption of energy, and does not include measures regarding the safety of the installation Infrastructure (that were also studied and recommended). Of the measures suggested, 402 were implemented by producers, representing 14% of the measures proposed.
On the other hand, the investment registered by the producers since the beginning of the audits is USD 1,4 millions.
According to the different surveys carried out by the project, the amount of implementations and investments are much higher than the previous mentioned. But the fact that the program could not collect formal proofs of all the investments implied in practice, that they could not be contemplated in the investment analysis (according to the rules of the program[5]). In turn, from the surveys carried out subsequently for the impact study, 88% of the producers

[5] The registered investment value arises from the documentation protocol of implementations that applied in the program, in which it was necessary to have the purchase invoice of the equipment to compute it as a registered investment, which implied in practice a sub register of the implementations.

assert that they have implemented at least one Energy Efficiency Measure after the audit.

Savings	Small	Medium	Big	Average
kWh/month	241	505	1207	651
Impact (%)	17	20	21	19
USD/month	133	197	387	236
Impact (%)	41	38	35	38

Table 7: Potential savings in energy consumption and in USD according to the scale of the establishment detected during the Energy Audits.

As can be seen in Table 7, it is estimated that the average savings per dairy farm, if all the suggestions are implemented, amounts to 651 kWh/month, representing a 19% reduction in active energy consumption. Those savings means a 38% reduction in the electricity bill.

3.3. Impact evaluation

In order to evaluate the impact of the program the energy consumption of a representative sample of dairy establishments that participated in the project were analyzed. Table 8 shows the total number of producers that are part of the cooperative and of them, the proportion that participated in the project.
26% of the farms belonging to the cooperative were audited during the program..

Producers	Non Audited	Audited	Total
Small	872	97	969
Medium	367	249	616
Big	300	194	494
Total	1539	540	2079

Table 8: Distribution of farms belonging to the Cooperative (CONAPROLE) by scale and by participation in the program.

The impact analysis was structured by the formation of several groups classified as detailed in Figure 4. In a first instance, telephone interviews were carried out with the producers to know, among other things, the degree of satisfaction with the program, the usefulness and the perception of the degree of savings obtained by the producers.

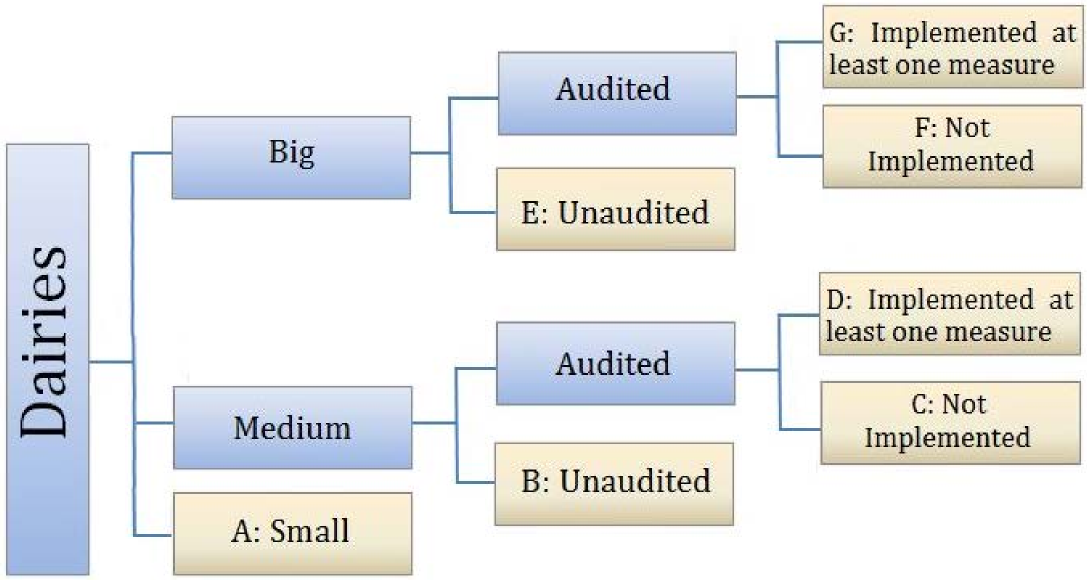

Figure 4: Groups for impact analysis.

Then, in order to obtain a 90% confidence level and a 10% confidence interval, the quantities of producers per group were established. These values are detailed in Table 9.

Producers	Non Audited	Audited	Total
Small	4	8	12
Medium	13	22	35
Big	10	22	32
Total	27	52	79

Table 9: Samples used in the impact analysis.

Table 10 details the number of producers analyzed disaggregating among those who implemented at least one measure of energy efficiency with those who did not take any action after the audit.

Group	N°
A: Small	11
B: Medium (Non Audited)	13
C: Medium (Audited – No implemented)	14
D: Medium (Audited – Implemented)	8
E: Big (Non Audited)	11
F: Big (Audited – No implemented)	13
G: Big (Audited – Implemented)	9

Table 10: Group of producers surveyed.

Subsequent to the telephonic survey, the study was complemented by an analysis of its history of power consumption, comparing, in the case of producers who actually implemented measures, the periods before and after they implemented these measures. The milestone used in those producers that did not carry out implementations was the date of the energy audit.
In order to measure the evolution of energy efficiency, the following relevant variables were studied: The energy intensity (kWh/1000lt), the electricity cost of production (USD/1000lt) and the monomial cost of energy (USD/kWh).

Evolution of energy indicators

Below is a summary of the energy indicators obtained after processing the data resulting from the survey carried out on the sample. In the case of energy intensity and electric cost, the median of the sample was considered, due, among other things, to the great dispersion of the results.

	Evolution kWh/1000lt	
Scale	Before/After (kWh/1000lt)	Difference (%)
Small	88-70	-20
Medium	44-45	+3
Big	39-41	+6

Table 11: Energy intensity obtained from the sample.

	Evolution USD/1000lt	
Scale	Before/After (USD/1000lt)	Difference (%)
Small	14,4-12,8	-11
Medium	9-7,5	-21
Big	6,9-6,4	-7

Table 12: Energy Cost of production obtained from the sample

Refering to large dairies (Big) a slight increase of 6% in energy intensity (kWh/1000lt), and a reduction in specific cost (USD/1000lt) of 7% was observed.
In the case of medium-sized dairies, a slight increase of 3% in energy intensity (KWh/1000lt) and a reduction in specific cost (USD/1000lt) of 21% was detected.

In the dairy farms that implemented high-impact measures (big investments), the energy intensity remained constant (the indicator was prevented from rising, as it happened in the rest). The small farms present reductions in both intensity and cost.
In large establishments, which implemented measures, a reduction in the monomial energy cost of 6% on average was found. For the medium sized ones, who implemented measures, there is a reduction in the monomial cost of energy of 10% on average. Small farms, on the other hand, experienced a 16% increase in their monomial cost of energy[6].
Regarding the evolution of the energy intensity (kWh/1000lt), results of difficult interpretation were obtained, with important variations among the different dairy farms, likely explained by external factors to Energy Efficiency that influence performance (climate, dairy productivity, irrigation use, production level, milk delivery temperature, increase in wash water temperature, etc.).

4. CONCLUSIONS

The Energy Efficiency Project in dairy farms successfully achieved 540 standardized and low-cost energy audits for producers dispersed geographically in Uruguay. It is a group of rural SMEs, with little technical capacity in energy management, so the contribution of the project was perceived as very satisfactory and highly relevant for the producers, according to the final evaluation surveys performed.
The potential for energy savings detected averaged 651 kWh/month, or 19% of consumption. Considering also the measures to reduce the unitary cost of energy, the potential cost reduction on average amounted to USD 236/month that is 38% of the energy costs of the establishments.
The final evaluation of the impact of the project was carried out on the basis of a random statistical sample, which included 79 producers, segregated by size and also taking a control group of farms that had not participated in the project. This evaluation included telephonic surveys, and quantitative evaluation of historical and post-project consumption.

From the qualitative point of view, it was found that 82% of project participants were satisfied or very satisfied, and 88% implemented at least 1 measure suggested in the energy audit report. Also, 71% indicated that they had plans to implement further recommendations in the future.
The suggested measures, most implemented, were those of low investment and very short payback periods, which affected mainly the unitary cost of energy (rate changes, reactive correction, timers in water heaters, etc.). In terms of high-impact measures (greater investments), it was observed that only 12% of medium-sized and 21% of big dairy farms implemented some energy conservation measures of this type. This explains why very good results were obtained in terms of cost reductions but not so evident in the reduction of energy consumption.

---

[6] All prices are referred and updated to 2016

As for the quantitative analysis, the evolution of energy performance indicators was measured. For large dairies, there is a reduction in the monomial cost of energy (in those who implemented measures) of 6% on average and a reduction in production specific cost (USD/1000 lt) of 7%.
For medium-sized dairy farms (which implemented measures), there is a reduction in the monomial cost of energy of 14% on average. A reduction in the production specific cost (USD/1000 lt) of 21% is observed.
As for the evolution of the energy intensity (kWh/1000lt), results of difficult interpretation were obtained, with important variations between the different establishments, possibly explained by factors other than Energy Efficiency (Climate, dairy productivity, irrigation use, remittance level, milk delivery temperature, increase in wash water temperature, etc.).
Considering all the mentioned aspects, the project is considered very successful in terms of confirming the possibility of carrying out standardized and low-cost energy audits for small and medium-sized enterprises (SMEs), achieving a high level of satisfaction, and impact in the participants.
The high incorporation of energy saving measures with low level of investment and short payback periods is also observed, and the low incidence in the implementation of "hard" measures (high investments) was detected as well. This indicates the need to analyze and develop specific instruments to promote this type of investments for the best design of this type of programs to be developed in the future.

References

1. IDB, "UR-M1041: Promoting Energy Efficiency and Renewable Energy in Milk Producers", http://www.iadb.org/en/proyectos/project-information-page,1303. Html? Id = UR-M1041.

2. Morison, Gregory, Hooper, "Improving Dairy Shed Energy Efficiency Technical Report", CAENZ, New Zealand, 2007.

3. CONAPROLE, Website of the program "Tambo and Energy", http://www.energia.eleche.com.uy.

4. Ernesto Elenter, "Identification of Initiatives with Innovative Potential for Renewable Energy in Dairy Farms" Project CONAPROLE-FOMIN ATN / ME-13114-UR, Montevideo, August 2013.

5. Joaquin Viquez Arias, “Production and characterization of excreta”, ECAG Magazine Informa, no. 49, 2009.

6. Sanford, "Energy Conservation on the Farm," University of Wisconsin-Madison, 2004.