

Energy Analysis and Selection Criteria for Third Party Financing of School Buildings

Manfred SAKULIN,
Ernst SCHMAUTZER
Institute for Electrical Power Systems,
Technical University Graz, Austria

1 - SYNOPSIS

In order to be successful and cost effective third party financing projects have to concentrate on objects which are characterised by a very bad initial condition concerning energy consumption, on the one hand, and by high energy costs exceeding a certain threshold, on the other.

2 - ABSTRACT

The paper describes an approach to find out appropriate objects based on a province wide inquiry in public buildings, predominantly schools, in about 600 municipalities in the province of Styria in Austria. A comparison of characteristic energy figures concerning electrical and heating energy is performed for about 150 schools in order to sort out those objects which have high total energy cost and high specific energy consumption as well. In a further step a detailed analysis is performed to find out the reasons for the high energy consumption and the points for improvements of cost-effectiveness.

3 - INTRODUCTION

In the last decades energy analyses in various countries have shown that one of the large energy saving potentials can be found in the sector of public buildings (EU-PROJECT, AGES 1997, FANTL 1984). However, the realization of these potentials is very difficult, - firstly due to the lack of public investment capital, secondly due to long pay back periods and thirdly due to the fact of split responsibilities and budgets for investment and for maintenance and operation of buildings.

A new way for solving that problem is third party financing, a solution which was applied at first in the United States rather early in the 70ies and 80ies. Third party financing means that an external private investor finances the cost for improvements of energy efficiency – e.g. replacement of heating systems, installation of heat insulation, installation of regulation systems, maintenance of the heating system, replacement of lighting equipment and other appliances, whereas the return of investment is yielded by the savings in energy cost. The customer – i.e. the institution using the building – has to pay the "old" high or only slightly lower energy cost. The difference to the new reduced energy cost is available for paying the annual capital cost of investment. A contract between the involved parties – the user of the building and the private financing investor – regulates the conditions - e.g. the number of years of continuation of the old payment rates, the influence of climatic changes, changes of the building usage, maintenance responsibility, ownership etc. In that way the user does not have to take over any investment risk or responsibility which might be beyond his scope of competence. The private investor takes the risk. Therefore, he has to select very carefully the objects for realisation of third party financing. A detailed energy analysis based on the assessment of energy specific figures and an inspection of the building itself are necessary, at least.

In the following, the paper describes an approach to select appropriate schools for third party financing, as it was performed in the province of Styria in Austria. Mainly primary and secondary schools, which are administrated by the municipalities themselves and not by the state, were analysed in a campaign organised by the Institute for Electrical Power Systems of Technical University Graz in 1998.

3.1. Energy analysis of schools

As already known from previous analyses performed in the 1980ies by Institut für Energiewirtschaft Vienna (FANTL), the specific energy consumption of schools varies in an extremely wide range. The reason for that wide spread is very complex: Energy consumption depends on several parameters – geographical location, type of the building, the status of the building's heat insulation, the heating system efficiency, the energy carrier, the heat distribution and regulation system, the size of the building, the usage schedules of the building with classrooms and gyms for teaching and sports – half day, full day – or for other purposes, the user behaviour etc.

3.2. Definitions

In order to compare different schools concerning energy it is necessary to introduce energy specific figures – e.g. annual consumption per square meter, per pupil etc. The definition of these parameters and characteristic figures must be documented carefully. One of the most important energy specific figures is the energy consumption divided by the floor space. Both parts - the energy consumption and the floor space as well - are defined in different ways in the literature and in the different national standards (ONORM 1800, ONORM 8110-1, SIA 180/4, VDI 3807, 1). Concerning energy consumption, it must be defined if it includes heating energy for room heating only - or also for warm water, and also electricity for light and other appliances.

Concerning floor space it must be defined if it means the outside area multiplied with the number of floors, the so-called gross floor space, or the useable floor space excluding walls, staircases, cellar, corridors, etc. Unfortunately, due to different definitions, and due to missing documentation, many studies of the past are not really comparable in their results.

4 - THE STYRIAN APPROACH 1998

Institute for Electrical Power Systems of TU Graz, which is currently involved in a SAVE Project dealing with energy management in schools, was looking for appropriate objects for third party financing in order to be able to perform a detailed energy analysis before and after improvement of the buildings. For that purpose – as described – a survey of Styrian schools was performed, based on a questionnaire which was sent to the mayors of the municipalities. All addresses are available in the internet (electronic telephone book), that means they are available in electronic form. From the 600 municipalities about 25 % answered, - a percentage which can be regarded as relatively high.

4.1. The questionnaire

The questionnaire – designed for a rough analysis (fig. 1) - was just one single sheet with rather simple questions, easy to answer and easy to handle. It just had to be filled in and returned by fax. This simplicity explains the rather high rate of returned questionnaires.

The questions comprise three parts:

- *The first part asks for energy consumption parameters:* the type of the heating system, the energy carrier and the amount and purchase date of fuel and electricity according to the energy bills. *The second part asks for building data:* outside dimensions, number of floors, useable space and extra space for gym and caretaker's flat. Additional questions are asked concerning for the year of construction and the year of last renovations. *The third part asks for the building usage:* hours per week for regular school usage and for extra usage.

4.2. Evaluation of the questionnaire

The evaluation was performed in order to select objects with best conditions for third party financing. First of all, these objects must have a high specific energy consumption and secondly, need a certain absolute volume of annual energy cost.

Fig. 2 shows the absolute input data directly depicted or derived from the questionnaire and presented as bar diagrams for the distribution of the total energy consumption, the gross floor space, the number of pupils and the total energy cost for 141 school buildings. The gross floor space is the area based on the outside dimensions summed up over the floors. For the ratio between useable floor space and gross floor space an average figure of 0,75 was derived from the answered questionnaires.

As can be seen, there is a large spread in all diagrams mainly depending on the size of the school as follows:

- Gross floor space from 200 m² to more than 10.000 m² with an average of 1911 m² Energy consumption from 25.000 to 1250.000 kWh per year with an average of 225.000 kWh per year. *Number of pupils from 10 to 1.200 with an average of 132 pupils.*
- *Energy cost from ATS 40.000 up to ATS 750.000 per year (EURO 3.000 up to EURO 50.000) with an average of ATS 180.000 (EURO 13.000) per year.*

Fig. 3 shows the specific energy characteristic figures, - also as bar diagrams ordered in falling size of the total energy consumption per gross floor space and, in the same way per pupil, and the total energy cost per gross floor space, and per pupil.

The results can be summarised as follows:

- *The specific energy consumption per gross floor space varies between 40 kWh/m²a and 500 kWh/m²a with an average of 166 kWh/m²a.*
- *The specific energy cost show a range between 30 ATS/m²a up to nearly 500 ATS/m²a (2 up to 35 EURO/m²a) with an average of 110 ATS/m²a (8 EURO/m²a).*
- *The energy consumption per pupil goes up from 300 kWh/a to 18.000 kWh/a with an average of 2.740 kWh/a.*
- *The energy cost per pupil shows numbers from 4 ATS up to 8.000 ATS/a (600 EURO/a) with an average of 1.778 ATS/a (130 EURO/a).*

Total energy consumption and total energy cost include fuel for room heating and warm water, plus electricity (HT: high tariff) for appliances. As can be seen in fig. 4, the portion of HT-electricity is around 14 % of the total energy consumption, whereas the corresponding cost share is much higher – nearly one third of the total cost. From this cost ratio follows, that improvements in the electricity sector in some cases can be as important concerning cost saving as improvements in the heating sector.

Fig. 5 shows a double bar diagram for the specific energy consumption per gross floor space and the corresponding total energy cost in the order of falling specific energy consumption. The bars are split in HT-electricity and fuel and, furthermore, coloured according to the energy carrier. This figure gives a very good overview and allows to consider different criteria for selection.

The main selection criterion is the initially existing energy efficiency: the higher the specific energy consumption per gross floor space, the higher is the potential for improvements and consequently for energy savings. However, there must be a certain size or volume of savings in order to cover the fix cost of pre-investigations and of the improvements, on the one hand, and to achieve acceptable payback periods, on the other.

Specific energy consumption figures below 70 kWh/m²a can be regarded as energy efficient, 150 kWh/m²a means average efficiency, and from 200 kWh/m²a upwards energy improvements are advisable (ONORM 8110 1998). In the cases exceeding the 200 kWh/m²a, school administration is informed and suggested to check the status of the building and the heating system in order to improve efficiency of the building.

5 - ESTIMATION OF ENERGY AND COST SAVING POTENTIAL

As can be seen from fig. 3 – in the graph for specific energy consumption per gross floor space, there are around 40 schools with energy consumption figures above 200 kWh/m²a.

Assuming (EU-PROJECT SAVE, EVA 1998, FREY 1994) that a target efficiency figure of 100 kWh/m²a can be reached by improvements of the buildings with reasonable efforts, the energy saving potential p_e can be calculated as follows:

$$p_e = \frac{\Delta e}{e} = \frac{e - e_t}{e} \quad (1)$$

e	specific energy consumption (kWh/m ² a)
Δe	possible reduction of specific energy consumption (kWh/m ² a)
e_t	$e_t = 100$ kWh/m ² a: assumed target of specific energy consumption (kWh/m ² a)
p_e	relative energy saving potential (p.u.)

The possible absolute energy cost savings per year follow by multiplying the total energy cost according to fig. 2 with the energy saving potential p_e .

$$\Delta C_{\text{abs}} = p_e \cdot C \quad (2)$$

ΔC_{abs}	absolute energy cost saving potential per year (ATS/a)
C	total energy cost per year (ATS/a)

Fig. 6 shows the result of this approach – a double bar diagram for the relative energy saving potentials in falling order and the corresponding absolute energy cost saving potential per year.

As can be seen,

- for the 40 schools with a specific consumption above 200 kWh/m²a the relative energy saving potentials p_e range between 50% and 80% of total energy consumption, and
- the absolute annual cost saving potentials are between 20.000 and 400.000 ATS/a and school (1.500 and 30.000 EURO/a and school).
- Assuming acceptable payback periods between 5 to 10 years, the above calculated annual energy cost saving potentials allows for total investment capital per school from ATS 100.000 up to 4 Million ATS (EURO 7.500 up to EURO 300.000).

In order to estimate the possible improvements this large range of the resulting investment capital must be seen in relation to the size of the school.

An estimation of the available amount of money per square meter of gross floor space (parameter c_{gfs}) or per square meter of building surface (parameter c_s) follows by dividing the absolute cost savings by the gross floor space or by the reference building surface S_{ref} according to equations 3 and 4 as shown in fig. 7.

$$c_s = \frac{\Delta C_{\text{abs}}}{S_{\text{ref}}} \quad (3)$$

$$c_{\text{gfs}} = \frac{\Delta C_{\text{abs}}}{S_{\text{gfs}}} \quad (4)$$

The reference building surface, which can be used to estimate the necessary area of heat insulation material, is derived from the gross floor space and the number of rooms using the approximation formula (5):

$$S_{\text{ref}} = 4 \cdot \sqrt{\frac{S_{\text{gfs}}}{n_f}} \cdot 3 \cdot n_f + 2 \cdot \frac{S_{\text{gfs}}}{n_f} \quad (5)$$

S_{gfs}	gross floor space (m ²)
S_{ref}	reference building surface including cellar and roof ceilings (m ²)
n_f	number of floors
c_{gfs}	possible specific annual investment capital per gross floor space (ATS/m ² a)
c_s	possible specific annual investment capital per surface area (ATS/m ² a)

- *The resulting possible specific annual investment capital ranges from ATS 50 up to ATS 250 (EURO 4 to EURO 18) per square meter of gross floor space (c_{gfs}), and from ATS 25 to ATS 130 (EURO 2 to EURO 10) per square meter of the building surface area (c_s).*
- *With the above mentioned tolerable pay back periods of 5 to 10 years, these numbers allow for investments of ATS 250 to ATS 3000 (EURO 18 to EURO 220) per square meter gross floor space, or ATS 125 to ATS 1300 (EURO 10 to EURO 100) per square meter of surface area.*

This amount of possible investment capital is in the range of actual cost for renovation or additional heat insulation. Normally, third party financing of energy saving improvements of buildings should not be a separate project, but rather be a part of a necessary building renovation and should help to allow the decision for better efficiency in energy relevant questions.

After the selection of suitable objects, the next step is an inspection of the objects in order to find out the reasons for the high energy consumption and to determine the best improvement measures for energy and cost efficiency (EVA). It must be taken into account that e.g. heat insulation for a small school could be even more expensive than the exchange of the heating system or the improvement of the regulation system for a large school. On the other side, also small schools may have a high specific cost saving potential, if an expensive energy carrier (e.g. HT-electricity) is used.

6 - CONCLUSIONS

In the paper presented, a simple way for the selection of appropriate objects for third party financing in the public school sector is described. A rough energy and cost analysis of 141 Styrian schools is the basis for the energy and cost figures, which were used to find out interesting objects. 30% of the investigated schools have a specific annual energy consumption per gross floor space of more than 200 kWh per square meter, and for 10% of these schools it was found that energy saving measures would be very cost effective. Additional information concerning energy carrier, age of the building and the heating system, which were also asked in the survey by questionnaire, will help to select suitable, cost effective measures for energy efficiency improvements and to reduce the financial risk of a future third party investor.

7 - REFERENCES

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Technische Universität Graz, Institut für Elektrische Anlagen **Tel.: 0316 873 7551**
Inffeldgasse 18, A-8010 Graz **Fax: 0316 873 7553**

Questionnaire: Analysis of Styrian School Buildings

Please use for every school a new questionnaire! Mark with a cross if applicable!

name of school:	date:/...../1998
postal code: city: street: tel.:	
contact person: fax:	
type of school: primary school; secondary modern school; other form:	
number of classes; number of pupils	

1. Energy consumption of the last three years – according to the bills

type of heating type: single stove heating; central heating serving one floor; central heating; other forms:.....
heating boiler: year of construction:
energy carrier: coal; biomass (wood;...); fuel oil light; fuel oil extra light; gas; district heating; electricity;

energy carrier	quantity	cost	electricity	cost
date of delivery or date of the bill	[kWh, liter, kg, m³,...]	[ATS] incl. VAT.	year	[kWh]
			1994	
			1995	
			1996	
			1997	

2. Facts of the building

details about the building:				location protected against wind: yes, no	
year of construction	ground plan (outside dimensions) *) length [m] x width [m]	number of floors	useable floor space **) [m²]	gym area [m²]	caretakers apartment area [m²]

*) if ground area is not rectangular, please draw an outline with measurements at the back of the questionnaire
 **) useable floor space: classrooms, teachers room, etc. (without corridors, staircase, cellar, caretakers apartment, gym)

last renovations ***)	year	planned renovations***)	year

***) measures to save energy like exchange of windows, heating control systems, building insulation,...

3. Building usage in the morning in the afternoon in the evening on Saturday

Average time of lessons per class: hours per week
Irregular buildings usage: gym hours per week; classrooms: hours per week;

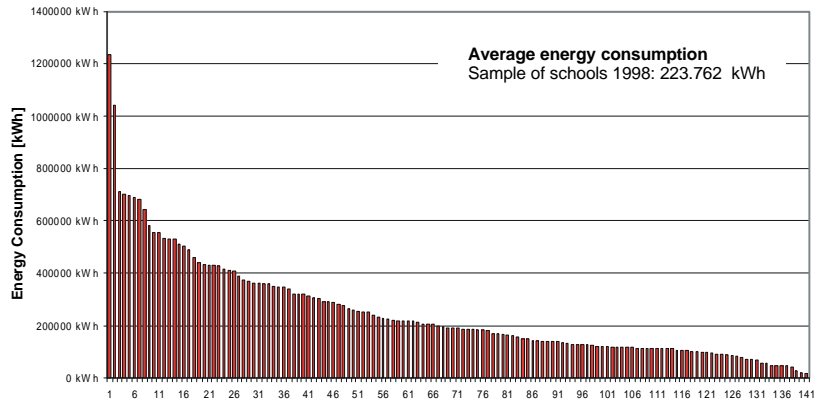
4. Comments (like weak points, features,...)

.....

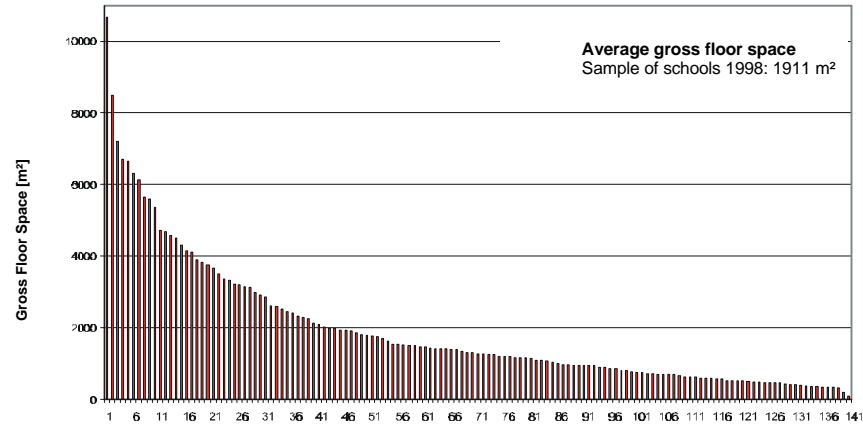
Are you interested in further analysis of your school?:	yes	no
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Fig. 1: Questionnaire.

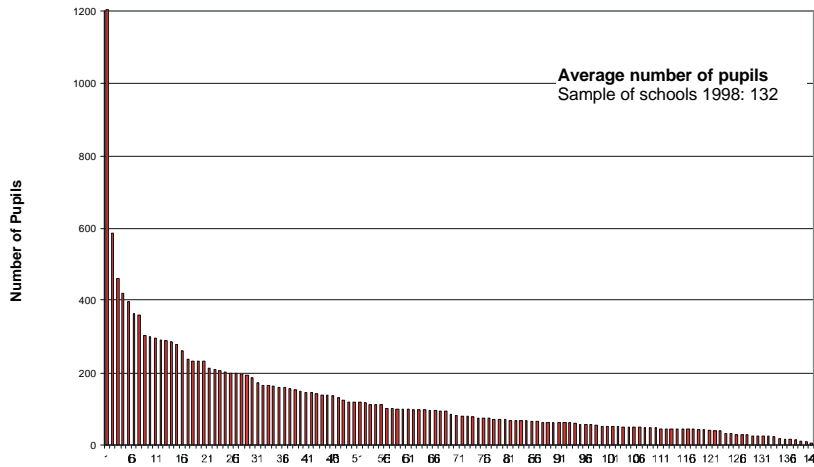
Energy consumption in schools



Distribution of gross floor space



Number of pupils in analysed schools



Energy costs in schools

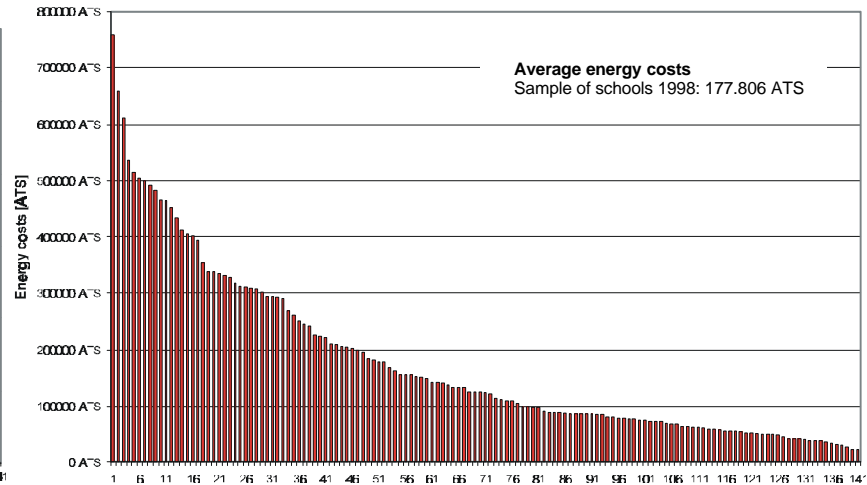


Fig. 2: Annual absolute energy figures of 141 Styrian schools, 1998.

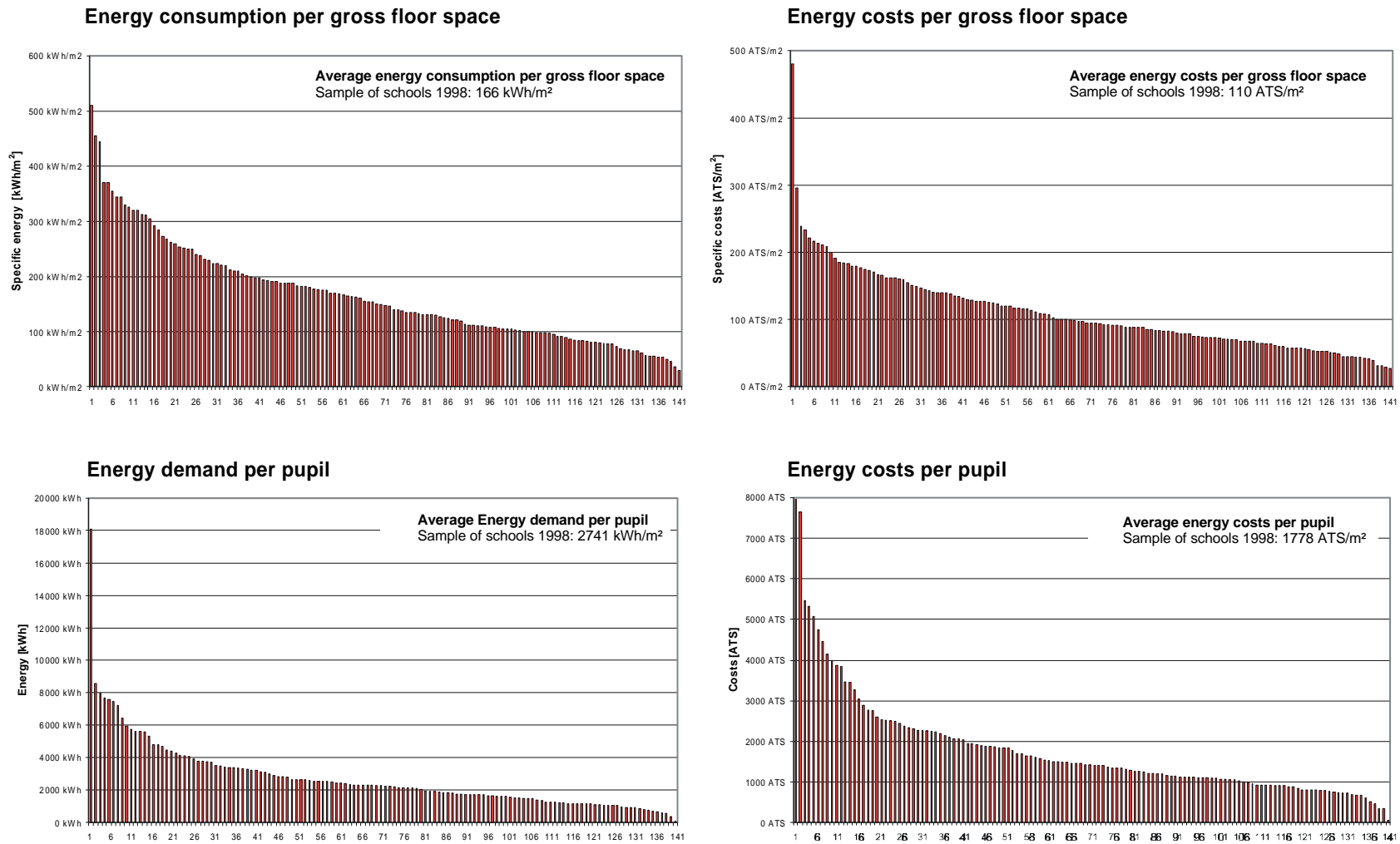


Fig. 3: Annual specific energy figures of 141 Styrian schools, 1998.

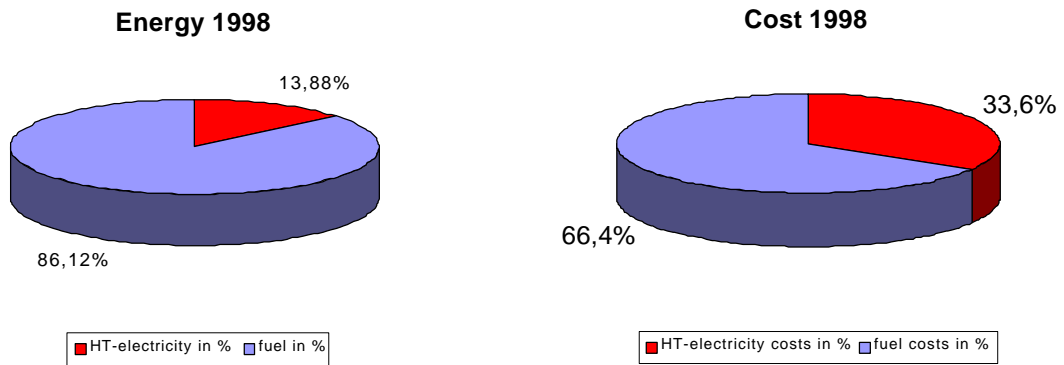


Fig. 4: Relation between High-Tariff-Electricity (HT) and fuel for heating concerning energy and cost, Styrian schools, 1998.

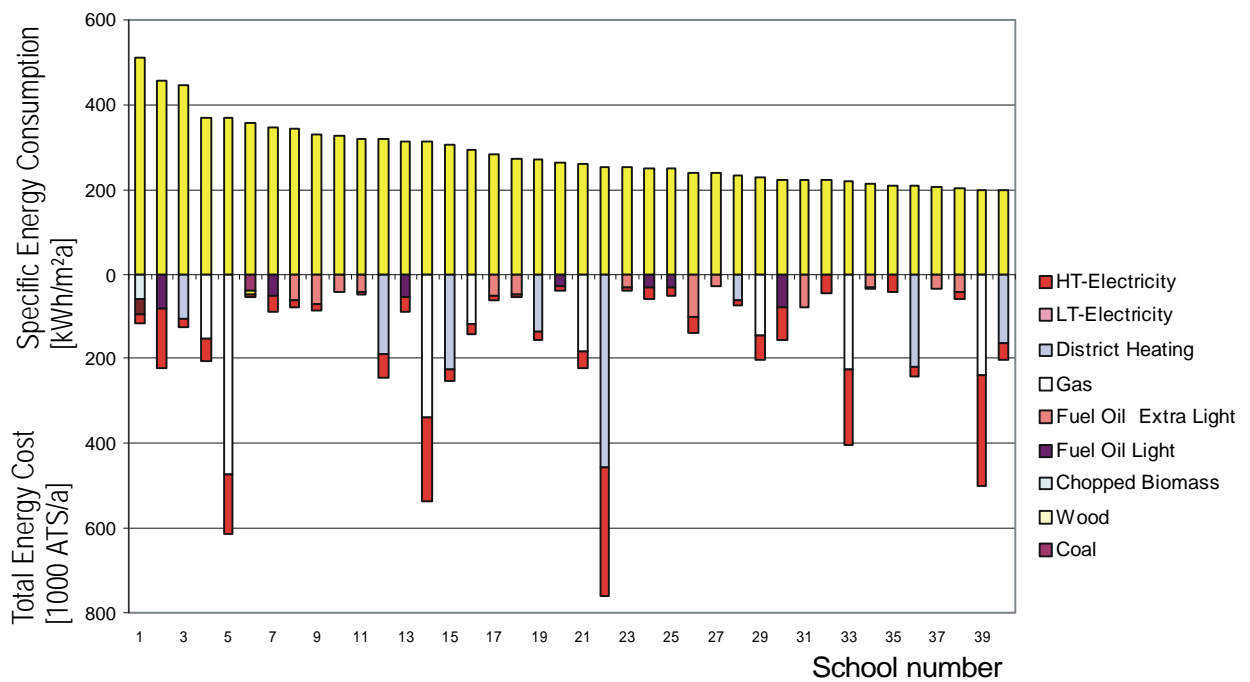


Fig. 5: Specific energy consumption and total energy cost, Styrian schools, 1998.

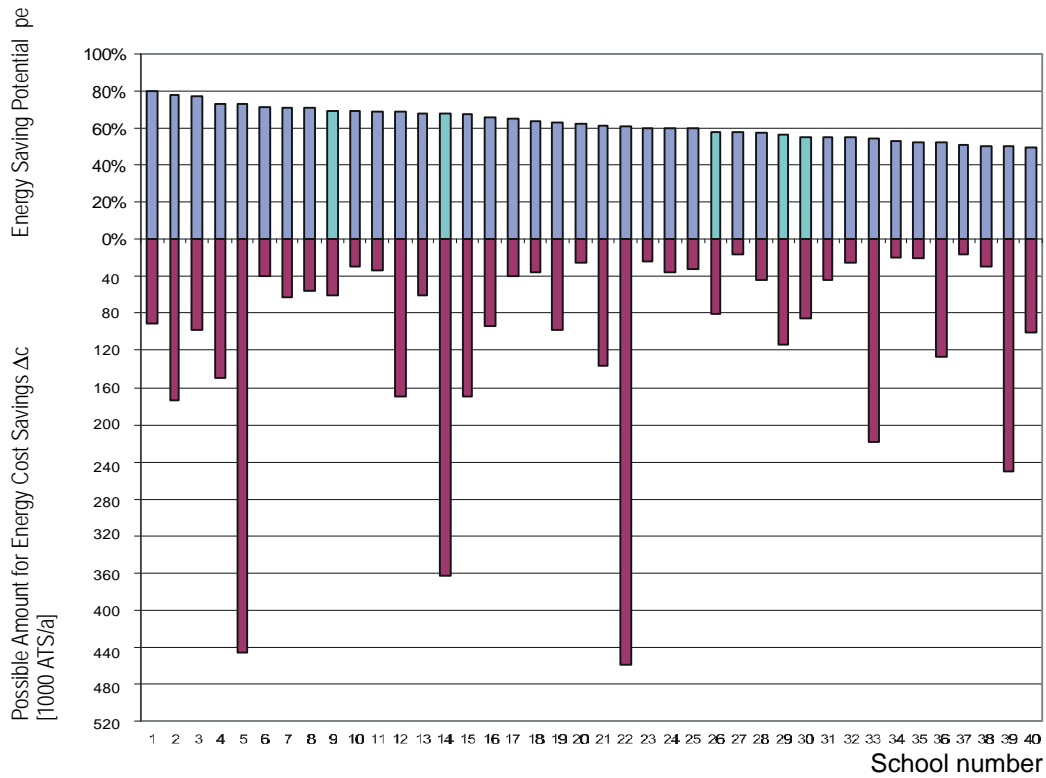


Fig. 6: Annual energy and cost saving potential, Styrian schools, 1998.

Upper bars: relative energy saving potential in % for schools with specific energy consumption larger than 200 kWh/m²a for a target efficiency of 100 kWh/m²a
 Lower Bars: corresponding absolute cost savings

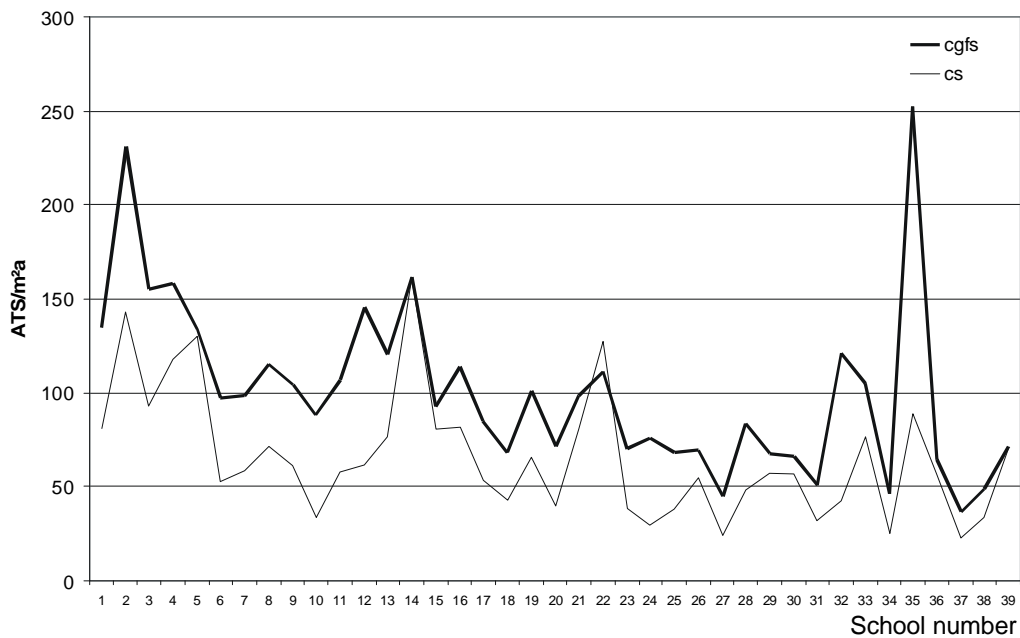


Fig. 7: Annual specific cost saving potentials, Styrian schools, 1998.

c_{gfs} cost savings per square meter of gross floor space
 c_s cost savings per square meter of building surface area