BIOMASS FOR FUTURE ENERGY AS A TOPIC IN SECONDARY MATHEMATICS CLASSROOMS

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ABSTRACT: Following the general didactical concept published first by the authors at the '12. Internationales Sonnenforum 2000' in Freiburg, meanwhile continued by several presentations with much positive reactions, this contribution presents further examples of mathematical problems concerning future energy issues. One of the most important cornerstones to build up a more effective, rational, and as far as possible renewable future energy supply system and structure is the use of *biomass* as stored solar energy. The problems presented here deal with the very important and indispensable topic 'Energy from Biomass'. They are suitable for lessons in secondary schools and include extensive explanations. This contribution is a further step to integrate such important themes in curricula of public schools. For this purpose, we have started an initiative supported and cooperated by the 'Deutsche Gesellschaft für Sonnenergie e.V. (DGS)', the German section of the ISES (International Solar Energy Society).
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1 INTRODUCTION AND MOTIVATION

One of the most effective methods to achieve a sustainable change of our momentary existing power supply system to a system mainly based on renewable energy conversion is the education of our children. Especially the young generation would be more conflicted with the environmental consequences of the extensive usage of fossil fuels. For our children it is indispensable to become familiar with renewable energies, because the decentralised character of this future kind of energy supply requires surely more personal effort of everyone.

In comparison to the parental education, the public schools give the possibility of a successful and especially easier controllable contribution to this theme. This can even be done advantageously for classroom teaching, as realistic and attractive contents have a particular motivating effect on students. In addition to that, a contribution to interdisciplinary teaching would be given, which is a significant educational method, demanded by school curricula [1]. Regarding the fact, that in Germany not all students participate at technical oriented lessons in a comparable proportion, it seems to be especially suited to treat this topic in mathematics education for this purpose.

In addition this would be quite profitable for mathematics education itself, as "the application of mathematics in contexts which have relevance and interest is an important means of developing students' understanding and appreciation of the subject and of those contexts" [2, para F1.4]. However, although mathematics curricula demand application-oriented mathematics education, this not only in Germany [3, p.110], there is a great lack of mathematical problems suitable for school lessons [4, p.251]. Especially there is a need of mathematical problems concerning environmental issues that are strongly connected with future energy issues. An added problem is, that the development of such mathematical problems affords the co-operation of experts in future energy matters with their specialist knowledge and mathematics educators with their pedagogical content knowledge.

2 DIDACTICAL CONCEPT

In such a co-operation the authors created first series of problems for the secondary mathematics classroom that will be completed by further ones. The cornerstones of the underlying didactical concept are:

- The problems are chosen that way, that the needed mathematical contents in order to solve them are part of mathematics school curricula.
- Advantageously every problem should concentrate on a special mathematical topic, such that it can be integrated in an existing teaching unit; as project-oriented problems referring to several mathematical topics are seldom picked up by teachers.
- The problems should not afford special knowledge of teachers concerning future energy issues and especially physical matters. For this reason all nonmathematical information and explanations concerning the problem's foundations are included in separated text frames.
- By going on this way information in respect to future energy issues is provided for both, teachers and students, helping them to concern themselves with the topic.

This didactical concept was first published by the authors at the '12. Internationales Sonnenforum 2000' in Freiburg [5], and meanwhile continued by several presentations in conferences respectively teacher education events ([6], [7], [8], [9], [10], [11], [12], [13], [14], [15]), with much positive reactions. The authors are grateful for the broad support they earned and the valuable hints and materials they received with regard to the development of further problems.

3 EXAMPLES FOR MATHEMATICAL PROBLEMS

This contribution provides in the following further examples of mathematical problems concerning future energy issues. The problems presented here deal with the topic 'Biomass for Future Energy'. They are suitable for lessons in secondary schools. (Some of the data used can be found in [16], [17].) With respect to the limited space in this paper, this presentation is focused on the basic structure of the problems, in order to give an impression of the didactical concept and the general principles.

The German version of the problems, including extensive explanations, and their solutions can be downloaded at the following internet address: http://www.math-edu.de under the topic 'Anwendungen'.

3.1 Example 1: Reduction of CO_2-Emissions

- This is an inter-disciplinary problem linked to the subjects of mathematics as well as chemistry, physics, and social sciences. Nevertheless, it may be treated already in lower secondary classrooms. In respect to mathematics the *conversion of quantities* is practised, knowledge of *rule of three* and *percentage calculation* is required.

Info:

> In Germany, an average private household consumes nearly 18000 kWh energy annually. 80% of this amount are for heating purposes and 20% for electrical energy.
> The energy demand for heating and hot water is mainly covered by the use of fossil fuels like natural gas, fuel oil or coal.

Assume, that the calorific values of gas, oil and coal can be converted to useable heating energy with a boiler efficiency of 85%. This means that 15% are losses.

a) The following typical specific calorific values are given

Natural gas:	9,8 kWh/m³
Fuel oil:	11,7 kWh/kg
Coal:	8,25 kWh/kg

Which amount of these fuels is annually necessary for a private household in each case?

b) The specific CO_2-emissions are approximately:

Natural gas:	2,38 kg CO_2/kg
Fuel oil:	3,18 kg CO_2/kg
Coal:	2,90 kg CO_2/kg

The density of natural gas is nearly 0,77 kg/m³.

How many m³ CO_2 are these each year for a private household in Germany in each case?

Hint: Helpful for your calculation is knowledge from chemical lessons. There you learn, that amounts of material could be measured with the help of the unit 'mole'. 1 mole CO_2 weights 44 g and takes a volume of 22,4 l, under normal standard conditions (pressure 1013 hPa and temperature 20°C). With these values you can calculate approximately.

Info:

> Wood is essentially made with CO_2 taken from the atmosphere and water. Spruce wood has a specific calorific value of nearly 5,61 kWh/kg. The specific CO_2-emissions are approximately 1,73 kg CO_2/kg.

c) How many kg spruce wood would be needed annually for a private household instead of gas, oil or coal? (Assume again a boiler efficiency of 85%.)
How many m³ fossil CO_2-emissions could be saved in this case?

Info:

> Spruce wood as piled up split firewood has a storage density of 310 kg/m³.

d) How many space has to be calculated in an average household for a fuel storage room, which contains the amount of wood for a whole year?
Compare this with your own room!

e) Discuss the necessity of saving heat energy with the help of heat damping.

3.2 Example 2: Pellets and Geometry

- This problem can be treated in lessons of *geometry, especially calculations of spatial figures*. The *conversion of quantities* is practised.

Info:

> A cone of wood pellets with a storage density of 600 kg/m³ has an angle of inclination of 60°. These pellets have a specific calorific value of 4,27 kWh/kg.

Figure 1: Pellets

a) Which height of the cone is necessary to supply a private household as described in 3.1 one year with heat? (Assume again a boiler efficiency of 85%.)

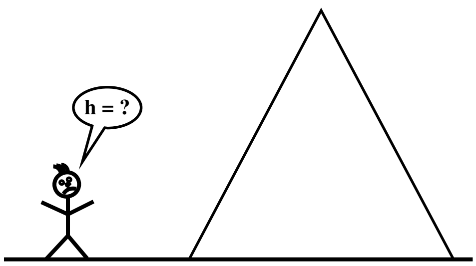

Figure 2: Cone of Pellets

b) For simplicity a single pellet could be seen approximately as a small solid sphere with a diameter of 12 mm. It has a density of 1000 kg/m³. How many pieces of pellets are in the cone in part a)?

c) Spruce wood has a specific calorific value of nearly 5,61 kWh/kg and a density of 0,41 g/cm³. How many spruce tree-trunks with a constant diameter of 0,3 m and a length of 10 m have together the same calorific value as the cone in part a)?

3.3 Example 3: Biomass and Linear Functions

- This problem can be treated in lessons of *linear functions; percentage calculation* is required.

Info:

> The calorific value of solid biomass for heating is dependent from the relative degree of the moisture. Therefore it has to be differentiated between a heating calorific value for dry biomass H_0 and the respective calorific value for biomass with moisture H. The reason for the difference is the amount of energy, which in the case of moisture is for the steam building process of the internal water.

The calorific value for heating in dependence from the degree of moisture can be approximated with the help of a linear function. Figure 3 shows the graph of such a linear function for a special sort of biomass A.

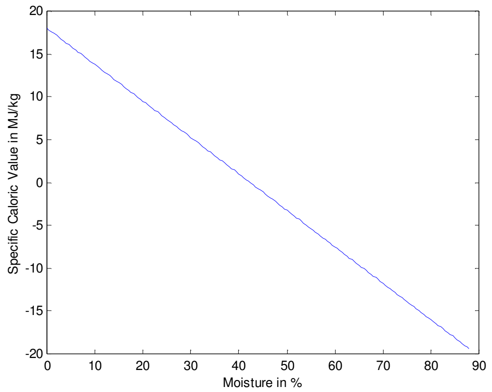

Figure 3: Dependence of the calorific value on moisture

a) Determine the corresponding linear equation to describe the dependence as shown in figure 3!

b) From storages with biomass of different storage duration three charges are to be mixed in a heating boiler. The mixture is:

10%	with	20% moisture,
50%	with	10% moisture,
40%	with	5% moisture.

Assume a good homogenous mixture. Which calorific value is now given by this mixture?

c) Which amount of biomass with 20% moisture can maximally be added to 1000 kg dry biomass, so that the mixture has at least a calorific value of 13 MJ/kg?

d) Another sort of biomass B has a specific calorific value of 10,146 MJ/kg for a moisture content of 10%, and in case of a moisture content of 30% a specific calorific value of 2,438 MJ/kg.
Determine the linear equation describing the dependence of the specific calorific value on moisture in this case.
Show this dependence graphically and interpret the difference of this graph from that one shown in figure 3.

e) Set the specific calorific value of dry biomass equal 100% and express the dependence of the specific calorific value on moisture in percents, both for biomass A and for biomass B.
Hint: For doing this divide each function term by the specific calorific value of the dry biomass and multiply by 100%. (Why?)
Compare the two resulting function equations and interpret your observation.

4 FINAL REMARKS

This contribution is a further step to integrate the important issues of future energy in curricula of public schools. For this purpose several initiatives have been started in Germany, supported and co-operated by the 'Deutsche Gesellschaft für Sonnenergie e.V. (DGS)', the German section of the ISES (International Solar Energy Society). The wide spectrum of respective activities going on has been presented amongst others also on the 3rd Solar Didactica within the Solar-Energy World Exposition. This event took place under the patronage of the German minister for education and research E. Bulmahn, expressing thus the great interest and importance devoted by politicians. The last event promoting future energy issues in secondary class rooms in Germany, the 5th Solar Didactica, just took place in Berlin and showed again the continuous interest on these topics.

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