A PREDESIGN TOOL FOR ENERGY EFFICIENT BUILDINGS THROUGH CLIMATE ADAPTATION

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Many preliminary architectural design decisions have a significant affect on the overall thermal performance of a building. In order to optimize the natural energy efficiency of a building, environmental considerations must be made in the early design phases.

CLIMAT (CLIMate Assessment Technique) is a computer program developed for the Apple Macintosh to provide designers with pre-design recommendations derived from an analysis of the climate - comfort - shelter relationships to which the building must inevitably respond.

The program utilizes climatic data such as average daily maxima and minima temperatures and humidities, wind speed and direction, precipitation, solar radiation, degree days heating and cooling, and winter and summer design temperatures. From daily minimum and maximum temperatures, hourly temperatures are generated for each month. Temperatures are then broken down into Day, Evening, and Night groups. A 10 F° band of human comfort is established, and varying levels of thermal stress and comfort are determined. Also calculated are sunrise and sunset times, and solar position throughout the year. This analysis forms a climatic profile of the site which is graphically represented to the user by the following charts and graphs:

- Temperature Graph (Figure 1)

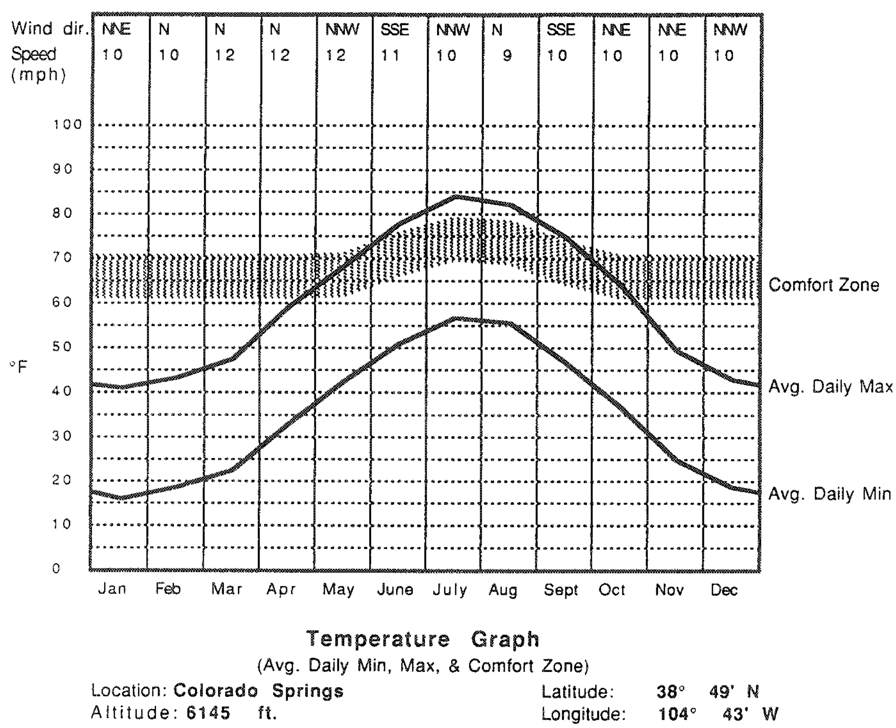

Figure 1. CLIMAT Temperature Graph

- Humidity Graph
- Hourly Temperature Graph
- 3-D Temperature Graph (Figure 2)
- Climatic Data Chart
- Diagnostic Data Chart
- 2-Hourly Temperature Chart
- Solar Position Chart

After the climatic profile is established, this information is passed to an expert system module written in CLIPS (a rule based expert system language developed by NASA), where architectural design recommendations are generated. These recommendations, consisting of both graphics and text, are then passed back to the main program where they can be viewed by the user through a recommendation menu. Here, the user is able to ask for more information about a given recommendation to find out which climatic factors were key in generating the recommendation. The user can also 'set' a recommendation area (such as entry location, or suggested wall material) to a certain value, in which case other recommendations will be generated around this 'static' value. This enables the user to create "what if..." scenarios.

CLIMAT presently addresses sixteen design issues, ranging from building grouping and building form, to the use of plants and water, to suggested interior and exterior wall materials. The program is structured to allow the addition of many more design issues. The program has been used to assist with design classes and has effectively produced design guidelines which, when followed result in more energy efficient buildings.

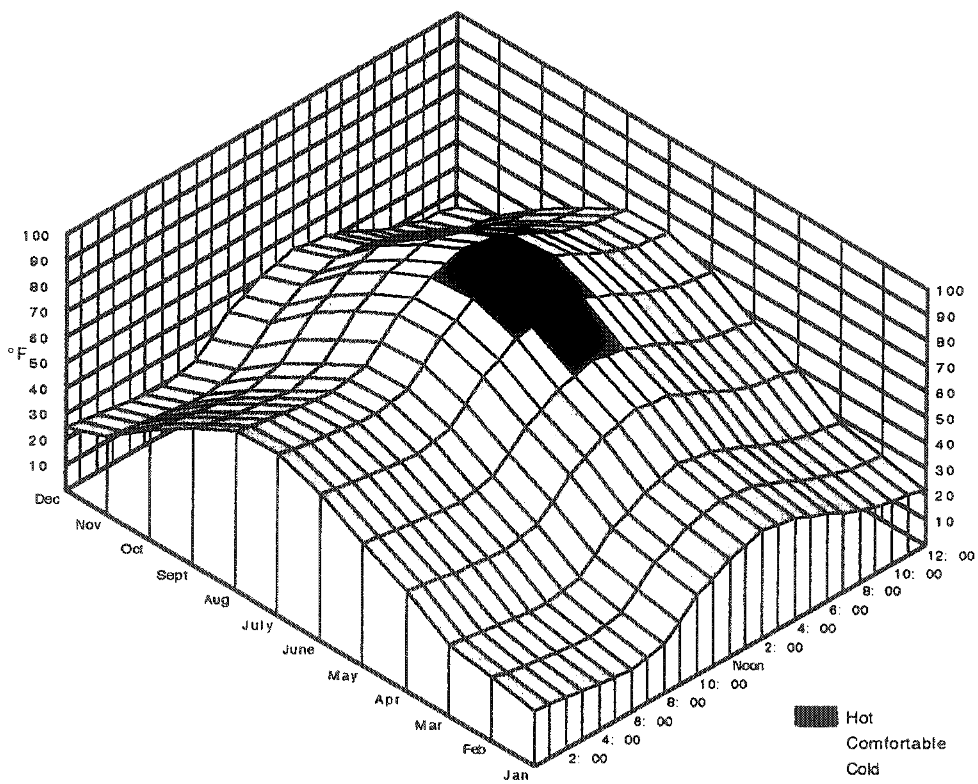

Figure 2. CLIMAT 3-D Temperature Graph

DATABASE OF THE ENERGY PERFORMANCE OF OFFICE BUILDINGS IN MONTREAL

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INTRODUCTION

The information concerning the real energy performance of large office buildings plays a special role at different levels of the decision-making process. For example, the architectural and engineering consulting firms use this information to define feasible target values for new office buildings, or to assess the potential for energy savings in existing buildings.

In order to define these data, a survey of the energy performance was carried out by the authors [1] in Montréal, Québec, Canada on a large sample of 68 office buildings, with a total rentable area of 2.6 million m^2. The information from the utility bills and the questionnaires was processed, and a database was developed using the following variables:

1. General building data: year of construction, building type (ex. office building with or without retail stores, with or without garage), building class, total rentable area, number of floors, glazing type, glazing-to-wall ratio, type of fuel, number of operating hours per day (lighting, HVAC systems);
2. Energy performance data: energy cost ($\$/m^2/yr$), energy consumption ($kWh/m^2/yr$), monthly average electrical demand (W/m^2), electrical-to-total energy consumption ratio, electrical-to-total energy cost ratio, cost of equivalent-kWh.

This paper presents some conclusions about the energy performance of large office buildings (total rentable area greater than 4500 m^2) in Montréal.

CONCLUSIONS

The main indices calculated for Montréal are summarized in Table 1. This table also presents the average values for the U.S.A. and the Northeast states (Maine, Vermont, New Hampshire, Massachusetts, New York, Connecticut, New Jersey and Pennsylvania) [2]. The purpose of this comparison is to show the effect of factors such as climatic conditions or utility rates on the energy performance. One can notice a higher energy consumption in Montréal than in the Northeast states, but a lower energy cost mainly due to the larger use and lower cost of electricity in Montréal.

The year of construction has a sensible effect on the energy performance of office buildings. Thus, the monthly average electrical demand in buildings constructed immediately after the 1973 oil crisis reaches an average of 80 W/m^2 floor area, due to a larger use of electricity as the main source of energy (Figure 1). The cost of equivalent-kWh is higher in new buildings than in older ones (Figure 2), because the former use more electricity, and its cost includes consumption and demand. The ratio electrical-to-total energy cost (Figure 3) varies between 0.6 (offices built between 1960 and 1970) and 0.95 (offices built after 1985). The larger use of electricity in buildings in the past few years is also due to the increase in the installed capacity of the office equipment (micro-computers, printers, typewriters etc.). A similar trend of using more electricity is experienced by the office buildings in Montréal and in the U.S.A., and is presented in Figure 4, where

Table 1. Comparison Between the Average Energy Performance of Office Buildings in Montréal, U.S.A. and the Northeast States

	Montreal	Northeast States	U.S.A.
Average energy consumption ($kWh/m^2/yr$)	455.3	344.1	334.6
Percentage of energy consumption by source (%)			
Electricity	68.0	62.4	63.5
Gas	15.0	11.9	25.5
Oil	15.0	13.4	3.9
Other	2.0	12.3	7.1
Average energy cost ($\$/m^2/yr$)	17.9	23.03	16.7
Percentage of energy cost by source (%)			
Electricity	73.0	87.9	87.2
Gas	7.0	3.7	8.0
Oil	6.0	3.3	1.4
Average cost of equivalent-kWh by source ($/kWh)			
Electricity	0.0415	0.0943	0.0686
Gas	0.0174	0.0207	0.0154
Oil	0.0149	0.0164	0.0171

for the new buildings the ratio of the electrical-to-total energy consumption is about 92% for Montréal, and about 76% for the U.S.A. The survey also found that about 12% of the sample buildings have the energy consumption between 250 and 300 $kWh/m^2/yr$, and 22% have the energy cost less than 14.00 $\$/m^2/yr$.

REFERENCES

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2. "Nonresidential Buildings Energy Consumption Survey: Commercial Buildings Consumption and Expenditures 1986", Energy Information Administration, Office of Energy Markets and End Use, U.S. Department of Energy, Washington, D.C.

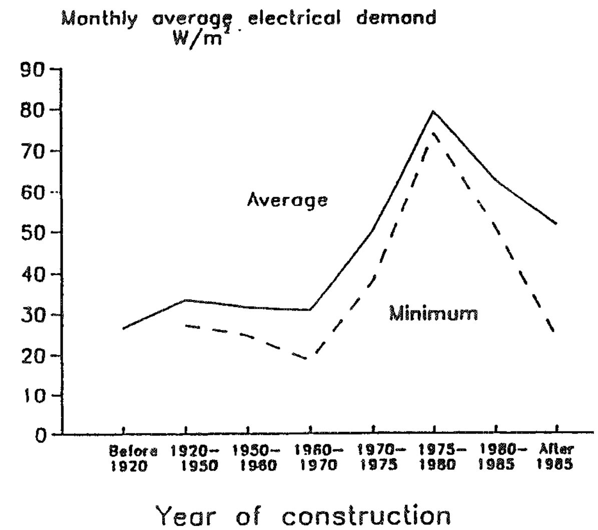

Figure 1. Monthly Average Electrical Demand Versus Year of Construction

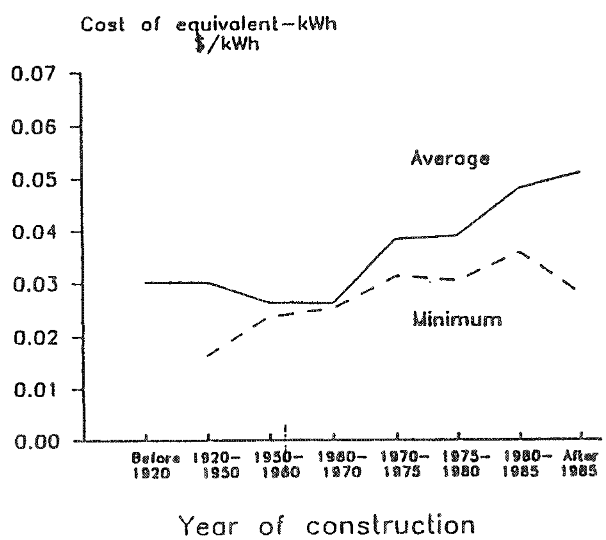

Figure 2. Cost of Equivalent-kWh Versus Year of Construction

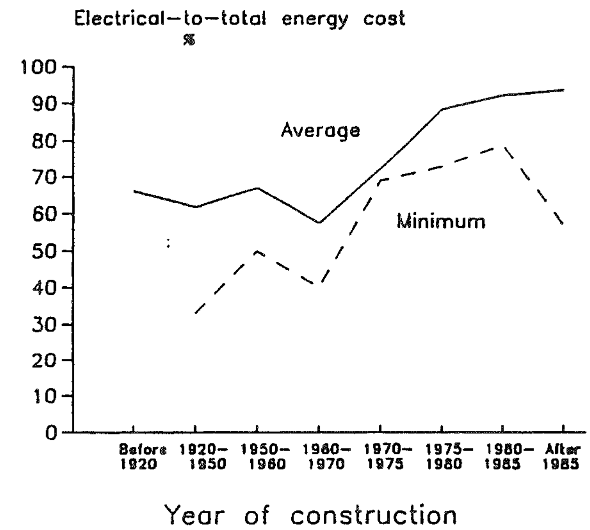

Figure 3. Electrical-To-Total Energy Cost Ratio Versus Year of Construction

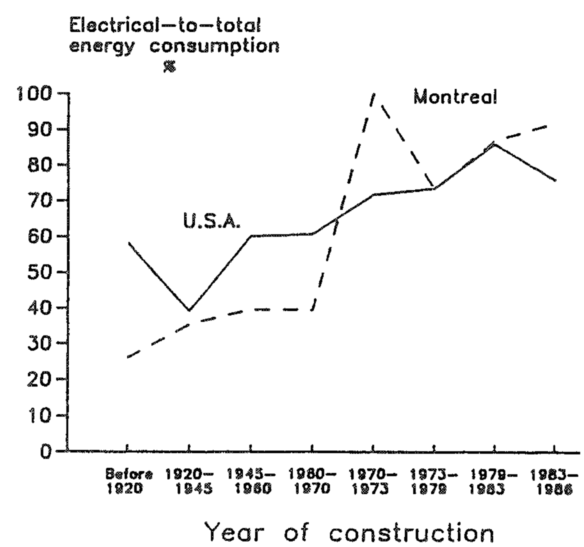

Figure 4. Electrical-To-Total Energy Consumption Ratio Versus Year of Construction