Plant Utilities Optimization through Environmental Management System in ISO14000 Environment

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DOI:10.26573/2007.1.2.1
Volume 1, *Number* 2
May 2007, *pp*. 93-103

The present work addresses the issue of defining a methodology able to select the best intervention(s) that facilitates reduction air pollution during the realisation of an Environmental Management System (EMS) according to ISO14000 regulation. The objective is to realise an EMS with the concurrent tasks of minimizing environmental impacts and maximizing the global performance in terms of energy saving, maintenance activities, and global management costs. This is done by defining three main parameters - time of the intervention, its complexity and economic expenses able to highlight the capability that a corrective measure can have to reduce the air pollution.

The proposed approach has been validated by analysing the plant utilities (electricity, compressed air, air conditioning, transports) of a firm producing smart cards. In the application case a cogeneration system and a solar cell system have been compared through our approach, obtaining a solution able to reduce the environmental impact and concurrently maximising energy saving.

Keywords: Environmental Management Systems, Energy, ISO 14000, Environmental Assessment, Risk Analysis

1. Introduction

For firms who have worldwide business, the acquisition of the Environmental certification according to the ISO 14000 international standards has become fundamental [11], [3]. As is well known in an ISO 14000 environment, the whole organisation and production processes are analysed and re-organised according to a set of rules and procedures included inside an Environmental Management System – EMS [8], [9]. In order to implement an EMS we have to refer to existing legislative tools, and particularly to the EMAS rule and the ISO 14000 family of rules [6]. These rules introduce a general approach to the environmental management but they do not define a criterion that is able to evaluate objectively the environmental impacts and, subsequently, a planning procedure of the corrective measures based on the evaluation of these impacts [5]. In addition, during the implementation of an EMS, special attention is also reserved to plan the actions pertaining to the reduction

of pollution and energy optimisation. For this phase as well, the present literature does not give any specific approach or a methodology for plant resources optimisation allowing, at the same time, both pollution reduction and energy savings.

Our approach is related to the definition of three main parameters - time of the intervention, its complexity and economic expenses [7], [12], which can be able to highlight the capability that a corrective measure can have to reduce air pollution and, at the same time, to maximise at least one of the three defined parameters.

2. The Assessment Method

The highlighting of the efficiency and effectiveness of a corrective action has been pointed out by the definition of the following three parameters

- **R** - *The re-establishment of environmental conditions*: this factor assigns greater values to interventions able to minimise the gravity of an environmental impact [2];
- $\mathbf{F_t}$ - *The factor of timeliness*: given an intervention the value of this factor is as greater as smaller is its installation's time and as easier is its maintenance [4];
- $\mathbf{F_c}$ - *The factor of economic convenience*: using this parameter we are able to give evidence to measures involving smaller costs of installation and maintenance [9], [12].

The proposed criteria is based on the main Risk Evaluation notions [4] and on an application of Failure Mode and Effect Analysis – FMEA [1] to the environmental problems in compliance with ISO 14000 regulations.

We have specially introduced three parameters able to highlight the capability of each corrective measure to reduce the pollution in the shortest time, with the minimum expense and minimum maintenance operations [8] defined by the following equations 1-3;

$$R_{i,k} = (G_{i,j} - G'_{i,j}) x (1 + \zeta_k) \qquad (1)$$

where:

i is a process

j is an environmental aspect

k is one of the possible measures able to optimise j

$G_{i,j}$; $G'_{i,,j}$ are the environmental Impact on the environmental aspect j made by the process i respectively before and after the installation of a specific intervention

ξ_k is equal to:

1 if we have to substitute periodically parts out of order;

$0,\overline{3}$ if maintenance procedures require only cleaning or washing of elements;

$0,\overline{6}$ when we periodically check-up the system

$$F_{t,k} = \frac{M_k}{T_k} \qquad (2)$$

Where

- T is the necessary time to install the proposal intervention;
- M is the mean time between two periodical maintenance operations:
- k has the same meaning of eq. 1

$$F_{c,k} = \frac{Ct_k}{n_k x Cm_k} \qquad (3)$$

where

- Ct_k is the first installation cost;
- Cm_k is the maintenance cost.
- k has the same meaning of eq. 1
- n_k is the number of maintenance cycles during the entire life of the measures k (V_{uk}). We have defined it as follows (eq 4):

$$n_k = \frac{Vu_k}{M_k} \qquad (4)$$

Using these three parameters we could choose, as a better intervention, the one that maximises the weight of $W_{i,k}$ defined by eq. (5) [10], [13]

$$W_{i,k} = \sqrt{R_{i,k}^2 + F_{t,k}^2 + F_{c,k}^2} \qquad (5)$$

3. The Case Study

In order to verify the validity of the proposed method we have applied it in a big firm operating in the production of Smart cards mainly for mobile phones and public phones. The plant in which the application case has been developed is involved in the production of cards for a national and international mobile phones provider (Figure 1) and of intelligent cards with a microchip inserted on for the new electronic passport (Figure 2). The plant was going to setup an EMS for ISO 14000 certification. Inside the plant there are two "clean rooms" (no dust or pollution inside) and two production lines for wafer cutting and chip insertion. The plant had some problem of energetic consumption due to the air conditioning system for the two clean rooms and for refrigerating machines.

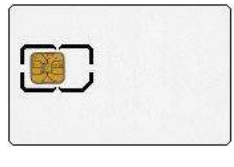


Figure 1 – Mobile Phone Card



Figure 2 - Electronic Passport Card

Table 1 – Timetable of ***IPW*** Rates H_f

		Winter	Summer	Total
F1	8,30-10,30 and 16,30-18,30 (mon-fri)	520		520
F2	6,30-8,30; 10,30-16,30 and 13,30-21,30 (mon-fri)	1430		1804,5
	8,30-12,30 (mon-fri) excluded August		374,5	
F3	6,30-8,30 and 12,00-21,30 (mon-fri) excluded August		1230,5	1230,5
F4	0,00-6,30 and 21,30-24,00 (mon-fri)	1170	963	5205
	Sat- sun Whole month of August	1248	1824	
Total				**8760**

Actually this plant utilizes methane boilers to produce thermal energy and electric refrigerating machines for summer air conditioning, but does not have any cogeneration or energy recovery systems.

Figure 3 reports the electric power consumption during the four scheduled rates (Table 1) of the main national Italian Power Supplier, briefly noted with ***IPW***.

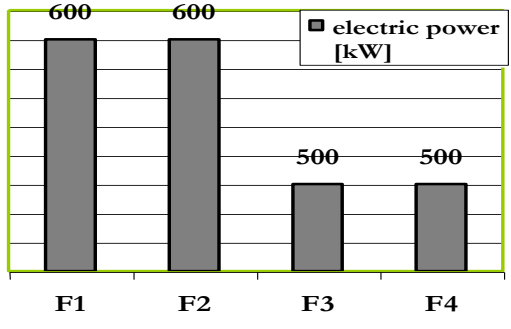


Figure 3 - *Electric Power Consumption*

Using these values we have obtained a total energetic consumption of 1.100 **TEP** (Equivalent Tons of Oil ≈ 11.000 kWh – eq. 6):

$$E = \frac{P_r x H_f}{\eta_{\mathrm{IPW}}} = \frac{(600 \times 520) + (600 \times 1804{,}5) + (500 \times 1230{,}5) + (500 \times 5205)}{0{,}374} \cong 1100 TEP \qquad (6)$$

where $\boldsymbol{P_r}$ is the electric power consumed during $\boldsymbol{H_f}$, and η_{IPW} the *IPW* efficiency.

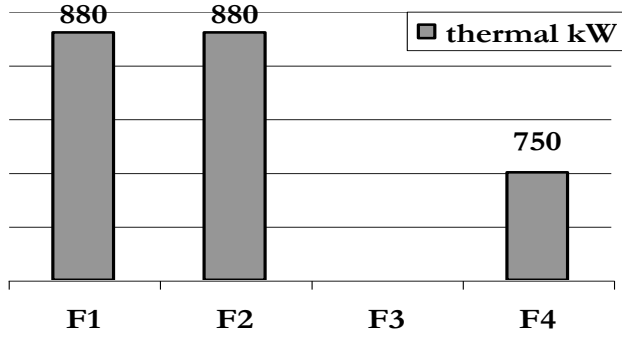


Figure 4 - Thermal Power Consumption

In the same way, we have evaluated a total consumption of methane (V_m) of 340 TEP[a] (eq. 7 and Fig.4).

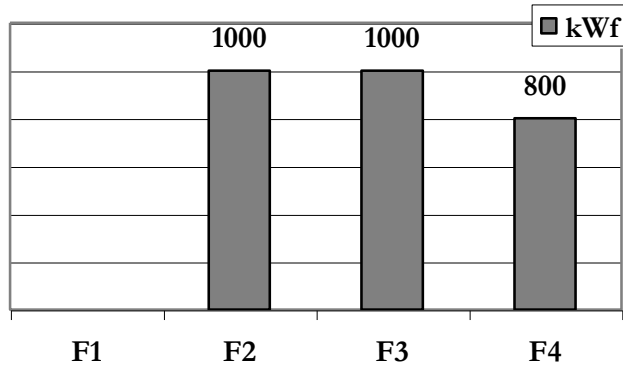
$$V_m = \frac{1}{\eta_c x P_c} x(P_r x H_f) = \frac{1}{0,9 \times 9,59} \times [(880 \times 520) + (880 \times 1430) + (750 \times 2418)] \cong 340 TEP \qquad (7)$$

where:

η_c is the boiler efficiency

P_c is the calorific power of the methane

Figure 5 - Frigorie Consumption [kW_f]



Finally, referring to the frigorie consumption of Figure 5 we have obtained a total energetic consumption of 110 TEP, as stated on eq. 8:

$$E = \frac{P_r x H_f}{COP_e} = \frac{(1000 \times 374,5) + (1000 \times 1230,5) + (800 \times 2787)}{3} \cong 110 TEP \qquad (8)$$

[a] 1 TEP ≈ 1.200 Nm^3 of methane

where $\mathbf{COP_e}$ is the Coefficient of performance (i.e. the efficiency) of the refrigerating machine.

With these results we have a total consumption of energy of **1550 TEP**. With the objective to reduce this amount of energy consumption we have used our method to compare a system producing electricity by a Combustion Chamber fed with methane (k=1) with a Solar Panels system (k=2). In the following two paragraphs we describe the features of the two systems and develop the comparison.

3.1. Alternative 1 – Combustion Chamber (k=1)

Using a system producing electricity by a combustion chamber fed with methane during the winter we are able to recover the high temperature working fluids and to use them as integration of the existing boilers, while in summer we can utilise them to "feed" an Absorption Heat Pump AHP in order to obtain the necessary frigorie power.

Referring to the total power requests of the plant we have sized this system choosing a combustion chamber able to produce 512 kW ($\boldsymbol{P_F}$) of electric power with an efficiency ($\boldsymbol{\eta_e}$) of 0,375; 342 kW ($\boldsymbol{P_T}$) of thermal power and an AHP able to produce 410 kWf (eq. 9) with a Coefficient of Performance (COP_{ASS}) equal to 1,2.

$$P_F = (P_T \times COP_{ASS}) = 410kW \qquad (9)$$

Finally, we have calculated the volume of methane, in terms of TEP necessary to produce the required power (eq 10)

$$Vm = \frac{1}{0{,}375 \times 9{,}59} \times (512 \times 8760) \cong 1.000\ TEP \qquad (10)$$

Since the plant needs 600 kW of electric power, the absorption from *IPW* is given by equation 11:

$$E = \frac{\left[\left(600-512\right)\times 520 + \left(600-512\right)\times 1804{,}5\right]}{0{,}374} \cong 50TEP \qquad (11)$$

In the same way, we have estimated a consumption of 180 TEP of methane for boilers (eq 12)

$$Vm = \frac{1}{0{,}9 \times 9{,}59} \times \left[\left(880-342\right)\times 520 + \left(880-342\right)\times 1430 + \left(750-342\right)\times 2418\right] \cong 180TEP \qquad (12)$$

In summer, using the warm refluis of the combustion chamber to "feed" the AHP, we have a methane consumption of 150 TEP, as stated by eq 13:

$$Vm = \frac{1}{\eta_C \times Pc} \times \left(\frac{P_f}{COP_{ASS}}\right) \times H_f =$$

$$\frac{1}{0{,}9 \times 9{,}59} \times \left[\frac{\left(1000-410\right)}{1{,}2} \times 374{,}5 + \frac{\left(1000-412\right)}{1{,}2} \times 1230{,}5 + \frac{\left(800-412\right)}{1{,}2} \times 2787\right] \cong 150TEP \qquad (13)$$

Summarising, we have a total request of 1380 TEP and an energetic saving equal to 11%.

After that we have calculated the Environmental Impact *G'*; to do that we have introduced an analytic method for the Environmental Impact Assessment able to provide the measure of the pollution's level produced as a crisp number rather than as a subjective adjective [13].

In general, terms the measure of pollution produced by a singular processing is based on Risk Evaluation and the Gravity (G) of an Environmental Impact and can be considered as the product [13] of these two factors (Figure 6); tables 2, 3 and 4 bring the adopted criteria and their values.

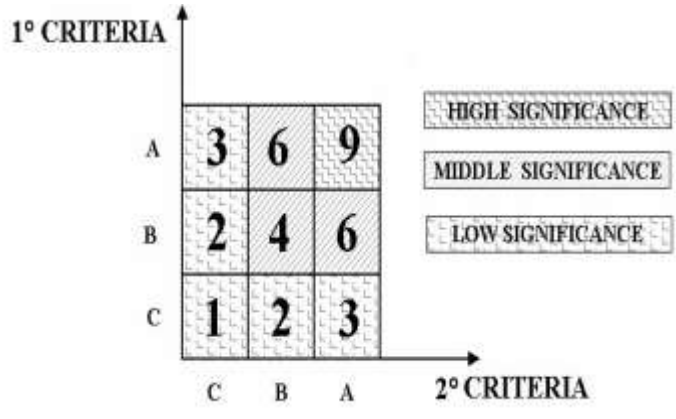


Figure 6 - Scheme to Evaluate the Environmental Impact

Table 2 –Criteria for the Normal Conditions of Operation

1° CRITERIA- (L) conformity with (L) law-line and/or internal qualification of (P) control parameter		**2° CRITERIA-(V)** Variation of control parameter in comparison with the previous year	
P>0,9L;	**A**	V>100%	A
0,7L<P<0,9L	B	90%<V<100%	B
P<0,7L.	C	V<90%	C

Table 3 – Criteria for the Abnormal Conditions of Operation

1° CRITERIA-(F) Frequency of abnormal events		**2° CRITERIA-(C)** Persistence of the environmental damage produced	
One a day;	**A**	Over 3 months;	A
One a month;	B	Over 1 week;	B
Over 6 months	C	1 day	C

Table 4 – Criteria for the Operation in Emergency

1°CRITERIA-(P) Probability of occurrence in emergency		**2° CRITERIA-Gravity (G) –**Irreversibility of environmental damage produced	
One in 3 months;	**A**	Irreversible event;	A
One a year;	B		B
Over 5 years	C		C

Using the values reported in Table 5 and 6 we have obtained an environmental impact (G') equal to two.

Table 5 – 1° Criteria

1° Criteria- Resource characteristics	**VALUE**
Derived by the coal or oil - electric energy	A
Methane - cogeneration	**B**
Renewable and/or recovered energy	C

Table 6 – 2° Criteria

2° Criteria - Specific consumptions in comparison with previous year	**VALUE**
More than 100%	A
Inclusive among 90% and 100%	B
Less than 90%	**C**

In order to calculate $W_{i,k}$ we have used the following input data (Table 7) obtaining an F_t = 4 (eq 14); an F_c = 0,91 (eq. 15) and an R= 9,1 (eq. 16)

Table 7 – Input Data

ξ	0,3
T	3 months
M	12 months
C_t	610.000 €
C_M	67.000 €
V_u	10 years

$$Ft = \frac{M}{T} = \frac{12}{3} = 4 \qquad (14)$$

$$Fc = \frac{C_T}{\frac{V_u}{M} \times C_M} = \frac{610.000}{\frac{120}{12} \times 67.000} = 0,91 \qquad (15)$$

$$R = (G - G')x(1 + \xi) = (9 - 2)x(1 + 0,3) = 9,1 \qquad (16)$$

3.2. Alternative 2 – Solar Panels (*k*=2)

A different proposal is to install about 300 sqm of solar panels to produce thermal energy; In particular, we have considered panels able to produce, as yearly average, 0,46 thermal kW/m^2, obtaining 150 kW (eq. 17) and methane consumption, during the winter, of 270 TEP (eq. 18).

Summarising equations 6), 8) and 18) we have a total request of 1380 TEP and an energetic saving equal to 5 %.

$$P_t = 0{,}46 \times 300 \cong 150kW \qquad (17)$$

$$Vm = \frac{1}{0{,}9 \times 9{,}59} \times \left[(880 - 150) \times 520 + (880 - 150) \times 1430 + (750 - 150) \times 2418 \right] \cong 270TEP \qquad (18)$$

Using the values reported in Table 8 and 9 we have obtained an environmental impact (G') equal to six.

Table 8 – 1° Criteria

1° Criteria- Resource characteristic	**VALUE**
Electric energy	**A**
Methane – cogeneration	B
Renewable and/or recovered energy	C

Table 9 – 2° Criteria

2° Criteria - Specific consumptions in comparison with previous year	**VALUE**
More than 100%	A
Inclusive among 90% and 100%	**B**
Less than 90%	C

In order to calculate $W_{i,k}$ we have used the following input data (Table 10), obtaining an F_t = 2 (eq. 19); an F_c = 7,5 (eq. 20) and an R= 4,8 (eq. 21).

Table 10 – Input Data

ξ	0,6
T	1 month
M	2 months
C_T	45.000 € [150 €/sqm]
C_M	100 €
V_u	10 years

$$F_t = \frac{M}{T} = \frac{2}{1} = 2 \qquad (19)$$

$$F_C = \frac{C_T}{\frac{V_u}{M} \times C_M} = \frac{45.000}{\frac{120}{2} \times 100} = 7{,}5 \qquad (20)$$

$$R = (G - G')x(1 + \xi) = (9 - 6)x(1 + 0{,}6) = 4{,}8 \qquad (21)$$

At the end, using equation 2, we have obtained the weights W_1 (alternative 1) equal to 9,98 and W_2 equal to 9,12 as stated in eq. 21 and eq. 22, and indicating that the best alternative is the first.

$$W_{9,1} = \sqrt{(9{,}1^2 + 4^2 + 0{,}91^2)} = 9{,}98$$

$$W_{9,2} = \sqrt{(4{,}8^2 + 2^2 + 7{,}5^2)} = 9{,}12 \qquad (22)$$

It is to be noted that the first alternative introduces bigger values of R (so it is able to better restore the environmental conditions) and a smaller value of Fc, that indicates less economic expenses with respect to the second one.

4. Conclusions

In this paper, we have proposed a methodology able to select the best intervention(s) that permits a reduction of air pollution and/ or to save energy consumption caused due to a wrong energy management. The methodology allows an easy implementation of an Environmental Management System according to the "rules" of continuous improvement proposed by the ISO 14000 and *Vision 2000* philosophy. It simplifies audits and gives an objective method to demonstrate to the auditor each choice that have been made with the aim to maximise energetic consumption and /or to reduce Environmental Impact. At the same time our methodology, in addition to an objective identification of the best solution is also able to quantify the influence of the parameters F_c, R, F_t on the specific solution adopted.

The industrial case has been related to a big firm operating into telecommunication systems and has given good results in terms of the improvements obtained both in terms of utilities optimisation and of environmental impact. Future studies could optimize the equations used to evaluate the risk and the gravity of an environmental impact, researching a procedure able to objectively define values related to the operative conditions.

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