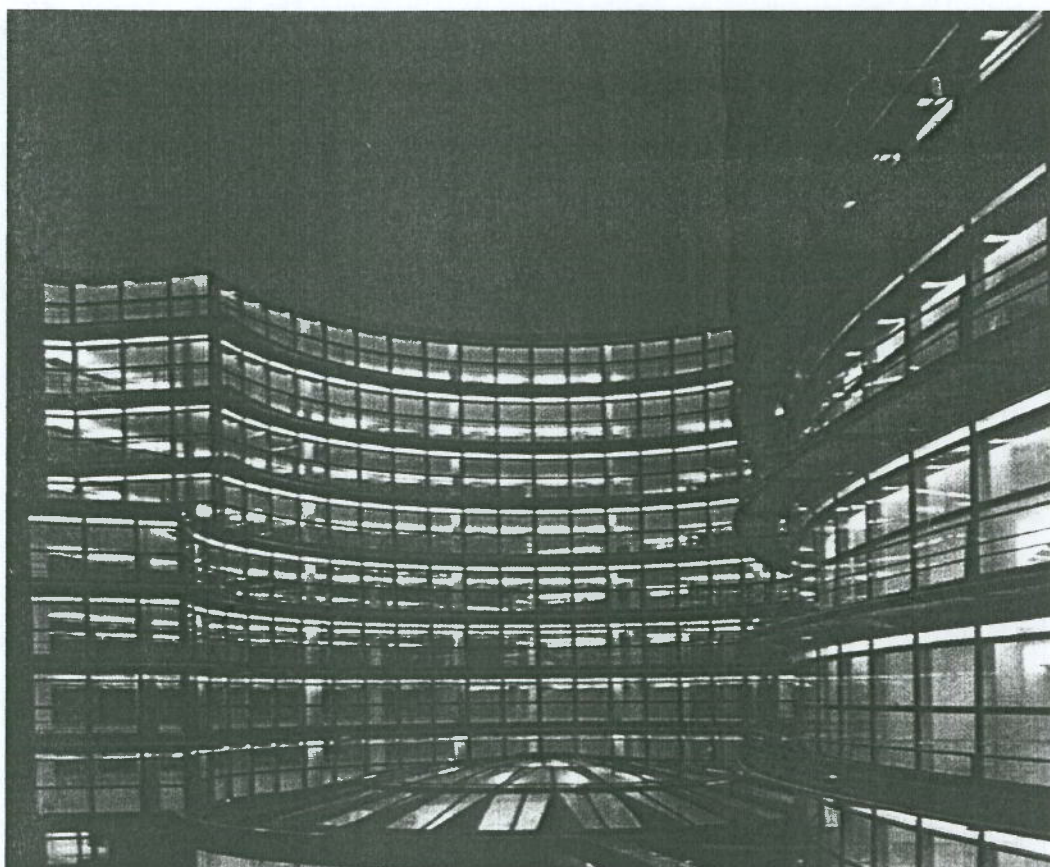


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Application of IPMVP to Italian ESCO Projects

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Summary

The paper reports a proposal of Protocol to realize an Energy Saving Measuring Program.

The proposed Protocol is based on the American IPMVP and is applicable where a final balance evaluation is allowed. The proposed Protocol may be applied only for improvements on existing plants, while it may not be applied to calculate the energy saving of a new plant, if a standard consumption is not established in advance from the Italian Electricity Authority.

Finally three different case studies are reported and discussed.

1 - Introduction

Usually, the energy saving calculation due to an energy efficiency improvement action must be always evaluated by means of the following relationship (1).

$$\boxed{\text{Annual Energy Saving}} = \boxed{\text{Annual energy before improvement}} - \boxed{\text{Annual energy after improvement}} \pm \boxed{\text{Adjustments}} \quad (1)$$

where:

Annual Energy Saving: amount of energy saved each year;

Annual Energy before Improvements: amount of energy consumed each year before the efficiency action (this value may be obtained by means of continuous measurement along one year or may be evaluated);

Annual Energy after Improvements: amount of energy consumed each year after the efficiency action (this value may be obtained by means of continuous measurement along one year or may be evaluated);

Adjustments: positive or negative quantity to take into account use variations of the plant before and after efficiency improvement. This value corresponds to the difference of energy consumed by the plant without efficiency improvements due to the plant use variation only. Adjustments may be systematic or not, depending from the variable predictably.

2 - Procedure for a Energy Saving Measurement Program

Determination of energy saving, due to a plant improvement, must be always effected on the base of a Measurement Program, that allows the checking of the accessions and the methods adopted for calculating the energy saving amount.

The Energy Saving Measurement Program is a document in which it must be reported:

- ↳ an accurate description of all the operations that have been or will be effected, possibly including the expected goals;

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- ↳ a description of all evaluated measures and of all operated forecasts, with the expected precision and a list of the analytic instruments used;
- ↳ the use, installation and test rules of all measure instruments needed for the Measurement Program.

This Program has to be more clear and exhaustive as possible, because it will be the main document on which the validity and the amount of declared savings must be checked.

In this paragraph it's proposed a base-scheme for the redaction of a Measurement Program. This scheme is divided into 7 simple basic points, that reflect the 7 points in which a Measurement Program has to be structured, and it is valid for any type of plant and/or intervention.

1. **Energy saving intervention plan:** plant modifications have to be accurately planned to obtain a good result both in terms of energy saving and Energy Efficiency Certificates. Moreover, in the planning phase, it is important to predict the actions necessary for the measurement of the really achieved energy savings.
2. **Evaluation of the energy saving intervention range:** a Measurement Program must be build, appraising the function of the plants, how the improvements influence the work, and the parameters (energetic and not) to be monitorated.
3. **Choosing one of the three "base methods":** the base method to apply must be chosen on the basis of both the considerations of item 1 and the kind of improvement on the plant. The three base method are those proposed by IPMVP and submarized below.
 - ↳ Base method A: energy savings are determined starting from values about the energy consumption (in all its forms) of the plant or a part of it. The measures can be done both with continuity, or on short periods divided by time. Some significant parameters for the energy saving determination, but not all, can be exstimated if the total effect of errors in exstimating isn't relevant compared to the final saving account.
 - ↳ Base method B: energy savings are determined starting from direct measurement of energy consumption of the plant on which it has effected the efficiency improvement.
 - ↳ Base method C: the method is adopted when the energy consumption of the whole plan must be monitored. Short or continual measurements after the plant improvements are allowed.
4. **Plant monitoring before improvements:** the attended result is the esteem of the first term of the equation (1), correspondent to the annual consumption of energy before the modification. Often to value with precision this term is not necessary to operate a continuous monitoring for one year, and is possible to use one of the following techniques:
 - ↳ examination of the invoices of supply of the energetic source or relief of the readings from the electricity meter of the distributor;
 - ↳ installation of instruments of measure to monitor one defined portion of system;
 - ↳ separate monitoring of parameters that concur to the consumption (as an example consumption of electricity and hours of operation);
 - ↳ esteem of the parameters that concur to the energetic consumption (for example the esteem of the ignition time of a public lighting system).

Parameters and measurements may be the following:

- ↳ energetic consumption and profile of the power input;
- ↳ plans and periods of occupation, plans of job, estimate of parameters connected to the production,...
- ↳ energetic rendering of the system;
- ↳ use conditions of the plant, periods of operation, parameters connected to the production, rendering of the system,...
- ↳ relief and inventory of all the devices involved, also through photo;
- ↳ if necessary, practical tests of operation, standardized cycles,...
- ↳ problems and breakdowns of the devices.

5. **Plant monitoring after improvements:** the attended result is the esteem of the second term of the equation (1), correspondent to the annual consumption of energy before the modification. In this phase must be found all the parameters before the modification and all the parameters that the introduction of new equipment forced to measure in order to allow the calculation of the energetic consumptions after the modification.
6. **Regulation of the use of the measure instruments:** it must be indicated the used devices, the used techniques of measure, the points in which have been made the measures, the procedures that have been followed.
7. **Calculation and drawing up of the final relation of the annual saving achieved:** to demonstrate the real value of the energetic saving and its persistence, every year must be delivered to the agency in charge for the check an Annual report in which must be explicit all the calculations made to determine the energetic saving, specifying clearly the way used to calculate the term "Adjustment" of the eq. (1).

3 - Application of the Procedure for a Energy Saving Measurement Program – Case studies

An example of Program of Measure realized according to the procedure mentioned at point 3.3.3 will be proposed in this chapter. After the Program of Measure, the first two Annual reports of the savings are presented.

3.1 - Description of the plant before the improvements

Three different systems of public lighting system at North of Italy for the improvement of energetic efficiency have been modified. The interventions consist in the installation of more efficient lamps and of adjustable reducing of flow.

The plan for the modification of the energetic efficiency of the lighting systems previews the following points:

1) User n. 157 548 425 – Cervi Street:

- ↳ installation of n.95 lamps of Sodium vapours H.P., power 70W, to replace n.95 lamps of Mercury vapours H.P., power 125W;
- ↳ installation of n.22 lamps of Sodium vapours H.P., power 70W, to replace n.22 lamps of Mercury vapours H.P., power 80W;
- ↳ installation of one adjustable lighting flux, power 16 kW.

2) User n. 157 548 450 – Risorgimento Street:

- ↳ Installation of n.78 lamps of Sodium vapours H.P., power 70W, to replace n.78 lamps of Mercury vapours H.P., power 125W;
- ↳ Installation of n.20 lamps of Sodium vapours H.P., power 70W, to replace n.20 lamps of Mercury vapours H.P., power 80W;
- ↳ Installation of one adjustable lighting flux, power 12 kW.

3) User n. 157 548 409 – Firenze Street:

- ↳ Installation of n.92 lamps of Sodium vapours H.P., power 70W, to replace n.92 lamps of Mercury vapours H.P., power 125W;
- ↳ Installation of n.10 new lamps of Sodium vapours H.P., power 70W;
- ↳ Installation of one adjustable lighting flux, power 10 kW.

It is previewed that the installation of the devices for the energetic saving will start after the relief of the three systems, necessary to define the starting conditions. The date to begin the works has been fixed on 22nd April 2000, and on 24th June 2000 has been tested the three systems.

3.2 - Improvement evaluations

System improvements will have the following effects:

- 1) User n. 157 548 425 – Cervi Street, n. 157 548 450 – Risorgimento Street e n. 157 548 409 – Firenze Street:
 - ↳ installation of lamps of different type involves a reduction of the power input and a variation of the luminous flow emitted;
 - ↳ installation of lighting flux reducer involves a variation of the profile of the power input of the plant;
 - ↳ the modifications do not influence the number of hours of operation of the plant.
- 2) User n. 157 548 409 – Firenze Street:
 - ↳ the installation of new points light involves an increase of the power input of the plant.

3.3 - Choice of the base method

It is chosen the base method A, even if the modifications and the measures take in consideration all the system, because the power input parameter in the successive period to the modifications is estimated for all and the three systems.

3.4 - Plant monitoring before improvements

All the systems interested to the modifications are characterized from a constant power input (if the short period of arriving to regime of the lamps is neglected and if the voltage of the electrical current supplied is considered constant). The annual hours of operation depend instead from twilight switch.

With the collaboration of the management company of the plant, on 20th April 2000 has been checked that:

- ↳ on the plant of user n. 157 548 425 – Cervi Street the following lamps were not working:
 - n.1 lamp vap. Na h.p. 250W;
 - n.3 lamps vap. Hg h.p. 125W;
- on the plant of user n. 157 548 450 – Risorgimento Street the following lamps were not working:
 - n.2 lamps vap. Na h.p. 70W;
 - n.3 lamps vap. Hg h.p. 125W;
- on the plant of user n. 157 548 409 – Firenze Street the following lamps were not working:
 - n.2 lamps vap. Hg h.p. 125W;

according with the company that habitually manages the lighting system and understood as the maintenance works, it is settled down that the 3 % of the installed lamps are constantly not working;

- ↳ in the last 2 years anomalies and out of service of the systems have not been taken place and the configuration of the plant is not changed (n. of light points, type of lamps, devices of ignition, etc.);
- ↳ timer switches and partialators devices of the lamps are not installed;
- ↳ for every system, with the instrument of measure Microvip 3 of the Elcontrol company recently setted from the manufacturer company and whose measures have turned out afflicted from an error lower than 0,2 %, has been carried out a power measure and voltage, immediately below the electricity meters of the electric power distributor; the measures have been carried out having cure that all the lamps had gone to full regimen; the results are in the table below.

Table 1 - Plant power input before improvements

User N.	Address	Voltage [V]	Power [kW]	Power of the not working lamps [kW]
157 548 425	Cervi street	386	20,1	0,7
157 548 450	Risorgimento street	378	15,1	0,6
157 548 409	Firenze street	382	11,9	0,3

↳ relief of the lamps of the systems before the modification:

Table 2 - Relief of the lamps of the systems before the modification

User N.	Address	N. of lamps Na a.p.			N. of lamps Hg a.p.	
		70 W	150W	250 W	80 W	125 W
157 548 425	Cervi street	-	17	6	22	95
157 548 450	Risorgimento street	20	3	-	20	78
157 548 409	Firenze street	-	-	-	-	92

↳ starting from the installed lamps, is possible to calculate the total luminous flow emitted from the three systems before the modification; the data regarding the luminous flow are obtained from the technical documentation supplied from the producers:

Table 3 - Relief of the total luminous flow emitted before the modification

User N.	Address	Luminous flow emitted [lm]
157 548 425	Cervi street	1.093.500
157 548 450	Risorgimento street	741.000
157 548 409	Firenze street	598.000

↳ starting from the invoices for the supply of the electric power of the three users, regarding period from 1st January 1998 to 31st December 1999, have been possible to draw the following; the definition of the below data has been possible from the readings of the monthly invoices and the monthly values are fruit of the average of the monthly values of the two years.

Table 4 - Energy consumption, power input and working hours before improvements - Cervi Street (n. 157 548 425)

Month	Energy [kWh]	Power input [kW]	Daily medium hours of operation [h]	Monthly hours of operation [h]
January	8.455	20,2	13,5	419
February	7.050	19,8	12,7	356
March	7.032	20,0	11,3	352
April	6.200	19,8	10,4	313
May	5.798	20,0	9,4	290
June	5.099	20,4	8,3	250
July	5.354	20,2	8,5	265
August	5.772	20,4	9,1	283
September	6.421	20,4	10,5	315
October	7.822	20,0	12,6	391
November	8.553	20,0	14,3	428
December	9.465	20,2	15,1	469
Total/Average	83.021	20,1	11,3	4.129

Table 5 - Energy consumption, power input and working hours before improvements - Risorgimento Street (n. 157 548 450)

Month	Energy [kWh]	Power input [kW]	Daily medium hours of operation [h]	Monthly hours of operation [h]
January	6.330	15,1	13,5	419
February	5.450	15,2	12,8	359
March	5.411	15,2	11,5	356
April	4.643	14,9	10,4	312
May	4.450	15,4	9,3	289
June	3.668	15,0	8,2	245
July	3.888	15,1	8,3	257
August	4.287	15,2	9,1	282
September	4.883	15,1	10,8	323
October	6.005	15,2	12,7	395
November	6.510	15,2	14,3	428
December	7.087	15,2	15,0	466
Total/Average	62.612	15,2	11,3	4.131

Table 6 - Energy consumption, power input and working hours before improvements - Firenze Street (n. 157 548 409)

Month	Energy [kWh]	Power input [kW]	Daily medium hours of operation [h]	Monthly hours of operation [h]
January	4.990	11,8	13,6	423
February	4.233	11,8	12,8	359
March	4.188	11,8	11,4	355
April	3.730	11,9	10,4	313
May	3.440	11,9	9,3	289
June	2.990	12,0	8,3	249
July	3.098	12,0	8,3	258
August	3.401	12,0	9,1	283
September	3.870	12,0	10,8	323
October	4.812	12,0	12,9	401
November	5.110	12,0	14,2	426
December	5.480	11,8	15,0	464
Total/Average	49.342	11,9	11,4	4.144

The variations of the power input recorded on all the three systems, are due to the not working lamps and to the variation of the supply voltage; for every system it is assumed like power input absorbed from the systems before the modifications the medium value recorded from the electricity meter of the distributor during the biennium 1998 - 1999.

3.5 - Plant monitoring after improvements

After the realization of the improvement of energetic efficiency, it is settled down to make the following:

- ↳ a clock is installed on the panel of feeding of every system, for the evaluation of the hours of operation; the instrument has got an error declared from the producer lower than 36 seconds in one year of operation and it does not need of setting; in the period from 1st July 2000 to 31st December 2000 the reading of the instrument is made at the end of every month, and in the following two years 2 times each year, precisely at the end of June and December; the greater frequency of the readings during the first year is because there is the necessity to verify carefully the operation of the flow regulators;
- ↳ during the test it has been carried out a relief of the installed equipment and the results are reassumed in the following tables.

Table 7 - Relief of the lamps and total luminous flow emitted after the modifications

User N.	Address	N. lamps Na h.p.			Luminous flow emitted [lm]	Variation percentage
		70 W	150W	250 W		
157 548 425	Cervi street	117	17	6	1.043.200	-4,6%
157 548 450	Risorgimento	118	3	-	702.800	-5,1%
157 548 409	Firenze street	102	-	-	571.200	-4,5%

All the lamps installed on the systems have been replaced with new lamps, and it is decided to adopt a system of substitution of the lamps with programmed intervals, in order to reduce to zero the number of the lamps out of service;

- ↳ during the test of the modified systems, the following measures are done on all the three systems:
 - voltage and power with the flow reducer inserted and set up to the maximum level of the voltage;

- voltage and power with the flow reducer inserted and set up to the reduced voltage level;
- voltage and power with the flow reducer inserted and set up to the maximum level of the voltage, after the lighting flux reducer;
- voltage and power with the flow reducer inserted and set up to the reduced voltage, after the lighting flux reducer;

Measures have been carried out having cure that all the lamps had gone at full power; the results are listed in the table below.

Table 8 - Measurements after improvements

User N.		157 548 425	157 548 450	157 548 450
Max voltage	Power [kW]	15,0	10,8	8,9
	Voltage [V]	386	384	384
Min voltage	Power [kW]	8,2	5,9	4,9
	Voltage [V]	386	384	384
Max voltage after lighting flux reducer	Power [kW]	14,7	10,6	8,7
	Voltage [V]	380	381	380
Min voltage after lighting flux reducer	Power [kW]	8,1	5,8	4,8
	Voltage [V]	320	321	320

These measures are repeated every six months, in order to verify if the trend of power of the system is constant:

- ↳ all the three regulators have been programmed on two levels of voltage (380/320 V), according to the timetable reported below

Table 9 - Programmation of the reducers of luminous flow

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Hour reduced regimen (320 V)	22/06	22/06	22/06	23/06	23/05	23/05	24/05	24/05	23/05	22/06	22/06	22/06
Hours daily reduced regimen	8	8	8	7	6	6	5	5	6	8	8	8

- ↳ measurements of electricity meter installed on the three systems have been collected at the end of every month (year 2000).

Table 10 - Working hours of the plant after improvements

User N.	157 548 425	157 548 450	157 548 409
July	271	273	275
August	294	295	294
September	314	310	313
October	389	389	389
November	427	423	428
December	480	488	488
Total/ Average	2.175	2.178	2.187

↳ measurements the electricity meter installed on the three systems have been collected at the end of every month (year 2001).

Table 11 - Working hours of the plant after improvements

User N.	157 548 425	157 548 450	157 548 409
June	2005	2021	2015
December	2187	2192	2199
Total/ Average	4.192	4.213	4.214

↳ During the period July 2000 - December 2001 have not taken place anomalies of the system and all the installed lamps worked correctly.

All the devices applied for the Measure Plan have been subjected to verifications and periodic calibrations.

3.6 - Annual report of energy saving for the year 2000

Consumptions before improvements have been obtained from the invoices of biennium 1998/99 and reported in Tables 4, 5 and 6.

Energy monthly consumption after improvements has been evaluated by means of following relationship (2).

$$\text{Energy [kWh]} = [(N^{\circ}h_{\text{tot}} - N^{\circ}h_{\text{red}}) \times P_{\text{max}} + N^{\circ}h_{\text{red}} \times P_{\text{red}}] \times N^{\circ}g_{\text{monthly}} \quad (2)$$

where:

$N^{\circ}h_{\text{tot}}$: Number of hours of monthly operation of the system;

$N^{\circ}h_{\text{red}}$: Number of hours of operation at reduced regimen;

P_{max} : Power measured from the electricity meter at the maximum regimen;

P_{red} : Power measured from the electricity meter at the reduced regimen;

$N^{\circ}g_{\text{monthly}}$: Number of days in the month.

Two different systematic adjustments must be take into account:

↳ adjustments related to the different number of hours of operation: they are calculated multiplying the monthly difference of operation for the average power input from the plant before the modifications;

↳ adjustments related to the different performances offered from the systems: they are estimated multiplying the difference of light emitted from the plant before and after the modifications for the inverse of the luminous efficiency of the plant after the modification for the number of hours of monthly operation of the plant after the modification; this parameter holds account also of the 10 new inserted light points in the user of Firenze Street and of the not working lamps founded before the modifications.

The measures of power made in December have evidenced that the power input is not changed in regard to the one recorded during the test of the systems and that is reported in Table 8.

Table 12 - Power reserved

		157 548 425	157 548 450	157 548 409
Before improvement	[kW]	20,1	15,2	11,9
December 2000	[kW]	15,0	10,8	8,9
Power reduction	[kW]	5,1	4,4	3,0

Table 13 - Saving evaluation - Cervi Street (n. 157 548 425)

	Consumption before improvement [kWh]	-	Consumption after improvement [kWh]	+	Adjustment (1) [kWh]	+	Adjustment (2) [kWh]	=	Saving [kWh]
Jul	5.354	-	3.011	+	120	+	-196	=	2.267
Aug	5.772	-	3.356	+	222	+	-213	=	2.425
Sep	6.421	-	3.486	+	-15	+	-227	=	2.693
Oct	7.822	-	4.149	+	-42	+	-281	=	3.350
Nov	8.553	-	4.773	+	-13	+	-309	=	3.458
Dec	9.465	-	5.514	+	230	+	-347	=	3.834
Total	43.387	-	24.288	+	502	+	-1.573	=	18.028

Table 14 - Saving evaluation - Risorgimento Street (n. 157 548 450)

	Consumption before improvement [kWh]	-	Consumption after improvement [kWh]	+	Adjustment (1) [kWh]	+	Adjustment (2) [kWh]	=	Saving [kWh]
Jul	3.888	-	2.173	+	235	+	-160	=	1.790
Aug	4.287	-	2.411	+	196	+	-173	=	1.899
Sep	4.883	-	2.448	+	-203	+	-182	=	2.050
Oct	6.005	-	2.961	+	-92	+	-228	=	2.724
Nov	6.510	-	3.368	+	-80	+	-248	=	2.814
Dec	7.087	-	4.030	+	330	+	-286	=	3.101
Total	32.660	-	17.392	+	386	+	-1.279	=	14.375

Table 15 - Saving evaluation - Firenze Street (n. 157 548 409)

	Consumption before improvement [kWh]	-	Consumption after improvement [kWh]	+	Adjustment (1) [kWh]	+	Adjustment (2) [kWh]	=	Saving [kWh]
Jul	3.098	-	1.812	+	201	+	-115	=	1.372
Aug	3.401	-	1.981	+	126	+	-123	=	1.423
Sep	3.870	-	2.048	+	-113	+	-131	=	1.578
Oct	4.812	-	2.445	+	-143	+	-162	=	2.062
Nov	5.110	-	2.825	+	26	+	-179	=	2.132
Dec	5.480	-	3.326	+	281	+	-204	=	2.231
Total	25.771	-	14.438	+	377	+	-913	=	10.797

3.7 - Annual report of energy saving for the year 2001

For this year the savings are calculated verifying the readings of the electricity meter at the end of December and June.

Consumptions before improvements have been obtained from the invoices like monthly average of biennium 1998/99 and reported in Tables 19, 20 and 21.

The monthly consumption of active energy is calculated using the previous equation (2).

Adjustment evaluation has been calculated in the same way as described before.

The measures of power made in the month of June and December 2001 have evidenced that the power input is not changed in regard to the one recorded during the test of the systems (June 2000) and it is reported in Table 8.

Table 16 - Power reserved

		157 548 425	157 548 450	157 548 409
Before improvement	[kW]	20,1	15,2	11,9
June/December 2001	[kW]	15,0	10,8	8,9
Power reduction	[kW]	5,1	4,4	3,0

Table 17 - Saving evaluation - Cervi Street (n. 157 548 425)

	Consumption before improvement [kWh]	-	Consumption after improvement [kWh]	+	Adjustment (1) [kWh]	+	Adjustment (2) [kWh]	=	Saving [kWh]
Jun	39.634	-	21.262	+	519	+	-1.450	=	17.441
Dec	43.387	-	24.468	+	743	+	-1.582	=	18.080
Total	83.021	-	45.730	+	1.262	+	-3.032	=	35.521

Table 18 - Saving evaluation - Risorgimento Street (n. 157 548 450)

	Consumption before improvement [kWh]	-	Consumption after improvement [kWh]	+	Adjustment (1) [kWh]	+	Adjustment (2) [kWh]	=	Saving [kWh]
Jun	29.952	-	15.347	+	639	+	-1.186	=	14.057
Dec	32.660	-	17.544	+	598	+	-1.287	=	14.428
Total	62.612	-	32.890	+	1.237	+	-2.473	=	28.485

Table 19 - Saving evaluation - Firenze Street (n. 157 548 409)

	Consumption before improvement [kWh]	-	Consumption after improvement [kWh]	+	Adjustment (1) [kWh]	+	Adjustment (2) [kWh]	=	Saving [kWh]
Jun	23.571	-	12.620	+	319	+	-841	=	10.429
Dec	25.771	-	14.545	+	520	+	-1.291	=	10.456
Total	49.342	-	27.164	+	840	+	-2.132	=	20.885

All economies achieved with improvements effected in the year 2000, have been repeated also in the year 2001, in very similar way.

4 - Conclusions

The energy saving results, obtained and calculated using the Measuring Program described above, have been compared with data indicated in the invoices of years 2000, 2001 and 2002.

A difference lower than 2% has been found and this confirms the validity of the present Measuring Program.

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