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# Energy performance assessment and a retrofit strategies in public school buildings in Rome

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ABSTRACT

The aim of this paper is to assess the quality of public schools in Rome in order to create a good database as a first-step in defining possible intervention strategies to reduce energy consumption in this sector. The urgency is not only determined by the criticality of the current situation but also by the observation of how a very important voice of losses is related to inefficiencies in the management of buildings and plants that can be easily overcome with simple and low cost actions.

The measures adopted to reduce consumption in school building sector were defined according to the dimensional, technological and architectural features of the schools. The analysis was performed by comparing the costs parameterized for standard retrofit interventions for the existing envelopes and plants to the benefits achievable by the interventions in terms of energy and money saving through a simple payback time analysis (PBT) useful to identify priorities for action. Finally, it has been estimated the environmental benefit achievable in 20 years through a spread action of refurbishment on plants and on envelopes.



## 1. Introduction

Public building should have an exemplary role in relation to energy saving for the whole community, as required by EU Directives [1–3]. This is more clear in school buildings, for their capacity to spread a new style of living based on ecological responsibility,[1] especially among future generations. In these buildings it is necessary to strike a good balance between cost reduction and high levels of comfort to influence student's performances [4,5] through efficient control systems for air temperature, humidity, air speed and air purifying.

Despite their importance, school buildings are characterized by high levels of energy consumption that are not justified by a good indoor air quality, since there are no air changing systems.

This research aims to carry out an analysis of the current situation and to identify strategies for energy saving [6–8]. Therefore the analysis will be focused on energy consumption for space heating, which is the highest share of energy consumption and the sector with the highest potential for reduction, generated by a low technological level in the building structure and plant system [9].

## 2. Methods

This research was limited to primary school buildings in Rome, which constitutes roughly 1296 structures for a total of 13.5 million $m^3$.

The analysis has been performed comparing three different data:

- Inventory of municipal school buildings containing general information useful to describe the composition in terms of number, type and dimension of buildings. This data was updated on June 30, 2000 and has been provided by the City of Rome's Department For Assets Management.
- Energy label of municipally-owned buildings, useful to describe the quality in terms of energy consumption for building's envelopes and plants, calculated through UNI-TS 11300 standards [10]. Although it is not possible to fully guarantee the homogeneity of this data, due to the high number of technicians appointed by the different districts, the large amount of data available (for about 820 buildings used as primary school) provides an excellent starting point for each analysis. These data are provided by the City of Rome's Department For Assets Management.

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[1] It is estimated that the Italian public school students are about 7.5 million, the teachers 0.9 (data: *Rapporto 2009 sulla scuola in Italia*, Fondazione G. Agnelli Dicembre 2008). Considering students, teachers and parents more than a quarter of the Italian population attends daily, school buildings.

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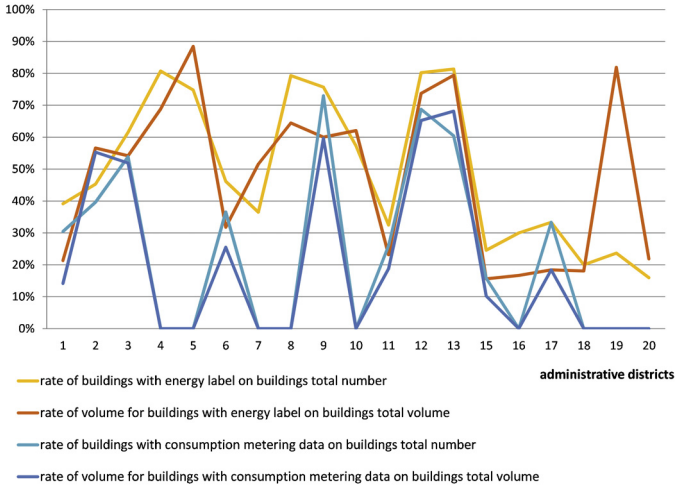


**Fig. 1.** Representativeness of the sample data on the total: percentage rate of the number of structures and total volume of analyzed buildings.

- Building consumption as heat transferred from several thermal power plants to school buildings, measured quarterly between 2003 and 2008 by counters. Consumption is measured as thermal plant's output because thermal plant maintenance and upkeep are managed by contractor companies. This data provides a high degree of objectivity to our analysis, while minimizing error rates. This data have been provided by the City of Rome's Department for Education for 382 buildings.

In a first step this data has been collected and classified taking into account the administrative subdivision of Rome's territory in 19 districts numbered from I to XIX excluding XIV, in order to achieve a geographical and partly historical distribution of data considering that peripheral buildings are often younger than the central ones. The sample considered includes (Fig. 1):

- 684 buildings with an energy label (50% of total buildings).
- 271 buildings with consumption's metering from 382 to 271.
- 261 buildings with both data available (20% of total buildings).

In a first step it have been performed an analysis on consistency of existing school buildings and an assessment of buildings' envelope and thermal plant through data provided by the inventory and the energy labels. In this way it was possible to create a model on which analyze the current energy consumption and measure possible intervention actions. In reality it would not be possible to compare data form energy labels and data from energy measurement, being a comparison between a theoretical consumption calculated using standard assessment and a real consumption, influenced by operating conditions greatly different from calculation's asset rating. However, it have been useful to separate out the individual items of consumption and, therefore, to define priority actions to reduce energy consumption. On the basis of this analysis were then identified some actions of intervention, that have been assessed by simple PBT.

## 3. Analysis on consistency of existing school buildings

The total volume of the City of Rome's public school buildings is 13,518,925 $m^3$, the average building volume is 10,431 $m^3$. This value however, is not very significant considering that the entire assets are formed by a highly heterogeneous group of buildings, from small scale kindergarten to large scale structures typical of the beginning of the 20th century.

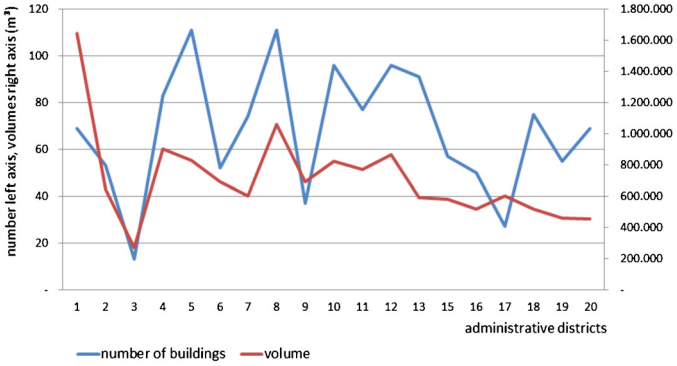


**Fig. 2.** Number and volume of existing buildings by district.

More information may be provided from the analysis of the buildings location. In peripheral districts IV, V, VIII, X, XI, XII and XIII are the highest number of buildings with lower average volumes while in central districts I, II, III, VI, IX and XVII, school buildings are in lesser number but are characterized by larger volumes (Fig. 2). The 68% of buildings exceeding 30,000 $m^3$ in volume are concentrated in the central area.

This territorial structure can easily be justified by an analysis of the historical development of current assets (Fig. 3). In fact, located in the central districts are the first communal public schools established in existing historic buildings, characterized by large volumes and high ceilings. Located in semi-central districts II, III, VI, IX, XIII and XVII are the first structures built specifically as schools in the period between the unification of Italy and World War II. School buildings constructed during these years all have some common characteristics: large volumes (often greater than those of the historic buildings), compact forms, load-bearing wall structures with floors in brick and concrete, flat roofs and large window areas.

After the Second World War and the population boom of the 1960s, we can clearly identify a final intense construction phase affected by the publication of the first technical standards for educational buildings [11]. These standards have greatly influenced the future buildings which all have common characteristics: more open volumes (entailing an increase of surface dispersant in equal heated volumes), maximum height of two floors (three for middle schools), extensive use of reinforced concrete structures with curtain walls and large window surfaces. A different class may be formed separately from kindergarten that – if some structures realized in portions of existing historic buildings in the city center are excluded – are often relatively recent constructions, characterized by small volumes, single floor and a tolerable wall thermal dispersion.

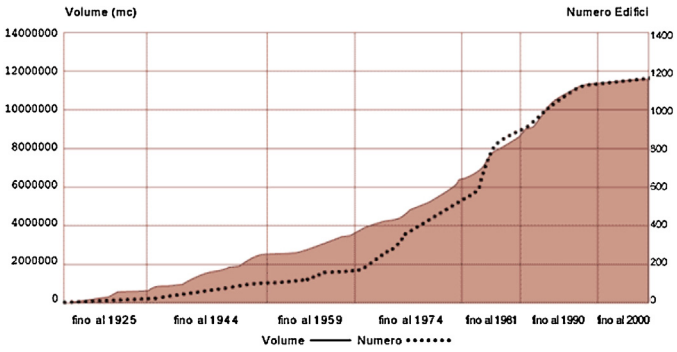


**Fig. 3.** Trend of growth in public school constructions in Rome, in terms of volume and number of building.