A FEW YEARS EXPERIENCE OF THE ENERGY CONSUMPTION OF A HIGH SCHOOL IN BUDAPEST

Istvan Gärtner
Árpád Secondary Grammar School, Budapest, Hungary, gartner.istvan@arpad.sulinet.hu
Physics Education PhD program, Eötvös University, Budapest

ABSTRACT

I analyzed the consumption of electrical and heating energy based on the data of meters between April 2012 and March 2015 in Arpad Secondary Grammar School in Budapest. In my presentation I summarize the experiences which were obtained from the data. First I compare and explain the consumption of energy between the years and between the different periods of the years. I determine the amount of energy per person and per student groups too, and with a little calculation I interpret the results. After another short calculation I outline whether is it worth for our school to change heating mode. Finally I suggest potential solutions for reducing the consumption of energy which may lead to savings for the school.

INTRODUCTION

The Arpad Secondary Grammar School (Fig.1.), located in the northern part of Budapest, was founded in 1902. From 2012 it has 22 classes, the number of students is about 700.

The building of the school is 75 years old, it has central heating and it is provided with electrical energy by Budapest Electricity Works. We cannot say this building is an energy saving one because of the bad status of the doors and windows and the outdated heating and electrical system. There is no air-conditioning, and both the heating and electric providers are independent from the school.

Fig.1. Árpád Secondary Grammar School in Budapest

AIMS OF THE WORK

The aims of the investigation were to collect and to present those two types of energy data (electrical and thermal energy) which are most important in the field of education in the school. After analyzing them it will be shown through an example taken from everyday life how the data can be made understandable for high school students. Based on the interpretation some options for energy saving will be suggested, too.

DATA FOR ENERGY CONSUMPTION

All energy data – presented in GJ unit – were read in every month from the meter readings between April 2012 and March 2015. The annual (Fig.2.) and the quarterly data charts below (Figs. 3.-5.) show the consumption of energy.

EXPERIENCES

On the annual chart (Fig.2.) it is noticeable that in the first and in the third year the ratio of electrical and thermal energy is about one quarter, but in the second year it is only about one third. The reason is that the temperature of the winter in 2013-2014 was about 2.5 centigrade higher than the hundred-year average so though the consumption of electrical energy increased a little, but the consumption of the thermal energy decreased by much more.

The other information is – as mentioned before – that the consumption of electrical energy increased. The value was higher not only in the second but in the third year. One possible explanation for this was the creation of a new information technology room which operated throughout the whole school year.

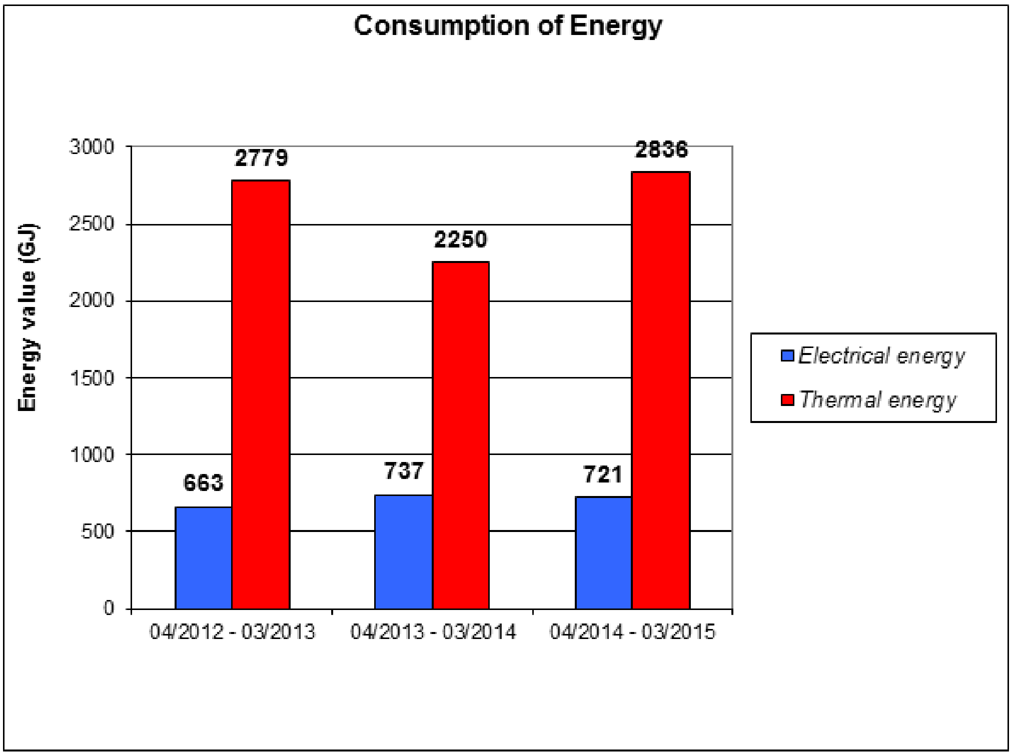

Fig.2. Annual data chart of energy consumption

The next three graphs (Figs.3.-5.) show the quarterly data charts. On all three graphs the periodicity can be seen and from left to the right we can separate the seasons, too. Probably it is not surprising that in the third and in the fourth quarters the thermal energy is 5-7 times more than the electrical energy.

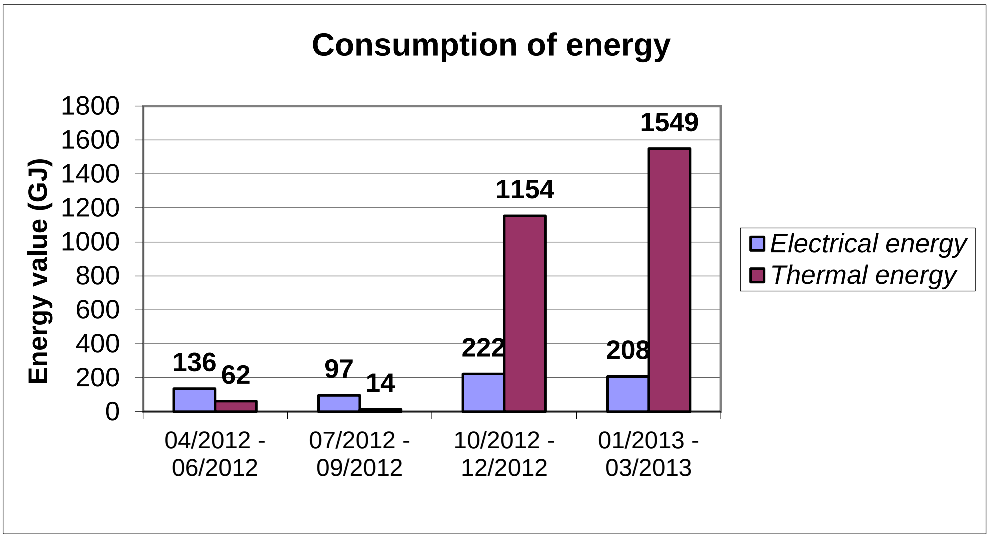

Fig.3. Quarterly data chart of energy consumption – 2012-2013

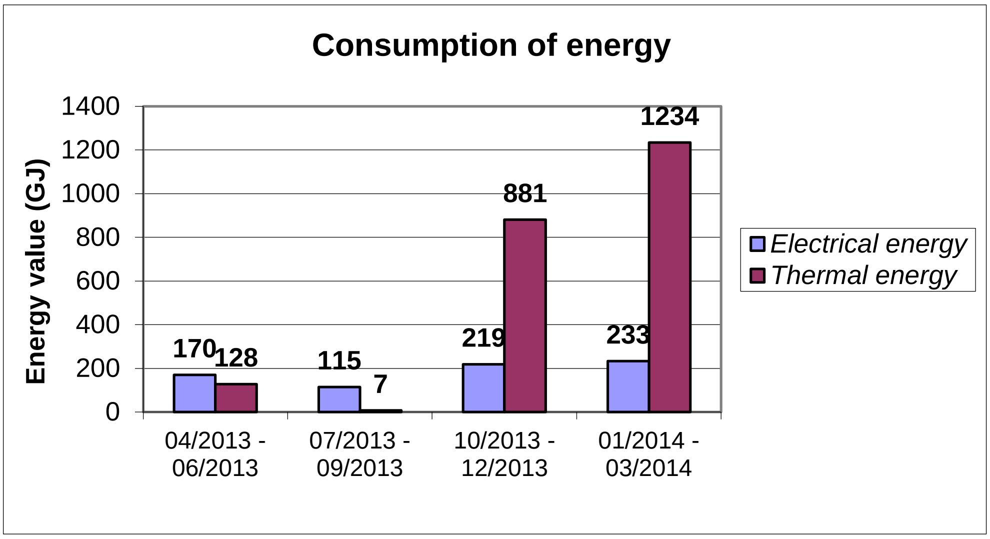

Fig.4. Quarterly data chart of energy consumption – 2013-2014

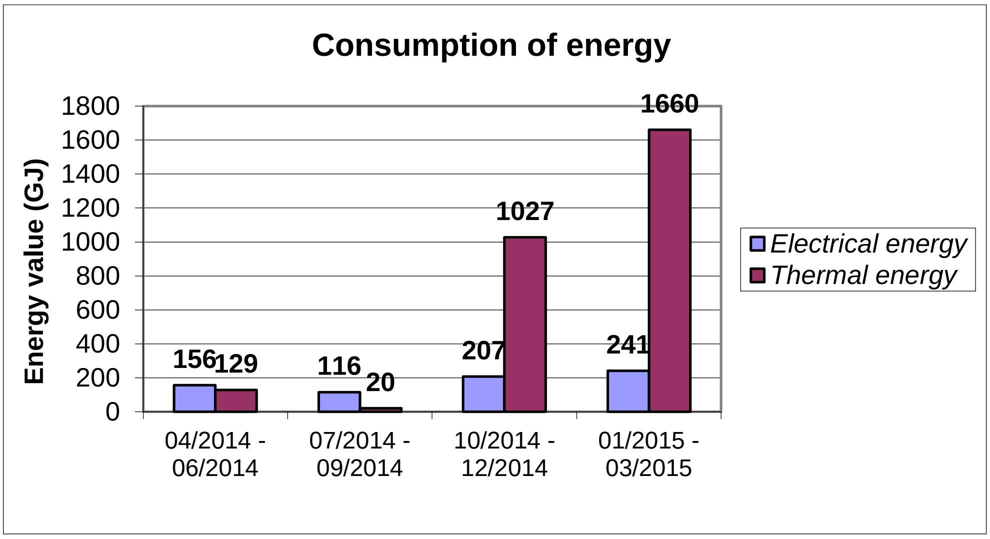

Fig.5. Quarterly data chart of energy consumption – 2014-2015

On the following diagram (Fig.6.) I show the cumulative annual energy values per capita. It is about 5 GJ on average per person.

I also calculated the price of this energy quantity, the value of it is about 100 Euros in Hungary in 2015.

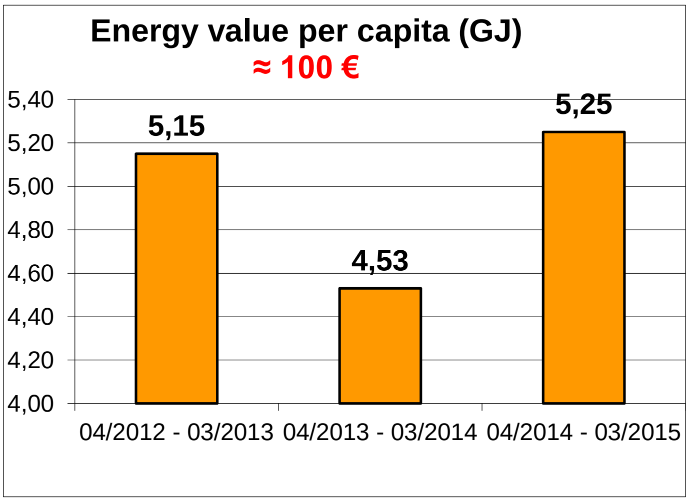

Fig.6. Annual energy consumption per capita

To make the data of the chart understandable for everyone I try to solve a calculation problem which is as follows:

The human body can burn 200 kilocalories in 10 minutes on an exercise bike in the case of a uniform load. The efficiency of the human body is 0.25 [3]. Calculate how much work can be done by a high school student and a class of 30 students in half an hour on it!

$$Q = 3 \cdot 200 \text{ kcal} = 600 \text{ kcal} = 2520 \text{ kJ} = 2.52 \text{ MJ}$$

$$\eta = 0.25$$

$$W = \eta \cdot Q = 0.25 \cdot 2.52 \text{ MJ} = 0.63 \text{ MJ}$$

$$\Sigma W = 30 \cdot 0.63 \text{ MJ} = 18{,}9 \text{ MJ}$$

The solution of the task is 0.63 MJ – assuming that the efficiency of the human body is about 0.25 [3] – and 18.9 MJ if we consider a class with 30 students. These values become clear if we assign such content to them which is in connection with the everyday life.

In our school the rooms are lit by fluorescent lamps, in each room the total power for lighting is 900 W. Let’s assume that the whole work of the class produces electric energy.

$$\Sigma W = 18.9 \text{ MJ} = 18900 \text{ kJ} = 18900000 \text{ J}$$

$$P = 900 \text{ W}$$

$$t = \Sigma W / P = 18900000 \text{ J} / 900 \text{ W} = 21000 \text{ s} \approx 5.83 \text{ h}$$

In this case the energy produced by the whole class is sufficient for less than 6 hours. It means that 30 high school students with hard training cannot produce the amount of energy that a school needs for the lighting of a room in the daily teaching.

It is interesting to determine how much time a high school student needs to produce the annual energy consumption. I used the data of the chart “Annual energy data consumption per capita” (Fig.6.) and I calculate with the mentioned 5 GJ average value. I also used the result from the first calculation problem which showed how much work can be done by a high school student riding on an exercise bike in half an hour. It was 0.63 MJ.

$$\Sigma E = 5 \text{ GJ} = 5000 \text{ MJ}$$

$$W = 0.63 \text{ MJ}$$

$$t = \Sigma E/W \approx 7936 \text{ half an hour unit} \approx 165 \text{ day (without interruption)}$$

I think the solution of the problem is hard to believe, but it should be clear from this result as well that the energy that we can produce in a mechanical way is only a fraction of the quantity that a school needs for its operation. If we try to compare the energy produced by mechanical work with the annual energy consumption, the difference is about two orders of magnitude.

In the light of this striking result it is worth thinking about what the options of a high school for energy saving can be. Even students know that switching off the unnecessary lights will not cause significant saving so we have to look for more efficient solutions.

One possibility would be to change the heating system from central heating to gas heating. Knowing and using the different parameters of gas heating [2],[4] which are typical for traditional gas boilers, after a short calculation we can realize that the costs would be only about 70% of the current costs but the implementation would require serious investment.

$$\Sigma Q = 2800 \text{ GJ (Fig.2.)} = 2800000 \text{ MJ}$$

$$\eta = 0.85$$

$$L = 34 \text{ MJ/m}^3$$

$$V = \Sigma Q / (\eta \cdot L) = 2800000 \text{ MJ} / (0.85 \cdot 34 \text{ MJ/m}^3) \approx 97000 \text{ m}^3 \text{ (price of it is about 32000 Euros)}$$

The other and maybe more viable way for us would be to use alternative energy sources [1], the most feasible of these seems to be the photovoltaic system.

This photo (Fig.7.) was taken in another secondary school – Fasori Gimnázium in Budapest – where the system has been working since April 2015. According to the descriptions – that the school got from the manufacturer – it can produce about 30 MWh = 108 GJ, mainly electric energy. It covers the whole energy demand of the lighting and it is about a quarter of the total electric energy. The school won 85% of the investment costs in a tender opportunity. This solution can be reachable in the future for our school, too [4].

Fig.7. Photovoltaic system in Fasori Gimnázium in Budapest

CONCLUSIONS

In physics teaching the concept of energy is very important. Students meet both with conventional and renewable energy sources during their physics studies. In my teaching process I only mention the topic of this presentation and try to interpret the charts and the results of the calculation problems first in the eighth grade. The main focus of the whole theme of energy saving is in the tenth and eleventh grade where besides the correct interpretation students can complete their knowledge with more calculations and measurements which are in connection with concrete devices (e.g. solar cells).

In this presentation first I summarized and presented the thermal and electrical energy consumption of our school in the last three years. I tried to interpret itwith an example where a comparison was made to the human power. Although it had a surprising and thought-provoking result, it can provide an opportunity to our high school students to recognize that the energy saving will be vital in their future life. On the other hand as a physics teacher I tried to adumbrate some possible solutions for energy saving in my school, too, but all my activities were directed at the didactic task to raise students' awareness of the importance of the problem.

Finally anybody can ask what can be implemented from these? I think the main purpose that students' thinking can develop is achievable. The realization of energy saving ideas needs not only much money but the human will, too. I have 9 more years to retirement and I would like to see it as an active teacher. So I hope….

ACKNOWLEDGEMENTS

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REFERENCES

1. https://secondlawoflife.wordpress.com/tag/energy-efficiency-human-body/
2. J. Goldemberg: *Energy: what everyone needs to know*, Oxford University Press, New York, 2012
3. https://www.eia.gov/todayinenergy/detail.cfm?id=14051
4. R. Wengenmayer, T. Bührke: *Renewable Energy*, WILEY-VCH, Weinheim, 2013