APPROACH FOR THE IMPROVEMENT OF ENERGY PERFORMANCE OF A STOCK OF BUILDINGS

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ABSTRACT

This paper summarizes the work performed by CSTB[1], ADEME[2] and the Ministry of equipment in France to improve the energy performance of the ministry stock of buildings: 7 millions square meters, 10 000 buildings, wide range of different buildings of different sizes and uses. The project has four major phases: analysis of existing tools for energy performance evaluation, identification of the end-users of the tools and definition of a building typology, development of tools adapted to the end-users, validation and improvement of the tools. Since the building managers' motivation is an important factor to improve the energy performance of the buildings, the study has tried to incorporate the end-users needs and constraints in the different phases of tools development.

INTRODUCTION

In the setting of the governmental program for energy savings and its public buildings section, the ministry of the equipment in France promotes the policy of improving the management of its property holdings. For this purpose, CSTB, ADEME and the Ministry of equipment in France are working together to improve the energy performance of the ministry stock of buildings: 7 millions square meters, 10 000 buildings, wide range of different buildings of different sizes and usages.

For this purpose the ministry of equipment is collecting information about characteristics of its buildings and their water and energy consumptions. CSTB has defined a typology of the ministry stock of buildings based on their functionalities, usages, sizes, operating modes, energy uses, etc., and a methodology for comparing their performance (different indicators of performance with auto and inter-comparison procedures). Associated with these tools CSTB has also developed web-based tools to advise building managers of diagnostic and improvement actions. During all the phases of the project a close collaboration has been developed between local and central managers of the ministry to collect their needs and constraints and to adapt the tools to the end-users. Today we have started the phase of validation by using a preliminary set of collected data and with the collaboration of a group of managers.

[1] CSTB : Centre Scientifique et Technique du Batiment

[2] ADEME : Agence De l'Environement et de la Maitrise d'Energie

OBJECTIVES

The objective of the project is to gradually and continuously improve the energy performance of the ministry stock of buildings.

To achieve this result we first need to help the managers of the ministry to evaluate the performance of their buildings, to give them information about the possible causes of under-performances and the different actions to be taken to improve their buildings performance. During the different phases of development we will tried to work closely with end-users in order to take into account of their needs and working constrains.

BACKGROUND

The performance evaluation of commercial buildings is mainly based on their energy consumption indices, as compared to reference indices established for similar buildings.

These indictors represent costs or consumptions (operating cost, energy consumption, water consumption, etc.) normalised by influencing factors such as net surface of the building, number of its occupants and could be also the number of served dishes per year for a restaurant.

Example of performance indicators

Operating cost pers surface	**Energy consumption per surface**	**Water consumption per occupant**
Euro/m^2 – year	kWh/m^2 - year	m^3/occupant - year

The reference values are statistics values of the indicators (mean, median, percentiles, etc.) established for a family of buildings. The indicators could be adjusted in order to take into account activity periods or outdoor climate conditions.

The comparison of the indicators with reference values helps the manager to evaluate the energy performance of its buildings. However the reference values are defined for a family of buildings with similar characteristics. To define the families of building for the ministry a typological study needs to be done.

TYPOLOGY OF BUILDINGS AND IDENTIFICATION OF END-USERS

We used two approaches for the typological study: statistical analysis and interview with the end-users.

Statistical approach

The statistical approach helps us to define part of the parameters that have important influence on the energy consumption of buildings, and those could be used to define a specific family of buildings.

The statistical study is based on the data of the GPI (Property Holdings Management) database. GPI is a tool developed by the ministry to collect and manage information about its stock of buildings. In the GPI database we can find information such as the locations of the buildings, their sizes, their construction dates, their annual energy consumption and the type of heating energy they used (gas, fuel, electricity, etc.). But we have little information about the building usage unless that the building can be considered mainly as office building or technical premises (workshops).

To evaluate the influence of a specific parameter on the energy performance of the buildings we calculate the energy performance indicators (kWh/m^2) for two groups of buildings distinguish by the specific parameter, for example:

- The first group is composed of small buildings (less than 400 m^2)
- The second group is composed of medium and large buildings (greater than 400 m^2).

Then with the statistical analysis, we tested the hypothesis that the two groups belong to the same populations or not.

The results of the test showed us that when we compare their energy consumptions per surface:

- The buildings which are mainly used as "office building" and those who are mainly used as "technical premises" belong to two different populations
- The buildings which used electricity as principal heating energy and those who used fossil energy also belong to two different populations.

For the "Surface area" and the "Construction date" parameters we need first to define significative values that can be used to distinguish different groups of buildings.

For the "Surface area", a set of iterative tests with different ranges of surfaces showed us that 400 m^2 for office buildings and 250 m^2 for technical permises are good trade-offs between the size of the samples for comparison (for the statistical tests we need to have) and the importance of the influence of the parameters on the energy consumption of the buildings.

For the "Construction date", we decide to use 1979, the year in which the building energy regulations were enforced, in order to have significatif number of samples to compare. In this case we try to test if the energy consumption per square meter is significantly different between the buildings constructed before and after 1979.

The results of the statistical test are presented in the following table. The percentage values give the probabilty that the two samples belong to the same population according to the statistical analysis.

With the help of this table, we conclued that:

- The date of construction (before and after 1979) has no significant influence on the energy consumption of the buildings,
- The size of office buildings (greater or less than 400 m^2) has influence on the energy consumption of the buildings heated with electricity,
- The size of technical premises (greater or less than 250 m^2) has influence on the energy consumption of the buildings.

Main use	**Heating Energy**	**Surface**	**Construction Date**
Office	Fossil	7%	28%
	Electricity	79%	73%
Technical premises	Fossil	0.09%	77%
	Electricity	0.5%	29%

The results of this first phase of the building typology study will be included in the tools for the analysis of building performance. It will help users to compare buildings of the same family.

Investigation and interview of end-users

The second part of the typology studies includes interviewing with the managers of different buildings of the Ministry of Equipment.

The energy management of the buildings of the ministry is mainly in charge of local managers. They are not experts of buildings operation and that task of management is an auxiliary task among their different duties.

During the interviews, we present to the local managers our objectives and our first results. Then we ask them to present their main constrains and the type of tools they will need for a better energy management and to improve the performance of their buildings.

The analysis of about twenty interviews shows that:

- The building managers identified their building types according to specific usage and their operating modes. Six different types of buildings have been defined with them and will be used in the typological approach (the Figure 1 present four types of those buildings).

Figure 1. Photos of four types of buildings of the ministry

- The information that the building managers have to provide must be reliable, clearly defined and as simple as possible.
- It is important to take into account of the level of comfort of the buildings when you are studying the performance of the buildings. The building managers will be more motivated to improve the energy performance of their buildings if they can also improve their comfort level.
- The building manager needs some simple and flexible tools with different levels of details in order to let them assess their buildings performance from a top-down approach.
- The tools must be accessible via the Intranet of the ministry in order to be easily and widely accessible.

DEVELOPMENT OF TOOLS ADAPTED TO END-USER

To analyze and improve the performance of the ministry of equipment stock of buildings we have developed two tools:

- GPBat: the tool to analyze the energy performance and water consumption.
- GDBat: the tool to help for diagnosis and to develop improvement actions.

We have also defined a set of modification for the GPI database in order to clarify and simplify the collection of data (local managers' demands).

The relation between three tools is described in the following diagram (Figure 2).

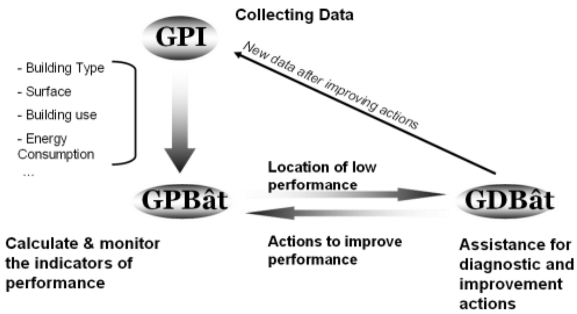

Figure 2. Relation between three tools : GPI, GPBat and GDBat

<u>GPBat Tool</u>

With the GPBat tool, the user selects first the parameters defining the family of building to calculate the indicators of performances and the reference values. The reference values are determined statistically from the family of buildings: the median represents the normal value, the first percentile the lower limit and the third percentile the upper limit.

The median, the first and the third percentile of the family are estimated as following:

- The median: it divides the sample in 2 parts (50% of data are higher than the median and the other 50% are lower). It is close to the average of the entire population for the normally distributed data. However, unlike the average, the median is only lightly influenced by the extreme data
- The first percentile defines the lower limit of the zone in which one finds 50% of data nearest of the median (25% of data are lower to the 1st percentile)
- The third percentile defines the higher limit of the zone in which one finds 50% of data nearest of the median (25% of data are higher than the 3rd percentile).

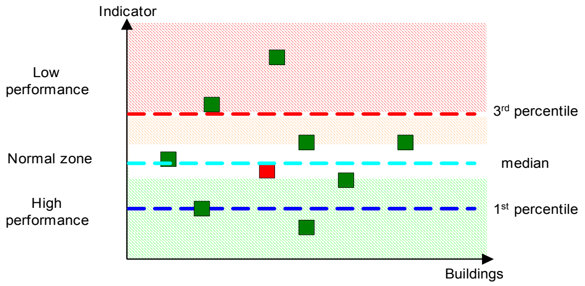

Figure 3. Graph for buildings performance comparison with low, normal and high zones

The median represents the mean performance therefore the target value to reach in medium-term if performances of buildings are worse than the median value.

The first percentile represents the level of high performance therefore the target value to reach in long-term.

The third percentile represents the level of low performance therefore the value targets to reach in short-term if performances of buildings are worse than this value.

Next, the user follows the hierarchical approach for its analysis:

- A first level of simple and easily interpretable visualization of building performances
- The next levels help the user to refine its analysis by the presentation of control panels and graphs of comparison.

The different indictors and the hierarchical approach are summarized on the following diagram (Figure 4).

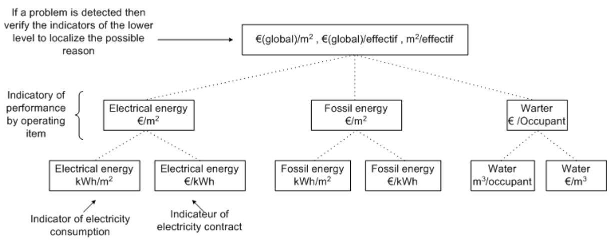

Figure 4. Description of the hierarchical analysis of indicators

Today, with GPBat the user can also follow the history of the performance of its buildings during a period of 3 years (Figure 5). In the future, this period will be extended to 5 years.

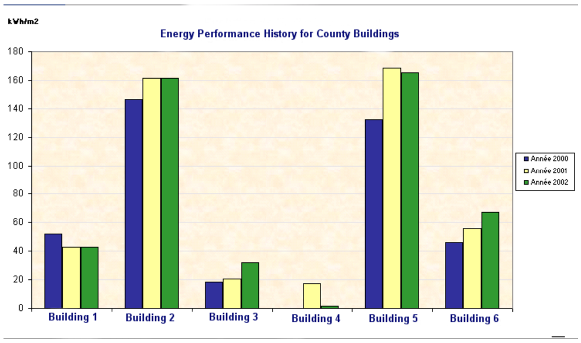

Figure 5. Graph for analyzing the history of the building performances

GDBat Tool

After analyzing the performance of its buildings, the user can find information about the diagnostic and the improvement actions with GDBat.

GDBat is composed of different items that are useful to look at in order to improve the energy performance of a building.

These different items are presented in the first windows of GDBat (Figure 6).

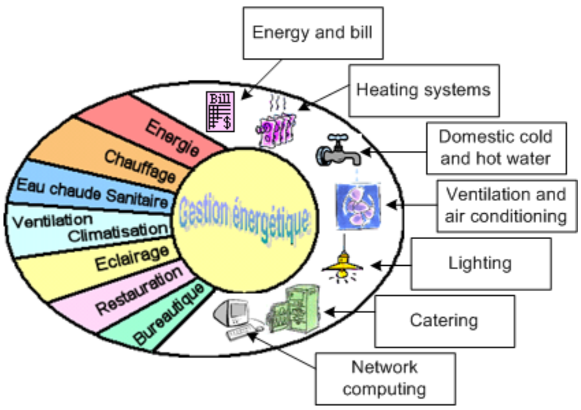

Figure 6. First window of GDBat with the different items to refer for improving the building performance

Each item has the same structure with each section followed with a main question (Figure 7):

- Comfort, are the occupants satisfied?
- Installation, can we improve the installations?
- Operating expense, can we improve the costs?

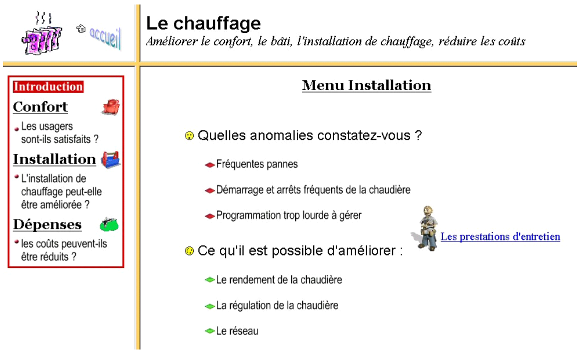

Figure 7. Heating system improvement approach

Then in each section a set of question guide the users to a set of response presented as “Causes” and “Solutions” with technical and economical information (Figure 8).

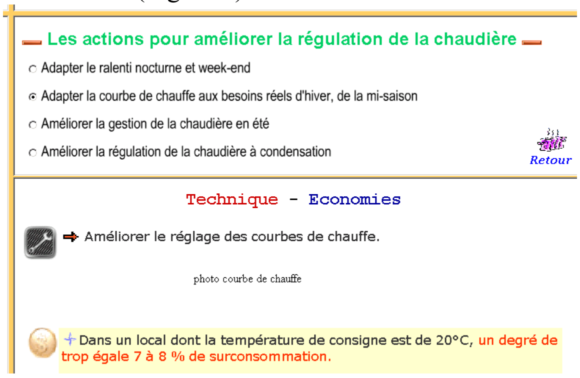

Figure 8. Heating control system improvement actions

The development of GDBat tool is near completion and it will be used in the future as a tool that end-users can improve by adding their own good experience and helping managers to exchange information about different items.

CONCLUSION

This paper presented our approach in developing tools to help building managers to improve their buildings energy performance. The work during the different phase of this study was done in close collaboration with end-users (who are not experts of building operation and that task of management is an auxiliary task among their different duties). We have tried during the development phases to find solutions that can motivate end-users and meet their needs and working constrains. For example:

- For the building typological approach, we developed a typology based on the ease of identification and the usage of the sites (groups of buildings) rather than a typology based only on purely statistical and administrative information.
- For the tools, we produced an easy-to-use system with a hierarchical approach that gives the possibility to the end-user of defining the level of details he needs to access.

Now we are starting a validation phase with end-users that can probably lead to simplification of the tools therefore more efficient for the managers to use.

Finally, the next phase will be to test our approach with another public owner of a stock of buildings.

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