# Exergy method to evaluation building wrapper performance

K. Fabbri

University of Bologna, DIENCA - CIARM, 2 Viale Risorgimento, 40136 Bologna, Italy
email: kristian.fabbri@unibo.it http://www.ciarm.ing.unibo.it/kristian

**Abstract**

*In this paper the calculation of energy valuation of building wrapper energy transfer is proposed. Heat exergy through wrapper transfer depends on temperature gap and heat transfer. Heat flow through walls depends on thermo-physics characteristics of the material. Heat exergy transfer could be used to evaluate an exergy flow through walls, and it is possible to settle an exergy index to compare different walls. The thermo-physics parameters could be related with heat exergy transfer and isolation heat flow through wrapper.*
*An exergy analysis could therefore be applied all over the year to propose an exergy (and economic) index for wrapped sub-system.*

***Keywords:*** *wrapper energy and exergy tool energy*

## 1 Introduction

Building wrapped is the technological sub-system in a building that regulates most of energy dispersion.
The cooling and heating plant are dimensioned in relation with wrapper performance, and indoor comfort perception depends on the wall inside surface temperature.
Wrapper performances depend on its components and relate the physical parameters; transmittance is the most important parameter. Outdoor temperature changes in relation with climate and latitude, whereas inside doesn't differ so much.
It's possible to know the amount of heat needed to warm up in winter and the one to be deducted to cool during summer. How is possible to calculate the energy performance of buildings taking account of outside seasonal temperature and inside thermal comfort? A simplified method to evaluate wrapper performance is here studied and discussed.

## 2 Wrapper exergy analysis

The method reformulates the research of the group LowEX for the program IEA ECBCS Annex 37.

The exergy valuation indicators are:

- exergy consumption by wrapper dispersion, in relation with outdoor temperature variation (to value low exergy plant system);

- exergy consumption related with convective reactions between the temperature gap between inside wall and room. This exergy index influences comfort perception.

The method here proposed is based on maximal and minimal temperature measurements in the meteorological station (localized in S. Arcangelo, centre of Italy) during years 2003-2004.

The analysis was carried out during December 2003, April 2004 and August 2004, arbitrarily taken as reference months for winter, spring, and summer seasons

### 2.1 Inside wall surface temperature calculations

Inside wall surface temperature depends on outdoor day temperature and wall transmittance.

$$U = \frac{1}{\frac{1}{h_e} + \frac{1}{h_i} + \sum_{j=1}^{n} \frac{s_j}{\lambda_j}} \tag{1}$$

$$U_w = \frac{1}{\sum_{j=1}^{n} \frac{s_j}{\lambda_j}} \tag{2}$$

$$t_{wall} = t_{in} - \frac{(t_{out} - t_{in})U}{U_w} \tag{3}$$

where U is the total transmittance [W/m2K]; $U_w$ is the wall transmittance [W/m2K]; $h_e$, $h_i$ are outside and inside adduction coefficient; $s_j$ is the thickness [m]; $\lambda$ is the conductance [W/mK]; $t_{wall}$ is the inside wall surface temperature [°C]; $t_{out}$ is the outside temperature average [°C]; $t_{in}$ is the inside temperature [°C]

Another very important parameter in wrapper performance evaluation is phase displacement during summer time. The wall components layers are (from inside to outside):

2 cm of plaster; 5 cm of isolation (polystyrene); 25 cm of alveolater brick; 2 cm of plaster.

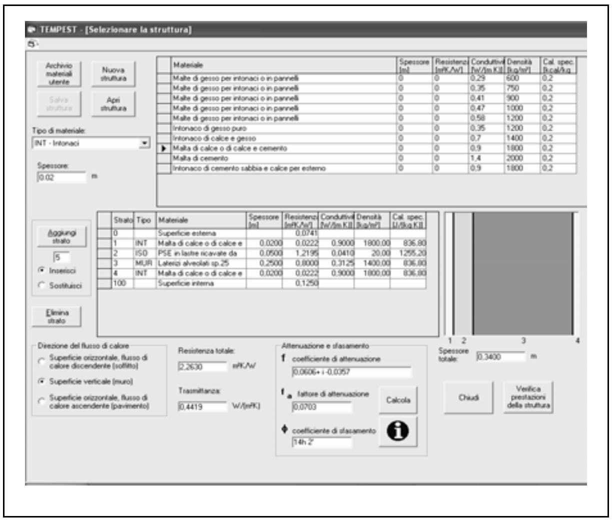


*Fig. 1.* *Wall transmittance calculation (by TempEst Software).*

The inside wall surface temperature during a summer day (related with solar radiation and transmittance) is reported in figure 2 and 3 (between 30 and 40°C). The transmittance U resulted 0.4419 (W/m$^2$K), with phase displacement of 14 hours.

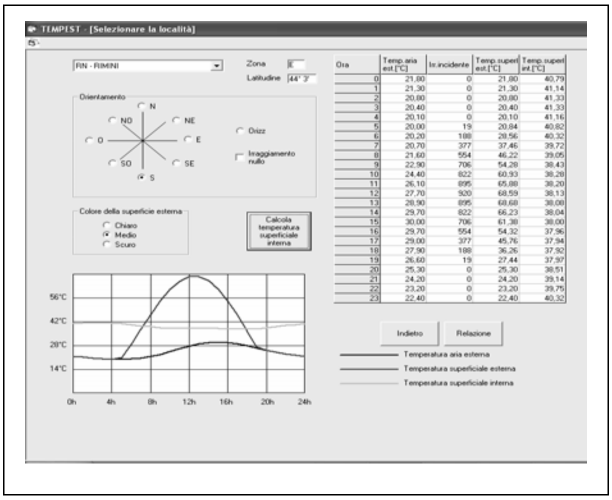


*Fig. 2.* *Phase-Displacement calculation (by TempEst Software).*

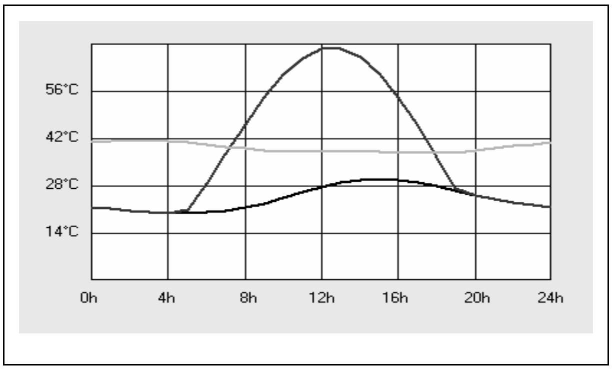


***Fig. 3.*** *Phase-Displacement graphics details (by TempEst Software).*

This analysis based on statistic doesn't allow to know the inside wall surface temperature during the months when conditions of discomfort are due to the lower temperature of the inner wall and during spring and autumn. With formula [3] it's possible to calculate the trend of the inside wall surface temperature in relation with trend of outside temperature, fixing inside room temperature at 20°C during winter, and 26°C during summer regime.

### 2.2 Exergy Method to evaluate wrapped performance

The second step is exergy evaluation. After having analyzed inside/outside temperature trend, it's possible to take account of the thermo-physics characteristics and energy dispersion of the wrapper (calculate with [4]).

Wrapper energy dispersion depends on the inside/outside temperature gap, as well as for exergy wrapper [5]. The exergy-surface consumed is calculated related with the temperature gap between the inside wall surface and the room [6].

$$Q = U \cdot (t_{in} - t_{out}) \tag{4}$$

$$Ex = Q \cdot \left(1 - \frac{t_{out}}{t_{in}}\right) \tag{5}$$

$$Ex_{wall} = \frac{Q}{(t_{out} - t_{in})} \cdot \left((t_{out} - t_{in}) - t_{in} \ln \frac{t_{in}}{t_{wall}}\right) \tag{6}$$

with: Q is Energy through wrapper (dispersion during winter time and overheating to be deducted during summer time) [W]; $E_x$ is Exergy thought wrapped [W/m$^2$]; $E_{x,wall}$ (Exergy Wall) is Exergy between wall inside temperature and room temperature [W/m$^2$];

## 3 Exergy analysis

Exergy method is applied to temperature trend during December, April and August, avoiding plant system.

### 3.1 Trend of temperature

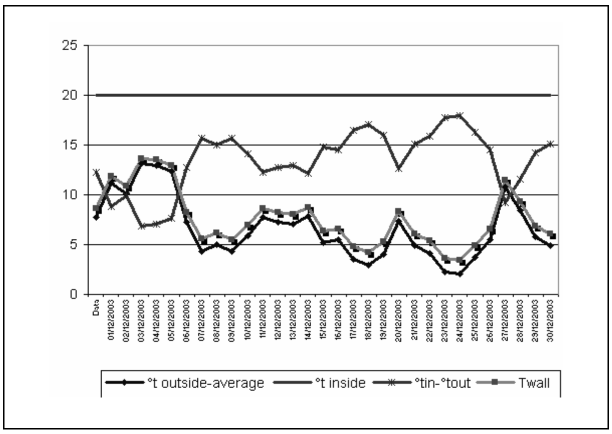


***Fig. 4.*** *Trend of Temperature in December*

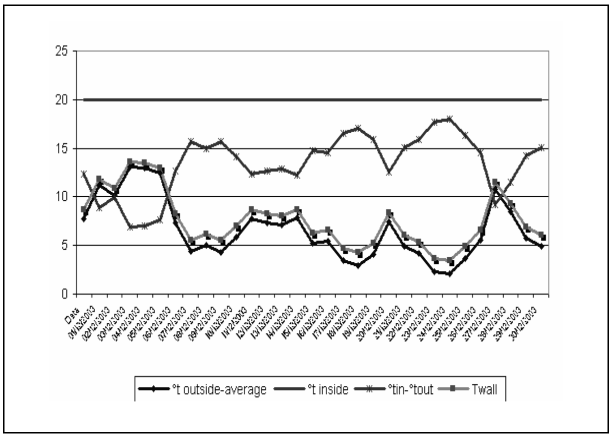


***Fig. 5.*** *Trend of Temperature in April*

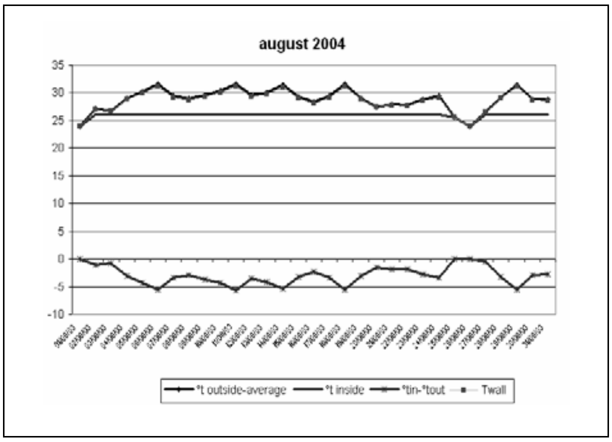


***Fig. 6.*** *Trend of Temperature in August with operating temperature inside = 26°C*

The inside wall surface temperature changes with the same trend of the outside temperature, highlighting a difference more or less of few degrees.

In August three days have an outside temperature lower of 26°C.

### 3.2 Trend of Energy through wrapper and Exergy and Exergy wall

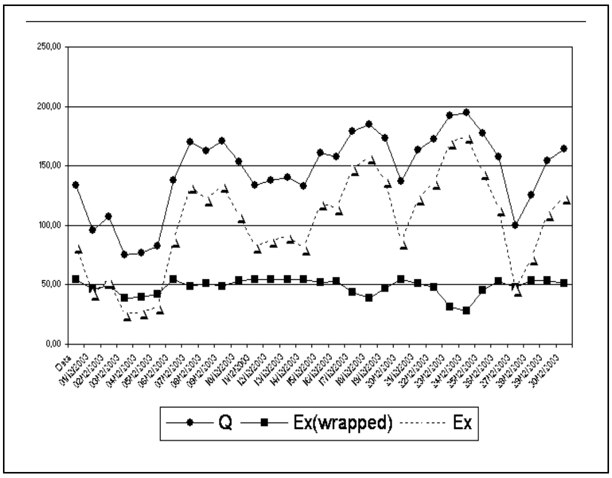


***Fig. 7.*** *Trend of energy and exergy variations in December.*
*The trend of Exergy wrapped is inverse to the trend of energy.*

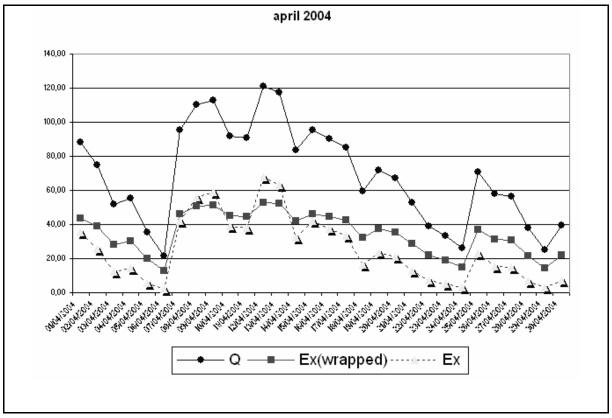


***Fig. 8.*** *Trend of energy and exergy variations in April. The trend of Exergy is the same of energy variations.*

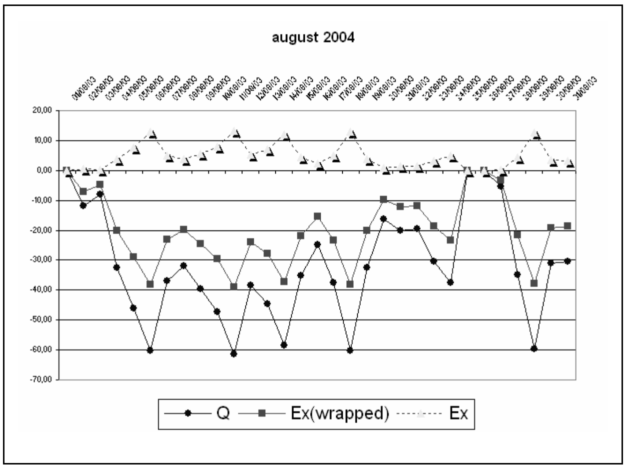


***Fig. 9.*** *Trend of energy and exergy variations in August. The trend of Exergy is positive and inverse to the trend of energy (inside room temperature 26°C).*

Energy dispersion and exergy dispersion through wrapped are compared, showing that they follow the same trend, while for energy dispersion and exergy wall the trend is inverse.

### 3.3 Trend of Ex/Q e $Ex_{wall}$/Q

The $E_{x,wall}/Q$ ratio describes energy and exergy relation in order to determine the dimensions of plant terminal inside a room. The $E_x/Q$ ratio describes the exergy consumed in relation with wrapped energy dispersion, in order to determine the proportion for plant power and sub system exergy plant consumption.

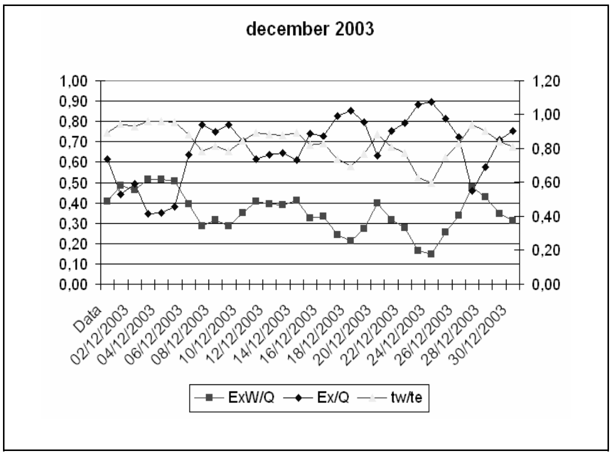


***Fig. 10.*** *December*

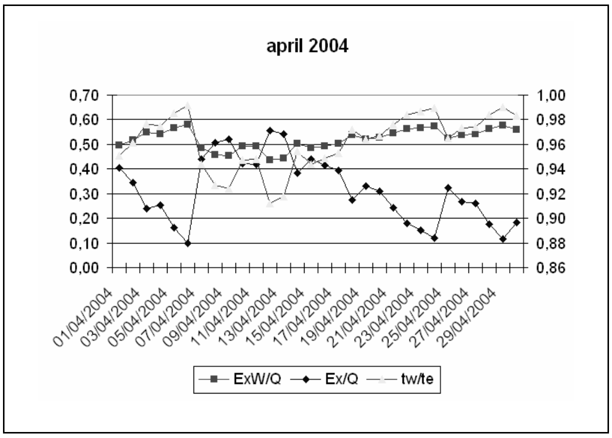


***Fig. 11.*** *April*

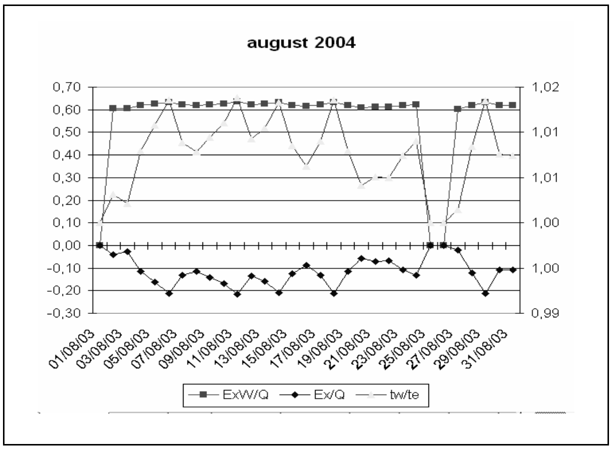


***Fig. 12.*** *August: (inside room temperature 26°C)$E_{xw}$/Q trend is opposite to $E_x$/Q trend*

### 3.4 Evaluation of exergy wall and exergy relation (in percent)

The relation between exergy wall temperatures and exergy wrapper, depends on the inside wall surface temperature:

$$Ex \cdot index(\%) = \frac{Ex_{wall}(t_{wall} - t_{out})}{Ex_{wrapped}(t_{out} - t_{in})} \tag{7}$$

This index is a coefficient of inside comfort perception measurement able to evaluate the exergy link of comfort inside perception.

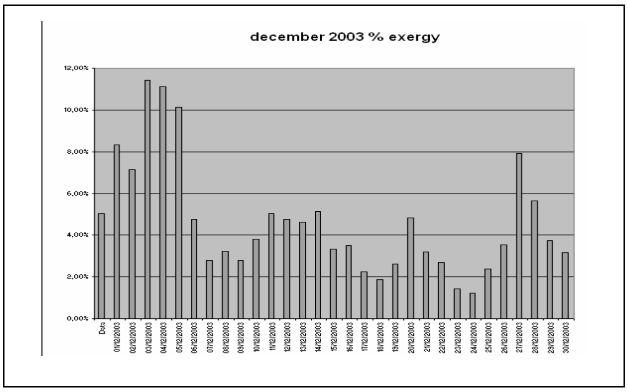


***Fig. 13.*** *December Exergy index.(%)*

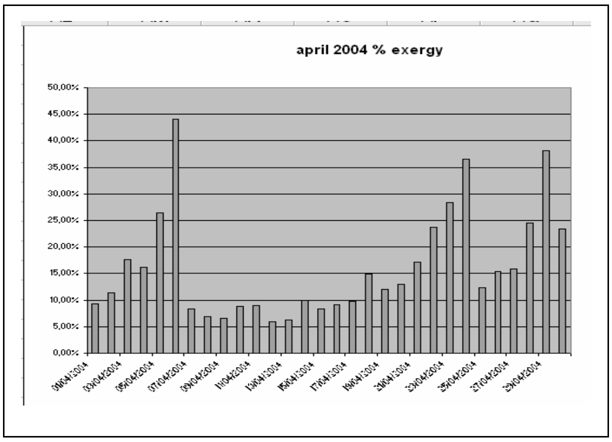


***Fig. 14.*** *April Exergy index.(%)*

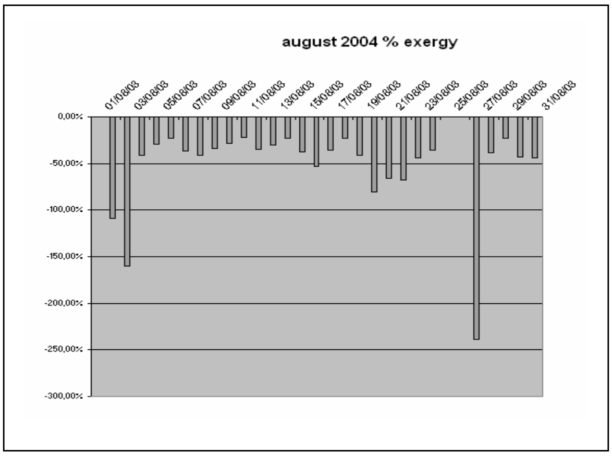


***Fig. 15.*** *August Exergy index.(%)*

### 3.5 Evaluation with another wall transmittance performance

A further calculation is made considering a new wall transmittance. The wall layers components are (from inside to outside): 2 cm of plaster; 8 cm of isolation (wood fibers panel); 25 cm of alveolater brick; 2 cm of plaster. Therefore, the new data of transmittance and phase displacemente are: U = 0.3149 (W/m2K); phase displacement of 16 hours (better than in the first example).

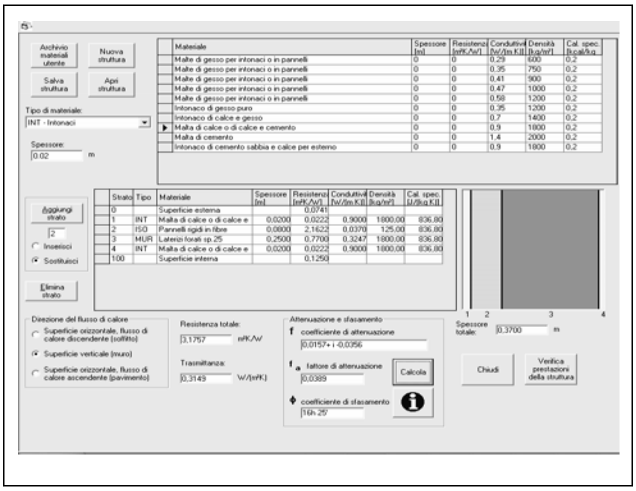

***Fig. 16.*** *Wall parameter (TempEst software)*

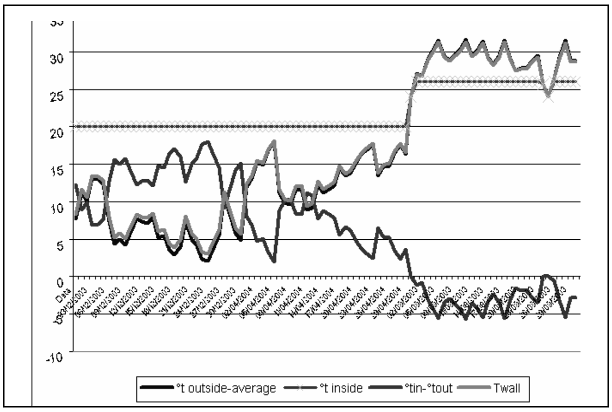


***Fig. 17.*** *Trend of temperature during December, April and August : Outside average temperature; operating temperature inside; gap inside and outside temperature; wall surface temperature.*

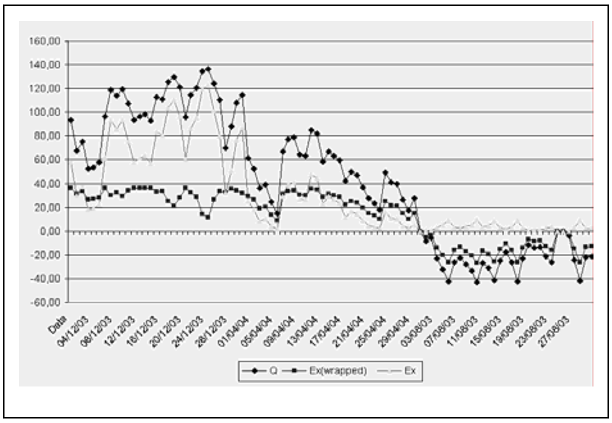


***Fig. 18.T****trend of energy, exergy, exergy wall (month of December, April, August)*

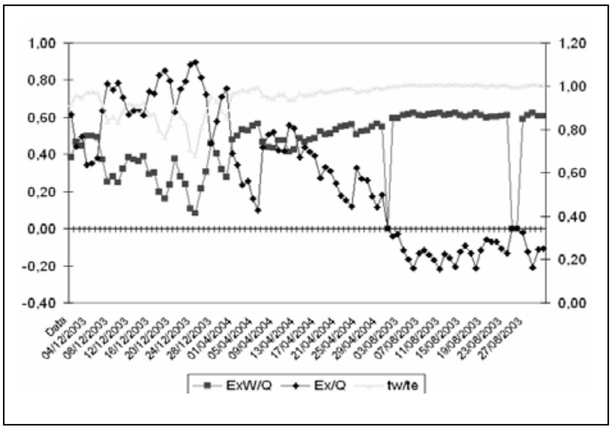


***Fig. 19.****Trend of energy exergy relation (December, April, August)*

## 4 Conclusions

In this paper one use of exergy method to evaluate wrapper exergy performances has been proposed. Some indexes to compare exergy, energy and temperature trend have been defined.
Which is the utility of this study? Which type of considerations can be extrapolated from these calculations? Exergy is an energy quality tool to evaluate wrapped performance and it's possible to joint different parameters during all year and in relation with outside clime variation.
Moreover these values can be utilised in the calculation of total exergy consumed in building, or to determine exergy maximum of plant system or of parts of plant systems.

## 5 References

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