Energetics for secondary schools

THESES OF DISSERTATION

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Introduction

Based on my doctoral dissertation, I use my electronic note, which was written in 2019 and has since been published as a book [1]. A significant part of the knowledge of the document comes from the lectures of Professor Dr. Ádám Kiss at the Doctoral School of Physics of Eötvös Loránd University, entitled "Energy Production and the Environment". In this dissertation these information will be supplemented, on one hand with the data collected and updated since then and with newer knowledge related to the topic, and on the other hand, with additional information that may help bring energetics closer to secondary school students.

Based on my nearly four decades of teaching experience and also on my personal conviction I believe that knowledge of the topic of energetics should be part of general science education. I think that due to the constant development of technology the future generation will need even more of the right scientific approach and the knowledge that underpins it, than the current one. Accurate knowledge of concepts in this area and correct interpretation of related data will also play a key role in this vision.

In my dissertation after a general energy description, I present the historical background of energy consumption and the most important data of the current energy supply system. In this I detail the current role of fossil and renewable energy sources and the advantages and disadvantages of their use. In a separate chapter I describe the current and future possibilities of nuclear energy in energy production and I also cover the situation in Hungary in connection with the Paks Nuclear Power Plant. To conclude the topic of energy supply, I outline the vision of energy policy based on my own thoughts and ideas.

In the final part of the dissertation, I will also briefly present the experiences we had with my wife and occasionally my students when we visited facilities related to energy production. In summary I explain how I will use the experience in my teaching work.

Objectives

The primary goal of the dissertation, similar to the idea of the originally written note, is to pass on the knowledge to the students, but it is also important to have a deeper understanding of the topic of energetics. Therefore I would like to present with physical approach the knowledge related to the energy sources and the energy production with them. From this, in

addition to a better understanding, I expect that the existing and evolving energetic approach will be based on accurate background knowledge.

A further goal would be to enable the interested students to perform relatively accurate calculations in the possession of the knowledge which they got or gained in practice with the visit to the energy production facility. I see all this necessary because the student may be in a situation as an adult, when he or she has to take a position on issues or even make a decision related energetics, and they can only do it with the accurate knowledge.

Theses

1. The relationship between energy and human societies [1]

I present the known units of energy, the areas of use, and the energy consumption in some historical ages. The data provided and the basic units for energy sources allow comparison with the values given in later sections.

The basic unit of energy and most of the associated prefixes are also known to all students, but the additional units and variables described in the dissertation are much less known. Nevertheless, they also need to be presented as they appear several times in the literature and in the media and students meet them. I think it is important for students to know the energy content of fossil fuels per unit weight and volume, because they can help them to understand the data of total energy production and energy consumption.

The annual amount of energy needed to supply the world's population cannot be produced mechanically by human labor. I prove this with the help of a counting task, and at the same time I draw attention to the fact that energy consumption has steadily increased throughout history. This process can be traced in the attached figure, the relationship between energy consumption and the current development of society can be seen, and the increasing pace of growth in the last period can also be discovered.

2. The system and future of the current energy supply [1]

I show the essential parameters of the current energy supply system, the Earth's energy balance and the role of the fossil fuels which ensure this. I highlight and

also provide evidence to support the problems arising from use and the expected consequences.

Using data, I present the development of the world's total and per capita energy consumption over the past 40 years. I make comparisons between the three largest energy consuming countries, as well as between Hungary and the world average, drawing attention to the extremely large differences.

The energy of the Earth is due to three factors, which come from solar radiation, the geothermal energy of the Earth, and the gravitational interaction of the Earth and the Moon, of which the energy transmitted by the Sun per unit time is dominant. As the energy of the Sun can hardly be exploited by mankind, currently only a fraction of it can be used to produce energy, so more than four-fifths of the required energy must be provided by mineral energy sources. I present these in detail, describing the probable values of their stock, their energy content, and their spatial location on Earth.

I also address the problems arising from their use, particularly in relation to pollution, which I support with evidence, and I give an interpretation of this. Among the possible consequences of climate change that is likely for the above reason, I draw attention to those that have already been fulfilled on Earth. I will also mention other issues that are not related to pollution and may be of further concern.

3. The issue of energy saving [1]

"Earth Overshoot Day" is the day in a given year when humanity consumes the amount of a natural resource that the Earth can regenerate in one year. I show that this day falls earlier in every year and in this connection, I draw attention with concrete ideas to the need for energy saving.

As a physics teacher, my goal is for my students to have an accurate understanding of the importance and necessity of energy saving, so I draw attention to "Earth Overshoot Day" and its occurrence sooner and sooner in that year's calendars.

The energy demand of a society is determined by three factors: the number of people living in the society, the social status of the society and its economic and technical development. Energy savings can only be achieved if changes in factors allow. Of the three, this can be achieved most in the case of an increase in economic and technical development. I present in detail the areas where, in my opinion, significant energy savings can be achieved, which in some cases can be manifested either in increasing efficiency or in expanding efficient

production. I also emphasize that the physics teacher has a key role to play in communicating the issue of energy saving to students. In addition to the accurate and credible transfer of knowledge, I consider an important task for the teachers to instruct students on how to evaluate properly the ideas of energy saving in the media.

4. Renewable energy sources [1]

Renewable energy sources are considered to be energy sources that can be continuously replaced within the historical time scale (≈ 10,000 years). After a general characterization, I present in detail the energy production from the direct and indirect use of solar energy, and I supplement these with the energy production process resulting from the tidal phenomenon and geothermal energy.

Energy production from renewable energy sources is suitable for replacing some of the fossil fuels, but it is unavoidable to mention the problems associated with them. The most significant of these is the low energy density, but the problem of energy storage, which is still unresolved today, cannot be neglected either. Another important aspect is the issue of economy and the analysis of the receptivity of members of society to accept change. These are associated by those environmental problems that occur in some way in the use of all renewable energy sources. They may occur in the area of direct interference with wildlife, or due to the aesthetic transformation of the environment, or even due to the final disposal of the materials used during the decommissioning of power plants.

On the topic of direct use of solar energy, I present the three possibilities with which we can "produce" energy in this way. In addition to describing the physical background of the operation, the advantages and disadvantages are analyzed in all three cases. Together with their data, I also give examples of these devices that are currently in operation, and for comparison, I do so for Hungary as well. In a separate section, I describe the current opportunities in Hungary and the plans for the future, and their expected participation in the energy production of the country.

In the chapter on indirect use of solar energy I discuss separately the role of water, wind, biomass, and wave energy as renewable energy sources. In each case I examine the possibilities of the establishment and its economics on a global scale, and I do all this in the case of Hungary, with the exception of wave energy. I present the advantages and disadvantages one by one, as well as their current and future share of the country's total energy production in the case of Hungary.

Although tidal energy, which is one of the renewable energies, does not play a role in Hungary's energy production, it will be described in this dissertation to the extent of a general description, the physical background and some interesting implementations found on Earth. Renewables also include geothermal energy, which, like tidal energy, is part of the Earth's energy balance. It is utilized in two ways, in the form of the production of electricity or the use of thermal energy. I present in detail energy production in both ways, and I highlight the relevant practical applications that are already operating in Hungary and that will be launched soon. In a separate section, I discuss the use of "small-scale" use, the "geothermal" heat pump, and then as a conclusion to the topic I describe the advantages and disadvantages of using geothermal energy.

5. Nuclear energy [1]

The meaning of the word nuclear is related to the nucleus, nuclear energy assumes energy that comes from the transformation of the nucleus. There are two types, nuclear fission and nuclear fusion, fission means the decomposition of a larger nucleus into several smaller nuclei, and fusion means the merging of several smaller nuclei into one larger one. I describe both options in detail, and I also present the operating nuclear power plant in Hungary in connection with the nuclear fission.

The phenomenon of nuclear fission was recognized by two German physicists Otto Hahn and Friedrich Strassman in 1939. In the years following the discovery the use of this knowledge was unfortunately limited to the production of nuclear weapons, the peaceful use which were manifested in energy production, began only after the end of World War II.

With the help of diagrams and the addition of additional explanations, I make understandable the phenomenon of nuclear fission and here concepts are also introduced in the dissertation that are not included in the high school textbooks. After interpreting the phenomenon I give an explanation of energy production, here again a concept (the "late neutron") is presented, which, although omitted from the high school curriculum, helps a lot in understanding, which is why I consider it necessary.

Closely related to the process of energy production is the examination of the entire nuclear fuel cycle, therefore I analyze each step related to energy production one by one. I also address the points that are the subject of the nuclear debate in society today.

To conclude the topic of nuclear fission, I present the Nuclear Power Plant in Paks, I describe its history, current operations, and plans for the future. I also draw the attention to the position that I consider important that high school students should be given credible information about the advantages and disadvantages of expanding the Nuclear Power Plant in Paks by the physics teacher.

A separate chapter describes the phenomenon of nuclear fusion, in which I outline, after a brief presentation of the physical background, this mode of energy production which is more favorable than fission.

6. The future of energy policy [1]

It can be seen that the secure and continuous supply of energy to mankind has become a matter of life for the functioning of society, without which the functioning will be unsustainable in the future. Society needs to recognize the current facts and the necessary actions for the present and the future that can ensure this. I show what I think are the current facts and what to do next.

The facts include the finite amount of fossil fuels, the limited participation of renewable energy sources in total energy production, the economic and social tensions caused by growing energy demand, and the short-term thinking of political systems.

My tasks include the development of organizational forms capable of making long-term decisions on the issue of energy management, the support of energy research and the realization of realistic dissemination of knowledge to the whole society. I greatly emphasize the responsibility of teachers who teach science subjects in secondary school, they must provide the secondary school age group with authentic and accurate information on the topic of energetics, as well as correct explanations based on physical background.

7. Experiences of visits to energy production facilities and their incorporation into teaching lessons [2],[3]

At the end of the dissertation, I give a brief summary of the experiences of my visits to power generation facilities and their use in teaching. In conclusion, I mark the goal I want to achieve in shaping my students' approach to energy in the coming years.

As a physics teacher, but also because of my interest in this, I consider it important that I be completely at home in energetics. Therefore I have visited the Nuclear Power Plant in Paks several times in recent years, and I use the information obtained from it to expand the knowledge of both myself and my students. Of course, in addition to nuclear energy, I am also interested in other energy production facilities, such as those based on renewable energy sources, and I have visited several hydropower and wind farms in the last few years. I plan to visit a solar power plant and a geothermal power plant this year and next year, accompanied by my students.

There is a dual purpose of incorporating the experience gained into my lessons. Of course one is the transfer of knowledge itself, because in my opinion, knowledge of this information as well as some specific data is necessary for a high school graduate. The other goal would be for the interested student to be able to estimate and thus compare on the basis of the economic and social aspects, which energy production methods may be favorable and which will not be worth operating in Hungary in the long run.

At the end of my high school physics teaching, in the last physics lesson of the school year, I write with all the 11th grade students I teach the "Energy Test" survey which is mentioned in the introduction of dissertation and presented in its appendix and whose issues are entirely related to energy. In discussing and evaluating this, I also have the opportunity as a physics teacher to clarify the false information and any misunderstandings in the minds of the students from their environment, and to put it in its proper place.

Summary

In addition to the communication of information, the attitude shaping and promoting the development of a realistic, knowledge-based vision also appears as a task in the dissertation. I sincerely hope that the energy-related presentations described here, the additional data, and the differences from the traditional high school curriculum as curiosities help me to accomplish this task as efficiently as possible. That would be the ultimate goal!

Publications forming the basis of the dissertation

1. Istvan Gärtner: Energetics for secondary schools
   http://fiztan.phd.elte.hu/files/written_mat/Energetics.pdf
2. I. Gärtner: Energy supply only with renewables? Why does Hungary need to extend its nuclear power capacity? *IoP Journal of Physics: Conf. Series GIREP 2019* **1929** (2021) 012078, doi:10.1088/1742-6596/1929/1/012078
   http://fiztan.phd.elte.hu/english/student/energy_supply.pdf
3. A. Juhász – P. Nagy: What do secondary school students know about energy? Teaching science in a modern and attractive way – Conf. Proc. (Budapest 2011) p. 354-363 (in Hungarian)

Publication not directly related to the theses

4. I. Gärtner: A few years experience of energy consumption of a high school in Budapest, *Int.Conf. Teaching Physics Innovatively, ed T Tél and A Király (Budapest: Graduate Sch. for Physics, Eötvös Univ., 2015) pp 137–142*
   http://csodafizika.hu/fiztan/letolt/konfkotet2015.pdf

Conference presentations, experimental demonstration

5. I. Gärtner: A few years experience of energy consumption of a high school in Budapest, *Int. Conf. Teaching Physics Innovatively ed. T .Tél and A. Király (Budapest: Graduate Sch. for Physics, Eötvös Univ., 2015)*
6. I. Gärtner: Energy supply only with renewables? Why does Hungary need to extend its nuclear power capacity? *Int. Conf. GIREP-ICPE-EPEC-MPTL 2019 Budapest*
7. Gärtner István: Elektrosztatika a mindennapokban - kísérleti bemutató, Kutatók Éjszakája, Budapest, 2016.09.30. ISBN 978-963-12-6672-6

Conference poster

8. I. Gärtner: A few years experience of energy consumption of a high school in Budapest, *Conf. Multimedia in Physics Teaching and Learning (Munich, Ludwig Maximilian Univ., 2015)*