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PREFACE

KIC is one of three Knowledge and Innovation Communities (KICs) created in 2010 by the European Institute of Innovation and Technology (EIT). The Climate-KIC aims to accelerate and stimulate innovation in climate change mitigation and adaptation, by integrating a network of European partners from the private, public and academic sectors.

KIC has launched the 2012 edition of its knowledge development programme called Pioneers into Practice (PiP). 150 participants from six European regions participate in the programme. The PiP programme started with a two-day Introductory Workshop at the six major European regions which form Climate-KIC's Regional Innovation Implementation Community (RIC) – Lower Silesia (PL), Hessen (DE), Central Hungary Gödöllő (HU), West Midlands (UK), Emilia-Romagna (IT) and the Valencian Region (ES). 150 enthusiastic Pioneers from a wide range of backgrounds have been selected to take part in the PiP programme from more than 200 expressions of interest. The Hungarian PIP partnership was the most relevant program player in 2012 with the 50 pioneers in the international program.

The PiP programme is committed to producing a new generation of specialists, entrepreneurs and policy-makers with high-level skills for the low carbon transition in Europe. PiP seeks to develop a mix of inter-disciplinary knowhow and managerial capability through a 'learning-by-doing' approach thus promoting the mobility of the practitioners between the three corners of the knowledge triangle in each region (i.e. research and education, business and public bodies). The six Climate-KIC Regional Innovation Communities are implementing strategies and initiatives aimed at addressing the challenges of climate change. This represents the ideal environment to gain hands-on experience on real challenges.

This special edition of the Hungarian Agricultural Engineering "Low-carbon economy in practice" is the most innovative written support for "Pioneers into Practice" program participant for the Hungarian activities and to get the relevant and up-to date information about the domestic research results and outcomes. With this collection of low-carbon research summaries we would like to give an orientation picture to the Hungarian climate friendly innovation lines.

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CONTENTS NO 24/2012

LOW-CARBON PROJECT DEVELOPMENT PROTOCOL (RUBIK'S CUBE SOLUTIONS) – SUSTAINABLE ENERGY AND MATERIAL MANAGEMENT

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Abstract

"The Rubik's Cube can seem alive as it heats up in your hand. The fact that each face of the Cube is made of three layers of three blocks has an important meaning. The number three seems to have a particular significance, relevant in some strange ways to the relation between man and nature, creation-preservation-destruction and fossil vs. renewable energy innovations." (Ernö, Rubik, 1980). The Cube is an imitation of life itself - or even an improvement on life. The problems of puzzles are very near to the problems of energy usage, our whole energy consumption is solving puzzles. If you can solve the Cube perhaps you can find good solution to supply your energy demand on a sustainable way.

Keywords

ow-carbon economy, renewable project development, Rubik's Cube, layer-by-layer method

Introduction

The Rubik's cube was invented in 1974 by the Hungarian professor and designer Mr. Ernö Rubik. The Hungarian cube was firstly a success in the central European countries, and then it became a real triumph in the whole world, from USA to China. The object had been conceived at first in order to develop the faculties of visualization of the pupils in architecture. It turned out afterward that the educational dimension of the Rubik's Cube was much important. It is indeed a natural and material representation of some mathematical and logical principles (Goudey, 2003). The international interest in the cube began from 1980, a great number of Rubik's Cube was sold at this time. The Rubik's Cube is not only a game, the cube is a system - each face of the Cube is made of three layers of three blocks has an important meaning. Each side or component is further divided into interrelated sub-components (dices). It helps in identifying relations and dependencies across the colors and components. The cube allows simultaneous execution and quick integration and absorption of change requests across components without altering any "project" concept.

1. The Rubik's Cube Story

It took Ernö Rubik 1 month of extensive practice to resolve for the first time its puzzle. Before that, he wasn't even sure that there was a method to succeed. "This object is a wonderful example of the rigorous beauty, the big wealth of the natural laws: it is a perfect example of the human mind possibilities to test their scientific rigor and to dominate them. It represents the unity of real and beautiful, which means for me the same thing." [Ernö Rubik] (Source: Goudey, 2003).

The Cube can seem alive as it heats up in your hand. The fact that each face of the Cube is made of three layers of three blocks has an important meaning. The number three seems to have a particular significance, relevant in some strange ways to the relation between man and nature. "mother-child-father, heaven-earth-hell, creation-preservation-destruction, birth-life-death." [Ernö Rubik] (Source: Goudey, 2003).

2. The sustainable life = resolving the cube

The Cube is an imitation of life itself or even an improvement of life. The problems of puzzles are very near to the problems of life, our whole life is about solving puzzles. If you are hungry, you have to find something to eat. But everyday problems are very mixed they're not clear. The Cube's problem depends just on you. You can solve it independently. But to find happiness in life, you're not independent. That's the only big difference (Goudey, 2003).

In your work you can find different problems, you have to solve these problems, in your work you have to build up different projects and programs. If you have enough experience in the field of problem solving you can manage these challenges successfully and on an easy way. You can get experienced e.g. in project development, if you get an experience by practicing how to solve the Rubik's Cube.

2.1. Low-carbon economy concept

There is an urgent need to transition to a low carbon economy to address the global challenges of diminishing fossil fuel reserves, climate change, environmental management and finite natural resources serving an expanding world population.

The main priorities in a low-carbon economy:

- All waste should be minimized - reduce, reuse, recycle,
- Energy should be produced using low carbon energy sources & methods - renewable & alternative energy sources, fuels & sequestration,
- All resources (in particular energy) should be used efficiently - more efficient energy conversion devices, combined heat & power,
- Wherever practical local needs should be served by local production - food, materials, energy,
- There is high awareness and compliance with environmental and social responsibility initiatives - industry, commerce and individuals (LCE Ltd, 2011).

In the case of low-carbon economy it is very difficult to manage these types of requirements. We take into account the above mentioned priorities at the same time by using the Rubik's Cube protocol. This protocol is a good process to manage the sustainable development goals.

3. Rubik based software development concept from the present (RCM)

There are various software development models evolved in the industry over the years. Each model has its own advantages, limitations, and constraints. These models are often bound to some organization, which further develops, supports, and promotes the methodology. A specific development model might not be suitable for all projects. Technology, resources constraints, time to market, and rapidly changing customer needs are different factors that a Project Manager must consider to evaluate and adopt a development model for a given project cycle. The Rubik's Cube software development methodology (RCM) is a general-purpose methodology, which is extremely useful in today's software development life cycle. It is especially applicable for incremental and legacy projects. The methodology (layer-by-layer method) suggests breaking software projects into logical components integrated together with defined interfaces. Identification and naming of these logical modules (analogous to sides of Rubik's Cube) is up to the Project manager (Ajay, 2011).

Our hypothesis based on the international experiences: the rubik's cube layer-by-layer solution (the most popular solution method) is a resolving method and a low carbon project development protocol in the same time.

4. Material and methods

The project development basically is an optimalisation process, which is based on different optimalisation fields. In the case of « low-carbon optimalisation » we have selected four different components: strategic fittings, market fittings, technical fittings, financial fittings.

The four sides (red, green, blue, orange) of this model are mapped to different project components, two sides (white and yellow) of the Cube are mapped to the input and output side of our project:

STRATEGIC FIT (RED SIDE)
MARKET OPPORTUNITIES (GREEN SIDE)
FEASIBILITY/TECHNICAL DETAILS (BLUE SIDE)
FINANCIAL EFFECTS (ORANGE SIDE)
INPUTS AND RESULTS (WHITE SIDE)
OUTPUTS AND RESULTS (YELLOW SIDE)

The « low-carbon optimalisation » divides a project into multiple components, it is not always necessary for each component to interact with other four components. While communication across components is the key, it is not mandatory that each component talks to every other component directly. Sometimes the communication is achieved via an interface cable or interfacing component. Important attribution – when we are executing acceptance technical relevancies at the blue side it is not always required to view the market opportunity that generates the executable for the project. Another example could be the financial feature (liquidity), which can be used in different form and independent from the market demands (Anderson-Doig 2000). Very important system attribution is that - some components of the project development require more frequent interaction amongst then others. From this aspect is very clear why so important the three dimensional project development structure. Generally we are planning and working only with two-dimensional strategic systems. (Two-dimensional structure shows the Figure 1.)

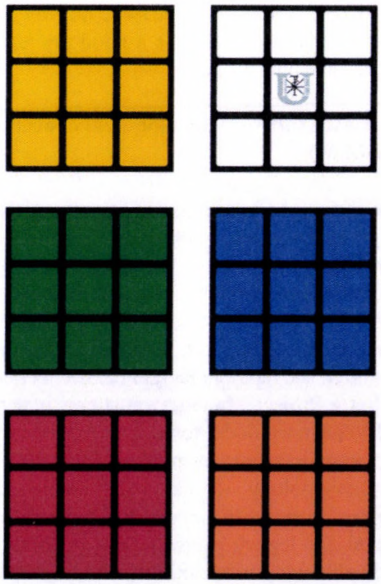


Figure 1. The two-dimensional parts of the Rubik's Cube by colours

The three-dimensional interpretation of the Rubik's Cube model will show to us the practical benefits of this project concept. For the deeper understanding the low-carbon project development protocol have to get acquainted with the meaning of the different sides.

Table 1. Meaning of sides of the Rubic's Cube

Colours	Meanings
white	INTPUTS AND RESULTS - Input requirements, market and governmental regulations to the products and services.
yellow	OUTPUTS AND RESULTS - Consumer's requirement, real value of the outputs (product and services).
red	STRATEGIC FIT - Relevant innovations to the profile, synergies and cooperation with other strategies (local /company/, sectoral, national, EU level).
green	MARKET OPPORTUNITIES - Market possibilities, position on the real and artificial market segments.
blue	FEASIBILITY - Harmony of the technological and market possibilities. Technical risks and opportunities.
orange	FINANCIAL EFFECTS - Type of finance, governmental tools, taxation, currency risk, liquidity.

4.1. Layer-by-layer method

How to solve a Rubik's Cube (standard cube (3x3x3)) is the recurrent question that we make ourselves when we see a scrambled cube for the first time. Having billions of combinations, it is nearly impossible to solve a Rubiks Cube by trial and error. There are several ways to solve a Rubik's Cube using the easiest methods for solving the cube for beginners. The simplest method of resolution for all the models, is to solve the cube by layers, beginning from the Bottom layer to the Top layer. The layer by layer method that is often used for the 3×3×3 cube is usually used on the Rubik's Revenge. One of the most common methods is to first group the centre pieces of common colours together, then to pair edges that show the same two colours. Once this is done, turning only the outer layers of the cube allows it to be solved like a 3×3×3 cube (Rubik's Revenge, 2011). In the case of layer-by-layer method we can find the analogy between the project development process and Rubik's Cube solving. On the next Figures 2., 3., 4., 5., 6., 7. you can follow the Rubic's Cube layer-by-layer solution process and the project development process in parallel. From the explanation at the Figures we can see the coherences and synergies among the project development components.

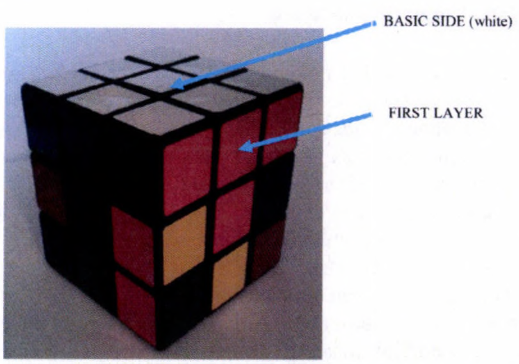
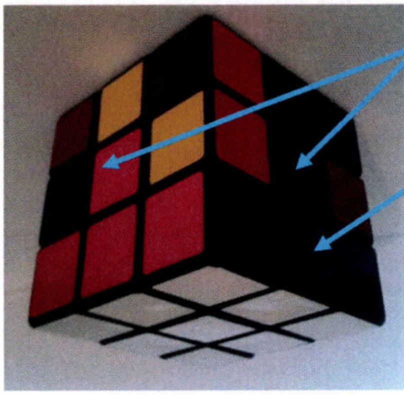


Figure 2. The first side (input side) and layer – the basis of the project development

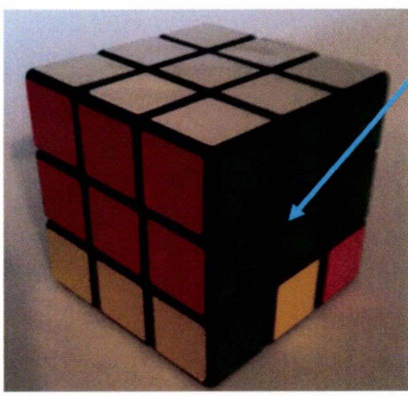


CENTRAL DICE

FIRST LAYER
(EDGE DICE)

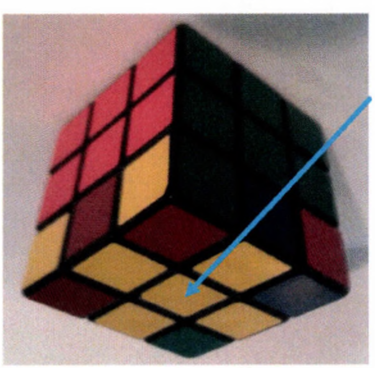
Figure 3. Central dice – it shows the coherences and structure of the project development process (the central dice is a fix point of the cube and fix character of the project component)

Each side and each dice of the Rubik's Cube harmonizes with the element of the project development. The central dices are the stabile components of the cube sides and project components. We can't move them from the original stand. The edge dices are mean coherent contact between two colours and two project attributions.



SECOND LAYER

Figure 4. Above the first layer - second layer will shows the harmony among the colours and project development components



THE YELLOW
CROSS ON THE
UPPER SIDE

Figure 5. The mystical yellow cross

After the second layer the yellow cross on the upper side means – harmonization of the strategic targets and the consumer's requirements. In this step we have to find the final element of the final colour. The sixth colour will shows to us the right direction to the success. By this way we can find the relevant « consumer requirement » in the case of project development goals.

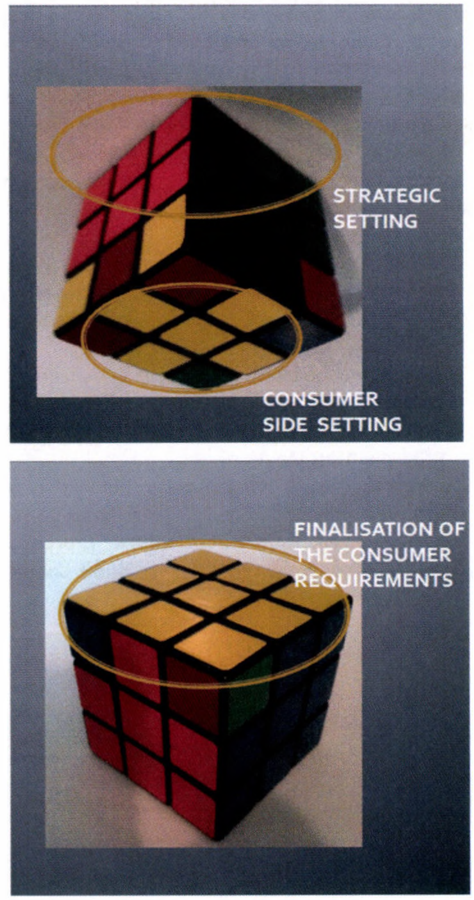
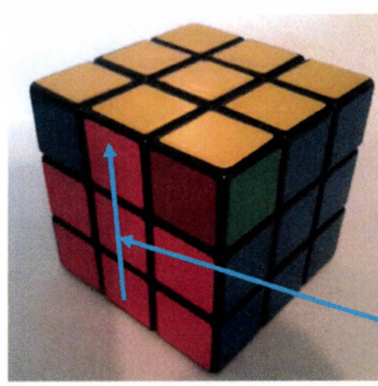


Figure 6. Strategic and consumer settings in the case of project development process

The „consumer" side fitting on the output side is the most important moment before the finalization of the Cube. Because of the sustainability the most important movement - input (white) side and output (yellow) side have to be in coherences before finalization.



DIRECT CONNECTIONS
BETWEEN WHITE AND
YELLOW SIDES

Figure 7. Creation stable contact between the input and output sides on four channels

After the harmonization between the input and output sides and requirements we have left only one engagement – to find the final element of the Cube.

Conclusions

The described "low-carbon project protocol" provides a helpful aspects of handling a sustainable project development by making an analogy to the way a Rubik's cube layer-by-layer solution. This protocol covers features like parallel development of components, identifying logical groupings of components, segregating them based on their dependencies on each other. The Rubik's Cube based low-carbon project protocol enables a project to deliver a working component even when rests of the components are not ready for a customer facing delivery.

Findings:

- Layer-by-layer solution is the model solution of the innovations – we can easy follow the innovation process step by step.
- Each side and each dice of the Rubik's cube harmonizes with the element of the project development :
  - A. central dice (stabile component of the cube side (relevant color) and project phase).
  - B. edge dice (coherent contact between two colours and two project attributions)
  - C. corner dice (very complex and complicate contact between three different colour and project phase)
- The low-carbon project development process is a parallel project protocol with layer-by-layer Rubik solution. This type of algorithm can define a special sustainable and low-carbon (minimal material and energy input) development.

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CONDITIONS OF SUSTAINABLE SOIL QUALITY VS. ENERGETIC USE OF FIELD-LAND BY-PRODUCTS

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Summary

Hungary extremely depends on external energy supplies – it is an obvious fact and the reduction of this dependence is a common task. The energetic use of stubble residues is a real alternative if all harmful aftermaths are known and there are also feasible solutions applied for the mitigation of damages. The attribute "sustainable" holds true of the energy but, as to the soil by which the biomass is produced, it is unfortunately false because this means an organic-matter and nutrient-element removal and, on top of that, the supplementation is doubtful. If the biological life of the habitat and its resistance against the harmful climate effects is in danger, the energy derived from the mass cannot be "bio".

Keywords

soil quality, removal of straw and stalk, water content

Introduction

The quality of the soil is determined by the processes taking place in it and its properties. Beside the natural soil properties, the human activities modify (make better or worse) the outcome of the processes in the soil. The soil cultivation does not change the clay content, the physical kind or the pH value. The longer-time soil use influences the soil cohesiveness (it might worsen or ease) and the soil moisture content range of cultivability (it gets wider or narrower). The physical properties changing with the soil cultivation (tillage) are the mechanical resistance, the looseness, the water, air and heat budget of the soil, and the surface profile. The living beings (useful or damaging) and their activity, the organic-matter content, the dynamics of the organic-matter decomposition and the crumb forming aptness indicate the biological value of the soil. The risk of plant growing, theoretically depending on soil quality as good, medium or low, is high, medium or low. The quality of soil may change in the good or bad direction conditionally on that whether the operations carried out on the soil improve, protect or worsen its natural properties and physical or biological state.

The permanent rise in price of fossil energy carriers and the limited reserves necessarily focus attention on the increasing utilization of renewable energy resources. At the beginning the first so-called plans of alternative energy production and use still met the regulations of environment protection, and were in harmony with the requirements of the sustainable development. In the newer plans, the sustainability is only a slogan and the energetic-purpose use of stubble residues gains more and more ground. The feedstock of "renewable" energy is annually yielded on the lands – on the soils which must be renewed year by year as well (Birkás, 2007, 2010). The rational supplement of organic matter for assisting the soil renewal is missing in the actual plans. (The ash mixed with vehicle medium for fertilizer application can be used but its value is much less than that of the incinerated material.) The question is whether the sustainable development, the stable husbandry and the effective climate damage mitigation with soils endangered in their physical, nutrient and biological state can be feasible or cannot in the agriculture.

Material and method

The present study is a summarizing paper. The data gained during the Soil quality vs. climate experiment in 2002 at Hatvan-Józsefmajor (Birkás, 2011, Birkás and Kisic et al., 2012, Birkás and Kalmár et al., 2012, Csorba et al., 2011) and the Stubble vs. climate experiments carried out in each summer since 2004 provide the background of the suggestions.

Results

Facts

According to the EU commitment, the factors endangering the soils are 1) Erosion, 2) Decrease in organic matter content, 3) Pollution, 4) Capping (overbuilding) of land, 5) Soil compaction, Decrease of biodiversity, 7) Alkalization and 8) Flood and earth-slide. So the decrease of organic matter content takes the second place in the order of importance. The resources of organic matter supplement in the importance order in Hungary are 1) stubble and root residues, 2) green manure, 3) farm or litter manure, 4) compost and 5) slurry.

In an average season, an amount of 20 to 21 million metric tons of stalk residue is formed on the arable land of 4.45 million ha (Gyuricza et al., 2012). The most is maize stalk (12 to 13 million t), the quantity of cereal straw is less (7 to 8 t) and that of sunflower stalk is about 1.4 to 1.9 tons. Considering it any point of view, the significance of this mass is great. The area where farm manure is applied is maximum 130,000 ha in a year. The application of green manure greatly depends on the summer weather; the actual area was 28,000 ha in 2011, and even less than this in 2012 and the application proved ineffective. Due to the decreasing livestock, the animal husbandry is not capable of covering the farmyard manure demand of the plant production therefore the stubble residue remains a necessary organic-matter resource for a long time in the future as well. The energy demand (1000 PJ/year) is real and resources must be found for this as well. The energetic utilization of stubble residues is a possible alternative as Gyuricza et al. (2012) indicated. However, they emphasize that the best solution would be to operate decentralized power plants with lower capacity (1 to 5 MW) since the running of power stations with the demand of large amount of feedstock in certain regions already now causes the quality worsening of the earlier eroded forest soils. The macro and micro-elements removed with the straw and stalk matter from the land can be supplied by rational application of artificial fertilizer but there is no good solution for the carbon supplementation. According to data provided by AKI AT (22 September), 2.73 million tons of straw was gathered from cereal producing lands, with a carbon content of 1,090,800 t, and amount of humus (due to the different husbandry practices) is 272,700 to 818,100 tons. It is a troublesome fact if the rape, pea or soy-bean stalk also removed from the land but not with animal feeding purpose.

Denomination

The meaning of the biomass – perhaps originally – is the definition "energetically utilizable plants, crops, by-products, vegetable and animal wastes". By ones who are interested in that, "the importance of the biomass materials is that they can be substituted for fossil energy carriers and, in this way, the sustainable energy use (sustainable development) is feasible" (see publications on internet). The attribute "sustainable" holds true of the energy but, as to the soil by which the biomass is produced, it is unfortunately false because this means an organic-matter and nutrient-element removal and the supplementation is doubtful. If the biological life of the habitat and its resistance against the harmful climate effects is in danger, the energy derived from the mass by incineration cannot be "bio". The case of necessity evolved from of the energy shortage has to be treated but the euphemism is a self-delusion. The exact denomination is 'energy derived from straw' or 'energy derived from stove (corn stalk)' etc.

The gain of the industrial-purpose removal of straw and stalk

Beside the experiments carried out, we have been collecting the below listed facts since 2007 in 14 counties in Hungary. The soils endangered most of all are in counties Baranya, Tolna, Bács-Kiskun (south region), Békés, Somogy, Vas, Győr-Moson-Sopron, and lately Fejér.

The use of straw for bedding is advantageous since the organic material returns into the soil in the form of farmyard manure (perhaps not to the same land where gathered). However, the industrial utilization results in a quite another situation. In an actual farm management, some advantages may attend this decision. 1) A less amount of straw or stalk residue theoretically eases the soil cultivation but the water loss of soil due to cultivation delays and the treading damage in summer and early autumn will increase the energy requirement of tillage. In a season of low rainfall, in the case of the tillage of 10 to 12-cm working depth, the extra diesel oil consumption is minimum 1.5 to 2.5 l/ha. 2) The number of plant-protection problems may be reduced in the case of succession of plants with similar pathogens; it is a help where the level of plant protection is low. 3) It is an income in the harvest season; however, some farmers give the land residue over to a user for nothing as they just want to dispose of the materials making the tillage more difficult. It may be asked whether the income from the sell of stubble residues compensates the disadvantageous effects of the organic-matter imbalance and the costs of the extra tillage energy. Also a problem is the supplement of P and K removed in the straw and stalk mass.

The risk of the industrial-purpose removal of straw and stalk

The negative aftermaths of the industrial-purpose removal of the stubble residues in the soils of an actual farm land are as follows: 1) Losing the supplement resource of organic matter is a high risk if there is no possibility of application of farmyard or green manure and, in addition, it is a carbon loosing cultivation practice. It is a pitiable experience that the producers selling straw in bulk – in any county – usually carry on a carbon loosing cultivation, including the delayed and bad stubble ploughing. 2) The stubble cultivation is delayed due to the longer baling and transport (often 3 to 8 weeks) and this is why the quality of stubble cultivation falls. Because of the increased water loss of the top layer, farmers till – irrationally – even deeper the stubble. 3) In a hot day a deep layer of the uncultivated cracked soil without the covering matter warms up (to 15 or 20 cm averagely 28 °C). Due to the undesirable warming-up, the water loss and the drying of soil increases. The water loss is not or hardly recovered in a dry season (experience in 2011 and 2012, Figure 1).

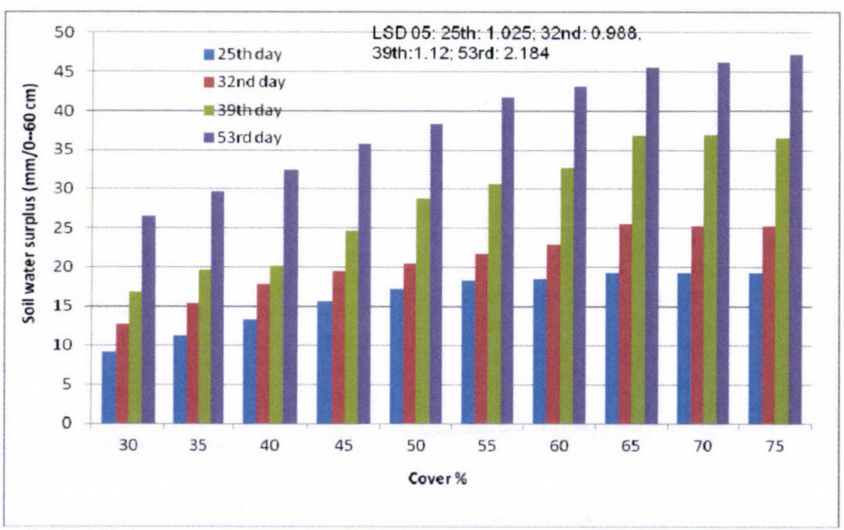

Figure 1. Soil water content surplus (mm) in an undisturbed soil covered differently during 53 days in rainless period (Hatvan, 1 Aug.-13 Sept, 2012) Water content at harvest: 270 mm/0-60 cm soil layer; Water content in the clean soil on the 53rd day: 207 mm/0-60 cm

In dog-days the temperature of the ploughed stubble layer between 0 and 8 cm is 28 to 30 °C but below this layer – only 22 to 24 °C. There was more water by 17 to 24 mm during 2 weeks in July 2012 in the covered soil than that in the uncovered one. 4) On soils got biologically passive due to the water loss and the crusted surface, the summer-end and autumn tillage requires more energy by 12 to 14 % (experiences of years 2007 to 2009 as well as 2011 and 2012). 5) Without covering, the soil is directly exposed to the drying, drop-impact and silting effects of the hotness and the summer showers and, because of this, the crumb formation fails or decreases. After the repeated cultivation pass, in the seed bed, the fractions of nut-like clods (25 to 42 %) and dust (19 to 33 %) are dominant. 6) There are more treading damages in the soil; beside the wheel-tracks of harvester, tracks of the balers and the transporting vehicles appear on the surface. The reach of treading damage in depth is 25 to 45 to 55 cm. 7) In the soil that lost its moisture, the shoot of weeds and volunteer plants extends and the chance for surveying the weed potential and the weed killing decreases. 8) The other extreme is common as well; on the stubble that has not been ploughed for weeks, the allergenic weeds shoots and develops the most quickly. 9) The stubble residue is a nutrient resource of plants; for example there is a nutrient-element (N, P, K and Ca) amount of 20 to 60 kg (see also data of Gyuricza et al., 2012). Over the world, 118 million t

NPK amount is forms in stubble residues which is 83.5 % of the consumption of artificial fertilizers in the world. The wheat straw, the straw of legumes as well as the maze stalk is a good potassium resource. If the supplement recovers the demand of the following plant rather than the shortage on the grass-land soil, a reasonable K-cycle can be achieved and the K-fertilizer demand – reduced. However, the interruption of the cycle arrests this saving. 10) There are many so-called half-way measures; a higher cereal stubble left behind is only theoretically is a good. Now the stubble cultivation is more difficult and only a deeper tillage can achieve a better mixing. In addition, they use conventional disc harrows after which the soil remains more cloddish and better dries. (To reduce the damage, rollers can be attached behind which has to be transported to the land separately.) The moisture saving effect of the high stubble is 1 to 2.2 mm/day in 2 to 3 weeks (data in 2011) but after deep stubble tillage the loss is 2.32 to 3.35 mm/day.

The loss list claims particular attention.

1. In the first year, due to soil drying, crusted surface and treading, a temporary quality worsening arises and it hits back in the increased R+M and fuel costs (Figure 2).
2. During a longer time the problem worsens; the nutrients removed in the straw and stalk should be supplemented but the income of residue selling does not cover the cost of chemical fertilizer. From the 2nd or 3rd year the lack of organic-matter recycling causes a serious worsening in soil quality; its obvious indicator is the lower water retention and the climate sensibility of the soil. Of course, in an extreme season, the decrease in yield cannot be avoided but the loss on the soils with decreasing organic-matter balance is multiplied in comparison with the well cultivated ones.
3. The harm caused by graniferous weeds (incl. many allergenic) growing between the straw windrows and bales has not been surveyed as yet.
4. During the transport of straw the roads are exposed to a damaging load and the roadside areas – to weed-seed and pathogen pollution.
5. A bad addition is the carbon losing cultivation; the combination of the lack of organic-matter supplement and the carbon losing cultivation is especially dangerous on (aslope, eroded, sandy and loamy) soils poor in humus.

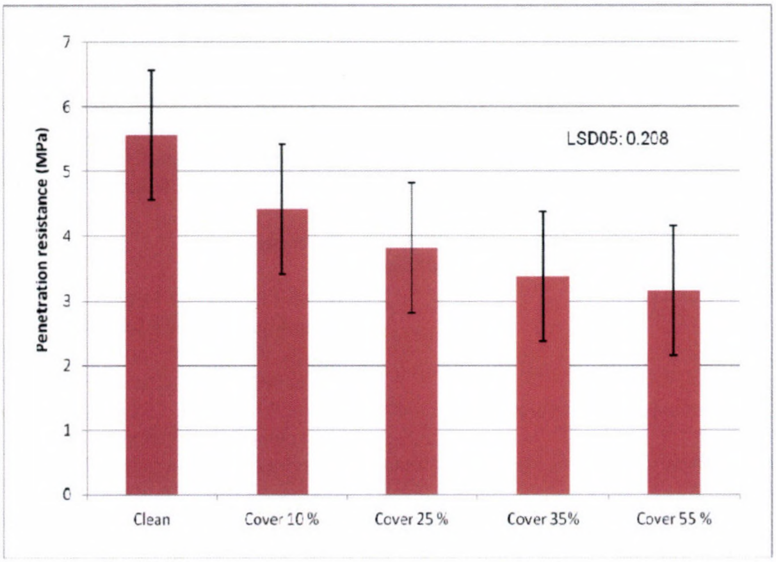

Figure 2. Typical penetration resistance (MPa) values in average of 0-65 cm soil layer in a dry season at different surface cover ratio (Hatvan, 16 July-30 August, 2012)

The reaction of cohesive soils should be considered as well; with worsening organic-matter balance, the negative effects of cohesiveness are more intensive – the cultivability moisture range narrows, the soil resistance and the energy requirement of tillage increases.

Organic-matter loss and climate damage

If new organic materials (stubble residues, farmyard manure) are not added into the soil, the by-product of the microbial respiration at first develops from the easy-to-degrade humus, and then – from the humus of difficult degradation. The loss is 20 to 50 % of the reserve in 2 to 5 years. When all organic matters get back into the soil but the cultivation is carbon losing, a slow carbon intake can be expected – annually about 0.6 %. The "unexpected" aftermaths of the carbon losing farming:

1. Decrease in water retention capacity (increased drought damage).
2. Decreased crumb formation (cloddish structure after basic tillage and dusty decay with any tillage; (Figure 3).
3. Worsening of cultivability; the optimum moisture range of tillage narrows and the tillage at unsuitable moisture content causes a hardly correctable fault (thicker plough sole).
4. Too quick re-consolidation of soil after ploughing or loosing: the 4 to 5-year loosening period cannot be held – often 2-year or more frequent period required.
5. Unexpected excess-water damage in the following year after loosening (due to the soil re-consolidation).
6. Worsening of the viability of land – deeper treading damage.
7. Worse effect of manures due to the worse structure and the duller soil life.
8. Increase in the energy demand of tillage (increased cultivation input on settled soil) – for deeper tillage, minimum 55 l/ha diesel oil on chernozem soil and 62 l/ha on meadow soil; in addition, the increase of passes required for the after-plough top-soil tillage.

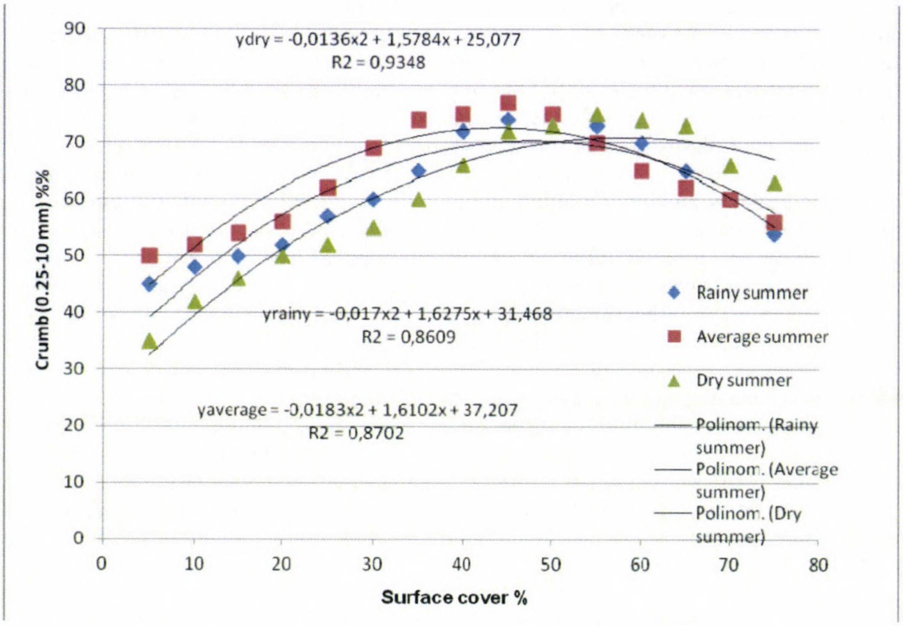

Figure 3. Surface cover ratio impact on soil crumbliness in different summer periods (Hatvan, 2004-2012)

The latest advertisements aim at the maize stalk. It is dangerous to store stalk close to the growing land up to the following summer because of the corn-borer risk. It was established in 2012 that the corn stalk (with the knowledge of its values) is necessary as roughage as well. In a dry autumn the soil-surface protection must not be neglected on the maize stubble either. It is a precondition that – to assist the moistening-up – the soil shall rest under the shred layer for several days.

Conclusions

1. The sustainable plant growing can be achieved only with positive soil-carbon balance.
2. If x t carbon is removed from the system, the same amount must be given back there.
3. Energy dependency of Hungary is a fact and rational solutions must be found, without endangering the foodstuff production of the country and the connected incomes.
4. If the stubble residues are planned to use for a long-term energetic purpose as well, its conditions have to be regulated (once from a land by 5 years).
5. If the gathering of the landscape-destructive biomass or the plants blocking the canals etc. were considered by the interested ones as well, Hungary would be competitive with the well-kept landscape against any other country.
6. From the willow and poplar experiments in Gödöllő, it can be seen that the protection as well as the improvement of soil quality can be achieved.
7. The energy grass and reed, the tree species of short cutting age in unsuitable areas for foodstuff production are cultivated biotopes and, in addition, they improve the micro-climate and the landscape.

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LOW-CARBON WATER FOOTPRINT CONCEPT IN HUNGARY
- WATER FOOTPRINT IN THE CASE OF BREAD AND PORK MEAT -

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Abstract

More and more news report on water-related extreme environmental phenomena. Some of these are natural, which are often beyond the human race. But others are definitely due to anthropogenic effects. We think the water footprint index is able to highlight national and international water-use processes and gives us the opportunity of organizing a sustainable, consumer-, environmental- and governance-friendly management.

Current research calls the attention to the significance and difficulties of this kind of domestic estimation presented trough the water footprint calculation of bread and pork in Hungary. The received data indicate the domestic water consumption trends in a modern approach. There is no doubt for me about the urgent necessity of water footprint calculation because as a result innovative, sustainability supported environmental, social, economical, and political relationships can be created - not just on local, regional or national level, but on inter-regional, European and even global stage.

Keywords

water economics, water consumption, externality management, environmental economics, climate change adaptation

I. Introduction

Water is classified among common goods, its place is among boundaries [fixed], its transportation and storage is complicated and costly (rather happens in the form of a product even at a national or regional level – for example grains, fruits, meat ...). In addition its substantive value is large (often not expressed in money), as it is related to life, beauty, wealth and health. People like the proximity of water. The economic consequence is that we should use it when and where it is available considering that it gravitates, leaks downward. There is always the threat of market failures in water supply so it has no homogeneous market because it is too expensive – pricing and water rate determination (can) cause extreme social conflicts and tensions. There is no other economic good that has such a complicated combination of characteristics like water (Savenije and Van Der Zaag, 2006).

Considering the Union's water use guidelines very limited data are available in FAO AquaStat and Eurostat databases. The latest data are from 2007 and not available for all countries. According to the existing figures water use of Malta is the typically smallest, and Spain, Great Britain, France, Greece and Germany are the largest. Macedonia emerges from the row where popular and industrial water consumption from 2004 to 2007 has considerably decreased. I have to emphasize that the underlying data are incomplete. European Water Partnership (EWP) has come into existence for the common solution of water problems, which assists in developing strategies and executing measures.

For the complex measurement of our water consumption A. Y. Hoekstra and A. K. Chapagain Dutch professors created as a result of an extensive research work the water footprint. Water footprint is the absolute quantity of the fresh water used during the production of a product or a service which expands on measuring contaminated water as well. This measure allows complex, horizontal and vertical sectoral data integrated multifactoral estimations. With its application still not known, sometimes not even suspected economic, social and political contexts may come to light, which is a new approach to our water-related personal and community attitude. So the water footprint means an all-time complex perception of water. The regular usages of water footprint calculations allow the re-evaluation of current water resource management in social and economic systems and points on the absolute measure of our diverse water demand. Water footprint can be calculated for a product, service, company, sector, nation, geographic unit or the whole humanity.

II. Virtual water and water footprint

Water footprint is the total quantity of water used to produce products and services by a person, company or nation. It consists of two main components: direct and indirect water use. Indirect use of water is measured as virtual water (the amount of water needed for produce a certain product). Water footprint includes blue water (rivers, lakes, water-barrier water), green water (rainfall at primary crop cultivation) and gray water (contaminated water after agricultural, industrial and domestic use). Although water footprint tells us how much water is used, the increase or decrease of the effect of full abstraction depends on location and time. The growth of water footprint in an area where water is abundant, probably does not have adverse effect on the society or the environment, but in a place where water scarcity is already experienced may cause serious problems, such as rivers drying out, habitats destruction, species extinction – besides it has impact on agricultural prices, stocks and local economies (WWF, 2010).

A product water footprint is similar to the so called 'virtual water content', although water footprint covers not only the quantity but the type of water used (blue, green, gray) and where and when it was used. Thus, contrast to the 'virtual' water the water footprint is a multi-dimensional indicator. A 'virtual' water term is used in the context of international or regional water flows. If a nation or a region exports / imports goods that means water is exported / imported on 'virtual' way. In this context we can talk about virtual water export and import, generally virtual water flow or virtual water trade (Hoekstra et al., 2009).

Types of water footprint

Product water footprint can be defined as direct and indirect fresh water requirement during its production. This is an estimation that considers water consumption and pollution of all the elements of the production chain. The calculation is the same for all kind of products coming from the agricultural, industrial or service sector. Product water footprint is divided into blue, green and gray parts.

Water footprint of a consumer is defined as the total amount of fresh water used and contaminated during the production of all the products and services consumed by the consumer. Water footprint of a group of consumers is the same as the total amount of water footprints of the individual consumers of the group.

Water footprint of a business can be defined as the directly and indirectly used fresh water during the operation and supply of the company. There are two main building blocks. Operational (direct) water footprint of a business is the used or contaminated fresh water during its functional operation. Supply chain (indirect) water footprint of the company is the used or contaminated fresh water during its input production, which is needed for the production. 'Business water footprint' or 'corporate water footprint' or 'institutional water footprint' can be used as well.

Water footprint of a given area can be defined as the total fresh water consumption and pollution of the area within its borders. It is extremely important to clearly define the boundaries of the considered area. It can be catchment area, river basin, province, state or nation, or other water or administrative territorial unit (Hoekstra et al. 2009).

In the light of the results

Because of the international trade of water-intensive products virtual water flows are moving around the world. Most of these flow in the wrong direction from water-poor areas to water-rich regions. The majority of these flows are food, bio fuel and cotton. Solution of this wrong-way flow could be if the dry areas would discontinue agricultural production, since the responsibility of this sector in water use is the largest worldwide. According to experts the solution is the change of import and export patterns, where tool would be modern water pricing. Nowadays some countries (like China or Saudi Arabia) are already taking steps to buy large and fertile places in Africa, Asia or Latin America. Instead of food, land purchasing. This is the guarantee of the access to water in the future. Land purchaser countries are not alone, directly competing with food production giants like Nestle or Coca-Cola (Spiegel Online International, 2009).

Water footprint calculation is a useful tool to build awareness around the used water that products consumed in the production value chain. But at this point of the developing method consumer labelling is at best leading to undesirable results or at worst misleading. This is due to underlying complexity behind the numbers of the water footprint of companies and the level of detail considering local environmental, economic and social impacts. The future of companies on water depends largely on their understanding, measurements and involvement. 21st century complex challenges on water are only growing in coming years and companies must be prepared to get involved beyond their own fences and traditional comfort zones to ensure long-term viability of this critical resource (WFF and SABMiller, 2009).

International water-dependence is significant and seems to increase with the continual world trade liberalization. Today, 16% of the world's water use is not for the production of goods for domestic consumption but for export. Considering this significant and increasing tendency according to Chapagain and Hoekstra (2007.) the national and regional water policy studies in preparation should include international or interregional virtual water flows analysis.

As an indicator of water use water footprint differs in three aspects form the classic water withdrawal (as it is shown at Figure 1):

- Not limited to blue water use, but also includes the green and gray water use.
- Not limited to direct water use, but also include indirect water use.
- Not include the use of blue water if it returns where it was.

	Water footprint of a product or consumer		
	Direct Water Use	Indirect Water Use	
	Green Water Footprint	Green Water Footprint	Water Use
Water Withdrawal	Blue Water Footprint	Blue Water Footprint	
	Grey Water Footprint	Grey Water Footprint	Water Pollution

Source: own editing according to Hoekstra et al., 2009.

Figure 1. Schematic representation of water footprint components

Consequently, water footprint offers a wider field of view of the relationship with the consumer or the producer and the use of fresh water systems.

III. Materials and methods

Background of the national research

In 2008 consumption of bread was 44.9 kg/capita – that was more than baker's ware and other cereal products in total. In the same year poultry (17.0 kg/person) was more popular, but I chose pork (15.8 kg/person) because in the light of water footprint calculation the existing data were available (KSH, 2010).

On the official website of the water footprint calculation wheat's website was not available during the writing of the paper (www.waterfootprint.org, 2010). Among National Central Statistical Office (KSH) public figures general data were available about water usage; there were no concrete information of the water consumption of wheat production.

In view of the information source (KSH, Gyorstájékoztató 2010) data relating to wheat production differentiates durum wheat from other wheat. The average of harvested durum wheat was less than 1% of the total wheat gathering (2004–2008) so I did not count with distinguished breed.

During the research I have used CropWat 8.0 software. This decision support computer program is developed by the FAO Land and Water Development Department. Water and irrigation needs of plants data is used for the calculation which were taken from soil, climate and crop data by the tool. It determines a watering schedule for different plants, to evaluate the farmers' irrigation practices (FAO, 2010/a). The other software I have used was ClimWat: developed by the FAO. It is a CropWat supporting computer program. All over the world, measures more than 5,000 synoptic stations to collect weather data. These stations may be the selection of the salvage program CropWat (FAO, 2010/b).

Water footprint of Hungarian bread

Blue and green water footprint of Hungarian wheat

To calculate the water requirement of wheat (crop water requirement – CWR) the used CropWat 8.0 software requested data was provided by several sources of information. Climatic data of wheat growing regions were supplied by the closest synoptic meteorological stations (Table 1), which data were imported from the program ClimWat. During the calculations I used the simplifying assumption used by Water Footprint Manual that the stations represent the same size of crop areas, so in this regard the weight of data are the same.

Table 1. Crop cultivation regions in Hungary and their associated meteorological stations

Crop	Region	Meteorological station
Wheat	Central Hungary	Budapest-Met.
	Central Transdanubia	Hurbanovo (SK)
	Western Transdanubia	Szombathely
	South Transdanubia	Pécs
	Northern Hungary	Miskolc
	Northern Great Plain	Debrecen
	South Plain	Szeged

Source: own editing

Considering the sowing of wheat there was no precise data, so for simplicity I dated the total quantity of all regions on the same day. From this the system calculated off harvest date, so it was everywhere at the same time. In this respect I relied on the existing FAO data and other factors in Water Footprint of Nations Appendix (Hoekstra and Chapagain 2004/a) for example estimates of humidity, root depth, crop coefficient and geological data. After all the required data are entered the software calculates the value of the reference evapotranspiration (ETo), the degree of solar radiation (Rs), the plant - in this case wheat - water requirement (CWR) and from these makes irrigation plan (Crop irrigation schedule). (Due to the special case of the water demand of rice the software can calculate only complement additional data, so rice (rice) and non-rice (not rice) plants are distinguished.)

The date I used uniformly for the wheat sown is October 15. from which the software worked with its already existing winter wheat FAO data. Considering the Water Footprint Manual assumption (during the cultivation the crop water requirement is fully satisfied) I determined from the used data that the wheat green and blue evaporation equals total water demand (ETgreen + ETblue = ET = CWR) (Hoekstra et al., 2009). The condition of these is the existence of 'ideal circumstances', which means that the plant growth and yield is not limited. During the use of this software it can be deflected.

The resulted estimated value of crop evapotranspiration (ET) must be converted, thus after multiplied by 10 we get wheat green, blue, and total water use (CWU) measured in m3/ha. After this can process water footprint be calculated, where wheat water use is divided by the yield. According to these the estimated process water footprint of a ton of wheat is just 1000 m^3. It is clear from the results that green water footprint is slightly more than blue one. This means that a little bit more than half of the process water needs in growth stage of wheat are obtained from rain and a part of it returns back into the atmosphere during evaporation. And a little bit less than half is provided from surface and ground water. (On national level the water requirement of 1 kg domestically cultivated wheat is 221 mm in the production period – calculated by FAO (Hoekstra and Chapagain, 2004/b)). It is important to note that this figure does not include blue and green water contents of the harvested plants. Average moisture content of wheat is 12-14%. This means that the water footprint of the crop itself is 0.12 to 0.14 m^3 / t, which is negligible in relation to the plant process water footprint.

Grey water footprint of Hungarian wheat

In the case of grey water footprint calculation there was relatively little data available for me, so I used estimations and conclusions at this relation as well. The effects of pesticides, other nutrients and herbicides beside fertilizers used in agriculture on the environment have hardly or not at all been scanned. In the absence of local, free-flowing water bodies' water quality standards (nitrates content) U.S. EPA (U.S. Environmental Protection Agency) standards were used which were also used by the Water Footprint Manual. According to this assumption the amount of nitrogen is10% which flows back into the water body of the applied fertilizer rate (Hoekstra et al., 2009). The data of gray water footprint calculation in connection with wheat production were available by KSH and FAO databases.

Gray water footprint of a ton of Hungarian wheat is an average 267.5 m^3. Wheat grown in Southern Transdanubia has the smallest gray water footprint. The one grown in Central Hungary has the largest one despite of the fact that here is the least amount of estimated water body pollution.

Water footprint of Hungarian wheat

Based on the above I conclude that total water footprint of the wheat grown in Hungary is 1,268 m^3/t. (According to summary tables given by www.waterfootprint.org the average water footprint of wheat which was grown in different places varies from 1,000 to 2,000 m^3/t.)

Water footprint of Southern Plain's wheat is 10%, Northern Great Plain's is 12%, and Central Hungary's 27% higher and Southern Transdanubia's 12% and Western Transdanubia's 16% lower than the national average.

From 1 kg of wheat average 0,76 kg flour is made, the rest is mostly wheat bran (≈ 0,228 kg) and wheat germ (≈ 0,012 kg) according to FAO data related to Hungary. (Less than 1% is lost, but it's so little rate that I have not counted separate thus. In addition, wheat germ has a very small share of the products, so it combined counted with wheat bran.) As additional data was not available for me I estimated the value fraction of the resulting flour based on Italian example at 0.88, which means that the 88% of the total value of mill products is flour (Hoekstra and Aldaya, 2009).

Based on the above the water footprint of flour, which can be estimated by the amount of green (WFgreen), blue (WFblue) and gray (WFgrey) water footprint of wheat regard to Hungary is (1268x0,88/0,76=) 1,468 m^3/t.

There is no significant difference between the water footprints of wheat flour and bread. In Hungary, on average 1,014 liters of water is needed to produce 1 kg bread. Central Hungary has the largest water needs (1290 l/kg) in this respect. This should be reduced (for example with technological change, development or production redistribution). Western Transdanubia (847 l / kg) and South Transdanubia (892 l / kg) have the smallest ones. This means that the domestic 'bread production" should rather focus on these regions. (In the lack of the regional share of "bread production" data the national average is based on the previous calculation, not a weighted average of the regional water footprints of bread.

Of course, bread production has many specifics so regional optimization appears pointless, but wheat and bread water footprint data clearly show where and what to produce and consume if we basically want to be water-efficient. It can be important in the light of the calculations to prefer mainly on the production sites of export wheat production where water footprint has the lowest values.)

The calculations and KSH figures show that the estimated annual water footprint of bread consumption per capita in Hungary is 45528,6 l/kg. At this point, I find it important to emphasize again that a very large part of the data used is based on estimates and conclusions.

Water footprint of Hungarian pork

Background

Official website of the water footprint of the products of animal origin page was still under construction during the research (www.waterfootprint.org, 2010/a.). From FAO (2003) data can be stated that in our country 100 sows get 1891 pig every year. The picking rate annually is also 133%. (A number of animals are taken from the total national herd for slaughter, or for live export in the same year. Here expressed in total percentage of same species including newborn animals.) Average slaughter weight of swine is 117 kg, average amount of meat weight is 97 kg (more than 80%, which is a very high rate). An average 3,6 kg of edible swine offal which is about 3% of the slaughter weight. The slaughter fat is 5 kg an average, it is roughly 4,3% of the slaughter weight. Skin has no data. In addition, the Agricultural Economics Research Institute (Hungary) records data including the swine breeding and slaughter on the slaughterhouses, too (www.aki.gov.hu 2010).

Water requirement of a pig farm can be detected on the simplest way on the relation of yield of pork and the water meter. This method does not count only with the water demand of the swine in biological sense, but reflects the technology water withdrawal also in which for example cleaning or process water losses are also shown. In addition, the topic can be complicated by differences of feeding habits of each swine species, differences of keeping technologies, of transport and ensiling habits of forage, by the diversity of nutritions' components (in which selection the price-value ratio has a major role as well) and quality standards (which should be considered in different stages of swine growth), or by the differences of watering.

Direct consumption of swine's drinking water is changing at different stages of its life in proportion to the live weight and the water demands of sows even differ from these. There are technologies to measure the storage of environmentally harmful and/or pollutant liquid end-product from metabolism but their application may vary like keeping technologies. Measuring household swine water demand is difficult; probably there is no separate water meter for this.

My oriental calculations for the estimation of the pork water footprint are shown below. According to the KSH calculated data approximately seven percent of the national swine stock is sow, so I did not deal highly with them, especially their water needs is highly dependent on their physiological trait.

On the count of swine water footprint the following assumptions have been calculated:

- Swines are kept in optimal conditions (vitality is good, no need for medical treatment, nutrients supply is nonstop, et cetera).
- Genotype and keeping technology are the same (such as comfort - crowd, lack of water or oxygen ...).
- Feed intake and feeding technology are optimal (for example, the regular feeding time, specific rations, et cetera).
- The quality of the food is the same as human's.
- Pork is a secondary product in terms of calculation, since processing is required - just like butter or sausage (Chapagain and Hoekstra, 2003).

According to Chapagain and Hoekstra (2003) and the conversation with Dr. John Gundel (former college of Agricultural Economics Research Institute - Hungary) the following data were based on for the calculation.

- Live weight a full-grown swine: 120 kg
- Daily drinking water needs of adult swines: 7,5 l
- Daily drinking water needs of 5-month-old piglets: 6 l
- Daily technological water needs of adult swines: 40 l
- Daily technological water needs of 5-month-old piglets: 10 l
- The slaughter age is 10 months.
- The water requirement of the feed consumed by swines is suspected 50%.

The determination of the amount of feed consumed to reach adulthood is assumed linear growth in feed consumption. This quantity is multiplied by the appropriate crop types' specific water needs, so we get the data on daily virtual water consumption of animals. Following Dr. Gundel (2005) I did not dealt with "... such – in some conception possibly listed here - feeding technology issues as feed storage, processing, handling and distribution, chemical composition ...."

Methodology

The formula used to calculate according to Chapagain and Hoekstra (2003):

$$VWC_a = VWC_{drink} + VWC_{serv} + VWC_{food} =$$

$$= \frac{\text{water from drinking}}{W_a} + \frac{\text{water from servicing}}{W_a} + \frac{\text{water from feeding}}{W_a}$$

Where:

VWCa = virtual water content of the live animal (m^3/ton)
VWCdrink = virtual water content of drinking (m^3/ton)
VWCserv = virtual water content of keeping (m^3/ton)
VWCfood = virtual water content of feeding (m^3/ton)
water from drinking = consumed water with drinking (m^3)
water from servicing = used water for servicing (m^3)
water from feeding = consumed water with feeding (m^3)
Wa = live weight of animal (tons). In our case Wa = 0,12 t.

Table 2. Water from drinking

	Piglet	Swine
Age (month)	2	10
Daily consumption (l/animal)	2	7,5
Average daily consumption (l/animal)	4,75	

Source: own editing

From Table 2 can be calculated the average water demand of drinking, which is in this case (the average daily consumption [l/animal] x time [days] =) 1448,75 litres for a swine.

Table 3: Water from servicing

	Piglet	Swine
Age (month)	2	10
Daily consumption (l/animal)	5	40
Average daily consumption (l/animal)	22,5	

Source: own editing

From Table 3 can be calculated the average water demand of servicing, which is in this case (the average daily consumption [l/animal] x time [days] =) 6862,5 litres for a swine.

Table 4. Water from feeding

Crop	Food quantity (tons/year)			SWD (m^3/t)	Crop water requirement (m^3/year)
	Swine	Piglet	Average food quantity		
Barley	0,39	0,003	0,197	247	48,7
Peas	0,018	-	0,009	1879	16,9
Wheat	0,069	0,001	0,035	898	31,4
Corn	0,221	0,013	0,117	731	85,5
Total	0,698	0,017	0,358		**182,5**

Source: own editing

Where:
SWD = specific water demand
(plant water requirement [m3/month] / plant yield [t/ha])

SWD result has been counted according to CropWat calculations from KSH and FAO data. The estimates of the quantities of feed based on Chapagain and Hoekstra (2003) calculations.

From Table 4 can be seen that the annual water consumption of swine is 182,5 m^3. The water consumption of animal feed can be extracted from this data, which is in our case (age of animal [year] x annual water consumption from feed [m^3/year] =) 152,1 m^3.

Table 5. Water use for prepare feed

	Average	
Food quantity	0,358	ton/year
Used water of preparation (about 50%)	0,179	m^3/year
Total quantity (in the animal's life – 10 month)	0,149	m^3/animal

According to these the virtual water content of pork is found below:

$$(1\,448{,}75 / 0{,}12) + (6\,862{,}5 / 0{,}12) + (152{,}25 / 0{,}12) = \\ =1\,338\,010 \text{ (l/t)}$$

This means that about 1338 m^3 of water is required to the "production" of 1 ton of swine. This calculation is illustrating actually the direct water demand of the process. Chapagain and Hoekstra (2003) estimate that worldwide average of this value is 3,5 m^3/kg. The above finding also inferred that direct drinking water consumption is low, less than 1% of this value and the technology water consumption is hardly more than 4%. Water content of consumed plants is responsible almost 95% of the virtual water content of 1 kg "swine".

Counting on the calculation above water footprint of 1 kg pork (VWCp) with help of the amount of virtual water content of live animal (VWCa) and process water requirement (PWR) can be figured out. [VWCp = VWCa+PWR x (vf/pf)] Based on Chapagain and Hoekstra (2003) processing water demand was calculated with 10 m^3/ton by the live weight of the animal.

Table 6. Product fraction and value fraction of swine products

	Product fraction (pf)	Market price (thousand HUF/t)	The value on 1 ton of live animal (thousand HUF)	Value fraction (vf)
Primary products: swine carcass				
Swine carcass	0,82	600	492	0,96
Edible offal	0,03	250	7,5	0,01
Fat	0,04	185	7,4	0,01
Skin	0,05	80	4	0,01
Total			**510,9**	
Secondary products: pork				
Pork	0,83	1250	1037,5	0,95
Eating fat	0,17	250	42,5	0,04
Total			**1080**	

Source: own editing according to Agricultural Economics Research Institute (Hungary), FHO and own estimation, 2011

From Table 6 can be estimated through swine carcass' water demand [(1338+10) x 0,96/0,82 = 1578 m^3/t] the water footprint of pork as well:

$$(1578+10) \times 0{,}95/0{,}83 = 1818 \text{ m}^3/\text{t}$$

Summarizing the above, we can say that virtual water content of 1 kg pork extracted from an (industrial range) 120 kg scaled swine as an example I took is 1,818 litres. That's almost double of the previously calculated value of 1 kg of bread.

IV. Results

The water footprint of bread has been successfully calculated at national level, this is 1014 l/kg. The investigation covered separately the seven statistical regions. As a result, I found that bread has the smallest water footprint at Western Transdanubia (847 l/kg), while the largest at Central Hungary (1290 l/kg). In addition, the context has become clear, that water footprint of flour is about the same as it is needed to produce finished bread.

Calculations proved and it is also shown above, that the largest water footprint of wheat is at Central Hungary of the seven statistical regions. South Transdanubia and Western Transdanubia have the best data.

The result of the domestic pork water footprint calculation is 1818 l/kg. In my experience the data required for these types of calculations have difficult availability.

Furthermore, it can be concluded from the calculations that the directly consumed drinking water is low, less than 1% and the technology is hardly more than 4% of the consumption of a swine. The consumed water content of plants is responsible for almost 95% of the virtual water content of 1 kg "swine".

V. Conclusions and outlines

On reviewing the literature my conclusions, recommendations are the following:

1. Hungary would have to fulfil voluntary data service to the EU as soon as possible. If each member state do the same we can get a picture of our own competitiveness, because – although we know that only same properties can be compared – there is also a competition among different areas, regions.
2. In addition, we can get a more realistic picture of our position in terms of hydrology - both the Union and in Central and Eastern European region. As a result, more accurate forecasts can be made both economically and in terms of the effects of climate change, providing safer living conditions for residents.
3. The data got in this way may present current disadvantaged areas in a novel approach, which could reduce the enormous economic and social differences at Hungary between the central region (Budapest and the agglomeration, Győr-Budapest axis) and 'rural' areas or the periphery.
4. As a result of more accurate and more widely available hydrological surveys should be recognized that in the (near) future Hungary can become a central, strategic area in hydrological sense. In my view, the spread of water footprint index could revalue current market prices of land and property. We have to make the best use of these positive potentials at national, regional and smaller regional levels.
5. The publicity of data service can not only serve community interests, gives also rise to exploiting speculations which can be influenced and should be kept at bay with adequate political infrastructure.
6. Water footprint calculations reveal a new dimension to agriculture, but we must recognize that the real bogeyman is the consumer himself. If one does not need clothes, coffee and other products coming from water-poor countries the global problem of water flow processes can be solved involving the local markets, which are closely related to sustainable consumption as well. At this point, pricing has a very important role with the support of local agricultural production to the local market. The key of this question is also in decision-makers hands.
7. In addition, spreading of voluntary standards systems across sectors (for example manufacturing, engineering, tourism, transportation) and appropriate information (developing sign and label system) related to water footprint would emphasis the liability of consumers and bring closer water footprint reduction case to the user.
8. However one must see that the responsibility of agriculture is not a few drops of water in the case of irrigation with fresh water. Building a non-potable irrigation-based structure could be considered, which even after the initial investment can be more cost-effective and sustainable than the current solution.

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DEPENDENCE ON BIOMASS, THE ROLE OF BIOMASS IN HUNGARIAN ENERGY SUPPLY

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The overall energy consumption in Hungary is about 1160-1200 PJ. This means the amount of primer energy sources, and real consumption is approximately 30-35% lower. The difference comes from conversion losses and the own consumption of energy converters. The major consumers include the inhabitants, traffic, industry and service industries.

Hungary has also joined the European Union's binding target of 20% renewable energy from final energy consumption by 2020, and aims at increasing the share of renewable energy sources from gross final energy consumption to 14.65% (Government Decision No 1002/2011 (I.14.)). By this, the gross quantity of renewable energy sources would add up to 165-170 PJ by 2020, which is to be used for electric power supply, traffic, heating and cooling purposes.

The increase in the generation of renewable electric power has increased primarily due to biomass utilization up to now. By 2010, the amount of renewable electric power reached 2600-2900 GWh/year, being equal to 7.1% of the net domestic electric power generation. The volume of biomass utilization became stable by 2009-2010, within which the amount of biogas consumption slightly increased, on the other hand, wind energy consumption raised to a significant extent, adding up to 620 GWh/year in 2010. Biomass was started to be utilized in greater quantities in 2004, the largest part of which was used to generate electric power. The reason for this was that user infrastructure did not require substantial investments, only traditional coal burning power stations had to be converted to multi-fuel power stations. The disadvantage of the technology is that the so-called waste heat produced during the generation of electric power in power stations can only be utilized to an insignificant extent, which causes a very low energy transformation efficiency of 20-30% (Figure 1).

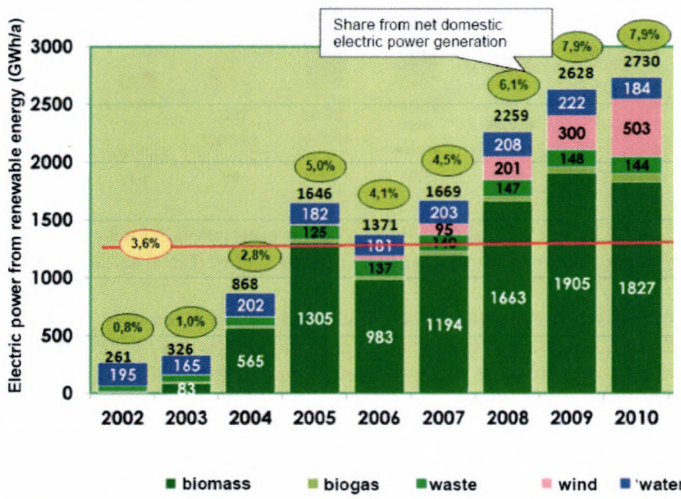
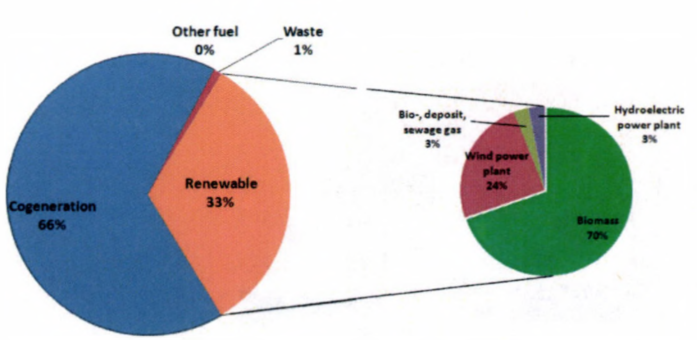


Figure 1. Generation of electric power from alternative energy sources

This quick rise was promoted by the support of the government given to the generation of electric power from biomass, irrespectively of the efficiency of production and utilization. Significant subsidies were provided to cogeneration (CHP) gas-fired power stations as well. Thus, 80-90 thousand million Hungarian forints were flown annually to cogeneration small power plants and renewable electric power suppliers as subsidy by 2010. From which 19-20 thousand million Hungarian forints were subsidy on electric power produced from biomass and 8-9 thousand million Hungarian forints were subsidy on other renewable sources like water, wind, geothermic, solar and other energy sources. The largest part of the subsidy was used to develop cogeneration power plants (Figure 2):



	Mill. HUF
Cogeneration	56680
Waste	827
Other fuel	0
Renewable	28007
Biomass	19520
Wind power plant	6812
Hydroelectric power plant	802
Bio-, deposit, sewage gas	873

Figure 2. The amount (in HUF) and rate of state subsidy in 2010

Even forestry experts agreed on that it was time to cut down and use the surplus, aged and sometimes ill trees although it occasionally led to misuse. The price of wood and consequently the income of forest managers considerably increased.

Seeing that deforestation was excessive in some places and the efficiency of transformation was low, the government withdrew the subsidy by 2011 from large non-cogeneration biomass-fired power plants and small amortised CHP gas-fired power plants. As a result, the amount of electric power output reduced to 1375 GWh in 2011, as against to the planned amount of 1870 GWh. Some 'worn-out' biomass-fired power plants were even closed down.

The government intends to implement a really ambitious plan on the utilization of renewable energy sources by 2020. The National Action Plan (NAP) specifies the production of electric power capacity of approximately 1530 MW by 2020 in the frame of a 14.65% renewable energy program (Figure 3).

The NAP continues to calculate with biomass as the major renewable energy source. Solid biomass primarily includes firewood produced by traditional sylviculture, agricultural by-products and plant-chips from energy plantations. Significant improvement is expected in the fields of biogas, agricultural wastes and residual materials from communal sewage purification plants. Wind energy utilization is of high volume, and is intended to be increased by 120%.

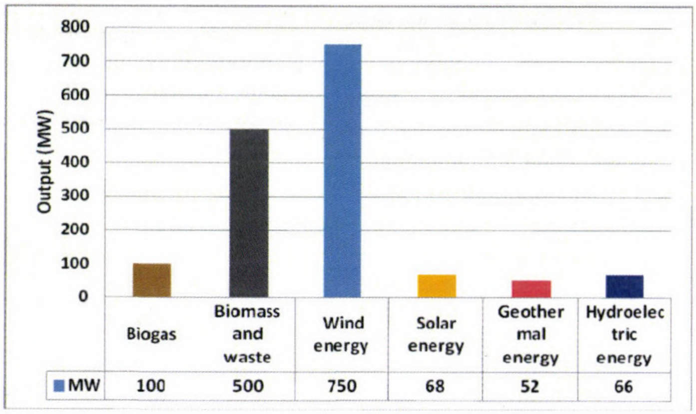


Figure 3. Expected electric power production capacity by 2020
(Source: National Energy Strategy (NEMZETI ENERGIASTRATÉGIA) 2010)

To reach the planned renewable electric power production of 5500-5600 GWh/year by 2020, biomass (including biogas) production and partially wind energy have to be increased significantly.

Biomass

From biomass we can produce heat energy, electric power and various gaseous, liquid or solid fuels (such as oil, alcohol, gas, biogas, chips, pellets, etc.).

Oil, alcohol and gas are used as fuels, while solid processed materials, for instance chips, pellets, briquettes are mainly utilized to produce heat.

It has to be acknowledged and should not be disregarded that the production of various biomasses requires substantial amount of energy (e.g. for converting herbaceous plant biomass into hard fuel pellet). Efficiency is demonstrated by the OUTPUT/INPUT (O/I) rate comparing the chemically bonded energy content of the end-product before use to the total energy content of all the energy sources used for production. In professional literature sometimes very beneficial rates are stated, for instance the O/I rate for hard stem energy plantation collected to the edge of fields is 15-20. It has to be noted that this rate is reduced by transportation, shopping and preparation, depending on the energy requirement of technologies, to O/I = 3-6 or even lower.

From the aspect of energetics, the amount of so-called net energy gain is to be examined, taking into consideration, in addition to the above, conversion losses as well. When only electric power is produced from biomass, the I/O rate does not exceed 3.0. When only thermal energy is generated (for heating) the O/I rate can be as many as 6, which is, of course, reduced by transportation.

These figures also indicate that biomass is not practical to be used only for generating electric energy. Combined production is much more advantageous when all the heat is utilized in addition to the generation of electric power. In this case, the efficiency rate is almost equivalent to heating (Figure 4).

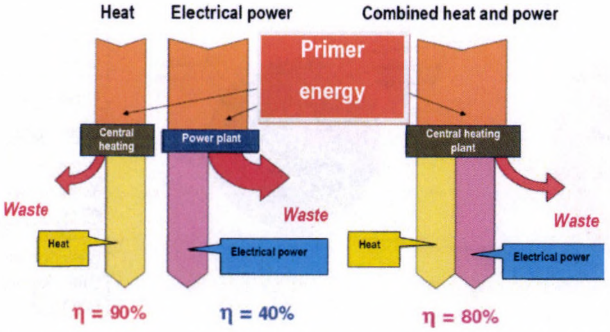


Figure 4. Efficiency of heat, electrical power and Combined heat and power generation (Source: Stróbl A. 2011)

There are a lot of estimations known on the total energetic biomass potential of Hungary. Some of which calculates with 200-300 PJ/year as the possible upper limits. It is estimated that the average biomass production from agriculture is approximately 100 PJ, while the maximum production is 170 PJ. The most important factor of uncertainty is the possible utilization of various biological by-products as the amount of cereal straw, corn-stalk, grape-shoot, etc. depends highly on weather.

Biofuels

The amount of cereals and oil seed crops used for biofuels adds up to 4% of the annual raw material production of the world.

Biodiesel

In 2010, 21 million m^3 biodiesel was produced in the world, 56% of which was produced in Europe. Biodiesel is mixed into diesel oil in the rate of 5%. This rate has to be doubled by 2020. The required production capacity (23 million m^3) is practically available, which is now operated with a utilization rate of 56%. In several countries where biodiesel was offered as a separate fuel, it was withdrawn from the supply of filling stations as price differences dropped to the minimum in comparison to traditional diesel oil, significantly reducing its market advantage.

In Hungary, biodiesel is marketed as a component of traditional diesel oil mixed in at a rate of 4.7%, which is to be increased to 8% by 2020. The biodiesel production capacity established so far in the country (180 thousand tons) is capable of meeting the demand of fuel producers and distributors.

To achieve the mixing quota planned and undertaken by 2020, 240 thousand m3 biodiesel will be required. This can be obtained from the processing of oil-seed rape (95%) and a minimum amount of sunflower produced in Hungary at the present level of production. It is also possible to increase the production capacity. Biodiesel production and utilization in Europe may be influenced by the market prices of oil-seed crops which has shown continuous increase lately.

Bioethanol

Bioethanol is used as a component of petrol-driven motor vehicles mixed in the fuel E85 and partially as a separate fuel. Last year, 4.4 million m^3 bioethanol was produced in the European Union, and 6.1 million m^3 was mixed in petrol, 27.9% of which came from import. European bioethanol producing capacity adds up to 7 million m^3, but it only operates with a utilization rate of 62.8 due to the high raw material (cereal) prices. In order to reach the targets by 2020, the EU has to increase bioethanol production to at least the double of the present amount, i.e. to 12-14 million m^3. Within the EU, only France, Spain and Hungary are capable of exporting bioethanol.

In Hungary, significant bioethanol production capacity has been established. In the near future, production capacity in the country will reach 810 thousand m^3/year. The majority of the product is exported as the amount used at present in Hungary is 75 thousand m^3/year, which will be increased to not more than 140 thousand m^3/year by 2020.

Biogas

Biogas production based on agricultural primary and secondary by-products and other biological wastes has increased substantially in the world. Europe is in the vanguard as more then 8500 biogas plants are operated here.

In Hungary, 46 biogas-producing plants are run at this time with an overall electric power generation capacity of 37 MW, from which 31 plants uses agricultural raw materials and the rest produces biogas from food and communal wastes or sewage sludge. The majority of the plants built in the vicinity of livestock farms and mainly using animal slurry and plant-based raw materials (silage, hay, residuals of cereal cleaning, etc) or food industry wastes have an output of 600-700 kW.

Using the biogas-producing capacity installed in the recent past, the country is able to produce 150-170 GWh/year electric power. This amount can be tripled or quadruplicated by 2020. It is important to ensure that waste heat is also utilized (for heating, drying, heating green-houses, warm-water fish-breeding) as this is required for the economic operation of plants. A solution could be the purification and concentrating of biogas (biomethane), enabling it to be fed into the natural gas network or used as fuel in motor vehicles.

Ecological sustainability

Experts involved in agriculture and soil management are right in criticising the utilization of cereal straw and corn-stalk for energy purposes and state that these materials are needed to maintain soil fertility and provide nutrition for the soil as a living organism. Accordingly, a substantial part of these materials has to be returned in the soil to maintain the original structure, water storage capacity of soil and to provide materials (carbon, minerals, microelements, etc.) required for plant growth. These experts claim that by continuously removing the yield from the field we degrade the soil, reducing its productivity as well as the nutritive value of the plants produced there.

The removing of some by-products such as grape-shoots, fruit trimmings does not mean significant ecological harm, however, they are not really important from energetic aspects either as their energy density is so insignificant in an unprocessed form that their transportation is not economic for distances above 20-25 km. Many people have reservations, with good reasons, about the utilization of wood produced in our forests in electric power plants, and the state subsidy provided for this.

Between 2004 and 2010, an annual amount of 6.4 PJ (400 thousand tons) wood was fired in Hungarian power plants, which requires over 500 thousand hectares of forests in addition to the usual timber felling. This was enough for 5% of the domestic electric power demand.

In the case of energy forests, much smaller areas are needed as much larger amounts of wood can be produced with 2- or 3-year turns. Professional literature contains very different data for this as well ranging from 2.0 to 14.0 tons of annual yield per hectare. Misinterpretations in evaluations are caused by that the moisture content of wood is not defined when yield is given. Fire-wood was traditionally used after a 3-year delay period in air-dry condition, which is not possible these days. Even if the wood is cut in winter with low moisture content and is used after a delay period in the next heating season, the moisture content will not be lower than 40-50% and the maximum net calorific value will only be 11-13 MJ/kg.

Calculating with the averages of values defined in literature for agricultural by-products, about 6500000 tons could be collected annually. Energy content is calculated in the next table:

Thus, calculating with 50% transformation efficiency, the amount of utilized energy is 42.25 PJ/year, which does not reach 5% of total domestic energy need, and it requires a fossil usage of 17 PJ/year.

Biomass utilization for the purposes of electric power generation diminished considerable even in 2011 because the state subsidization of electric power was ceased. In accordance with the NAP, the restoration of the subsidy cannot be expected. Biomass utilization for heating can only be performed in larger village or city central heating plants (industrial, public utility, private sector). The majority of these will apply cogeneration systems favourable from the aspect of energy efficiency as only these types will obtain state subsidy in the future. Such facilities can be utilized for longer times and with higher effectiveness. The same applies to labour utilization, and the return of invested capital is of higher chance.

By-product	Energy content	Energy content	Operational energy rate	Fossil requirement
Tons/year	GJ/tons	PJ/year	O/I	PJ/year
6 500 000	13	85	5/1	17

Alternative electric power programme

Figure 5 demonstrates the planned increases in electric power by 2020.

The plan shows that the present biomass production is intended to be increased by about 70%. Accordingly, the increase in biomass has to be doubled in comparison to the level of the year 2012 to achieve the target by 2020. However, the development requires substantial costs: 580-650 million euros (160-180 thousand million Hungarian forints) only for the power plants, which will give an overall amount of about 300-350 thousand million Hungarian forints together with infrastructural facilities.

Ecological sustainability also sets a limit to the plan as the expected increases in food production also have to be taken into consideration.

The concept of decentralized biomass-firing small power plants is reasonable especially when raw materials can be provided from the vicinity of the settlement. It also facilitates local employment, but their construction does not seem feasible in many cases under the present economic trends as they require significant resources.

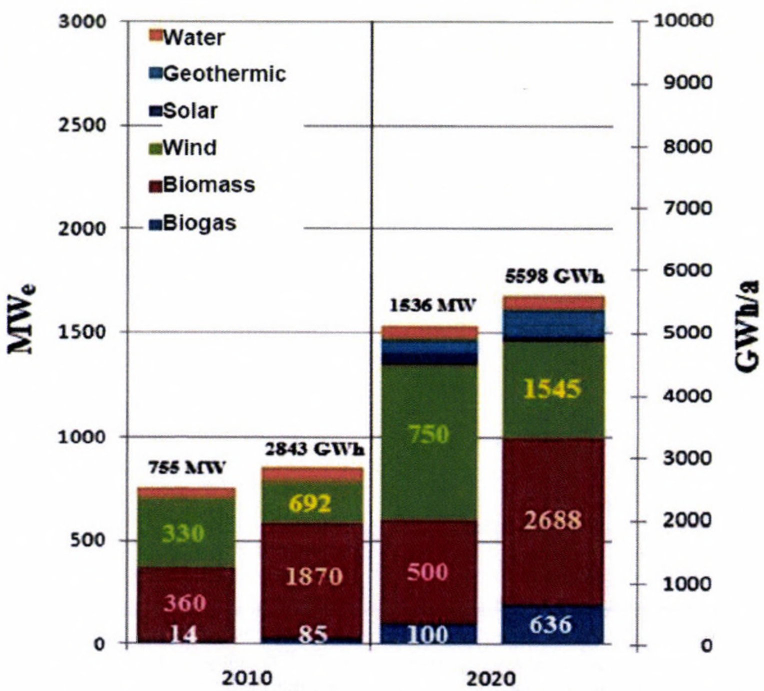


Figure 5. Planned quantity (MW) of various renewable energy sources and expected production (GWh) (Source: National Energy Strategy (NEMZETI ENERGIASTRATÉGIA) 2010-2030)

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CARBON SEQUESTRATION OF GRAIN CROP SPECIES INFLUENCED BY NITROGEN FERTILIZATION

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Abstract

The climate change phenomena may be related to the rise in atmospheric CO_2. Crop production can be a major tool regarding both adaptation and mitigation. The negative effects of climate change can be limited by changes in crops and crop varieties, plant nutrition, and various agronomic techniques. The global potential of carbon sequestration through crop production, land use and soil management practices may offset one-fourth to one-third of the annual increase in atmospheric CO_2.

In a small plot field experiments the most characteristic agronomic impacts (biological bases, production sites, plant nutrition and crop year effects) influencing the efficiency of carbon sequestration of two major crop plants; wheat Triticum aestivum and maize Zea mays have been studied. The aim of the research was to observe, identify and quantify agronomic impacts and their interactions that may have an influence on organic matter formation and so on carbon sequestration. The present paper provides information concerning the results of the trial. Crop variety and plant nutrition proved to be the most powerful factors influencing organic matter production. Interactions have been found between crop plant genotypes and N levels applied.

Keywords

carbon sequestration, maize, winter wheat, plant nutrition

Introduction

One of the major issues of mankind is global climate change. There is a continuous rise in temperature escorted by the increasing frequencies of weather anomalies. In case of Hungary two facts can be observed; the ascending levels of temperature rise, with a magnitude of 1 °C and the annual precipitation decrease. Human activities are significantly altering the natural carbon cycle (Lal 2004). Long-term rise in atmospheric CO_2 highlights crop production regarding both adaptation and mitigation. The negative effects of climate change can be limited by changes in crops and crop varieties, improved water-management and irrigation systems, adapted plant nutrition, protection and tillage practices, and better watershed management and land-use planning (Berzsenyi and Lap 2005; Márton 2005; Sárvári 2005, Pepó 2010). The global potential of carbon sequestration through crop production, land use and soil management practices may offset one-fourth to one-third of the annual increase in atmospheric CO_2, a most endangering GHG (Lawlor 2002).

The carbon cycle is a complex series of processes through which all of the carbon atoms on earth rotate. In one part of the cycle, plants absorb carbon dioxide from the atmosphere and through photosynthesis incorporate the associated carbon atoms into sugars and other molecules necessary for growth. Plants use some of these to generate energy in the respiration process, which returns carbon atoms back to the atmosphere in the form of CO_2 (Jolánkai et al 2005). However, much of the carbon absorbed remains locked up in the plants' biomass until decomposition or various releases of that via food chain processes, and other ways of chemical conversion.

Materials and methods

The Szent Istvan University Crop Production Institute has recently started a new research programme on exploring the most characteristic agronomic impacts (biological bases, production sites, plant nutrition and crop year effects) influencing the efficiency of carbon sequestration of two major crop plant species; wheat Triticum aestivum L. and maize Zea mays L. The aim of the research is to observe, identify and quantify agronomic impacts and their interactions that may have an influence on organic matter formation and so on carbon sequestration.

The trials were set up at the Nagygombos experimental site with a parallel version sown at Szárítópuszta in a three years consecutive series between 2007-2010. Six Martonvásár high starch maize hybrids were used in the trials representing different genotypes (Mv 250, Maraton, Norma, Gazda, Mv 454 and Mv 500) and a broad range of maturity groups (FAO 200-500). Also five wheat varieties (Mv Magdaléna, Alföld 90, Mv Suba, Mv Csárdás, Mv Toborzó) were exposed to ascending levels of nitrogen applications. Experimental double row 10 m2 plots were designed in randomized blocks for maize, and full 10 m2 plots in split-plot arrangement for wheat crop were sown both with four replications. The nitrogen applications were as follows: N 0, N 80 kg/ha, and N 120 kg/ha respectively. Basic plant nutrition and plant protection treatments were identical and appropriate regarding the agronomic requirements of the experimental field and providing ceteris paribus conditions to the trial.

Phenological, herbological, phytosanitary observations and yield characteristics have been evaluated. Yield samples were analysed for quality features (protein, carbohydrate, starch, cellulose, fat, ash etc). Carbon sequestration values were estimated on the basis of grain yield and total above ground biomass dry matter production.

Results and discussion

The present paper provides information concerning the results of the trial. Crop variety and plant nutrition proved to be the most powerful factors influencing organic matter production. Interactions have been found between crop plant genotypes and N levels applied.

Maize trial data are presented by Table 1. Grain yield, plant dry matter and carbon content values are presented by each hybrid in N application variants. Both hybrids and nitrogen applications proved to be significant concerning C values. Plant nutrition proved to be a strong factor in comparison with hybrid effects. However maize hybrids have shown differences as well. In general the results suggest, that late maturity hybrids had higher carbon sequestration abilities, but this difference was influenced by the nutritional levels, too.

Results of the winter wheat experiments are summarised in Table 2. Identical to the other trial, grain yield, plant dry matter and carbon content values are presented by each wheat variety in respective N applications. Compared to the maize trial data, wheat varieties were found to have less consequent specificity regarding C content, however N applications had really strong interactions with varieties. The difference between untreated control and N applications proved to be significant in all varieties, however 80 versus 120 kg/ha teratments had less impact on that.

Table 1. Carbon sequestration of maize (Zea mays L.) hybrids, Nagygombos

0 N Hybrid	Grain yield kg/m^2	Plant dry matter kg/m^2	AG biomass C content estimate, kg
Mv-251	0.48	0.34	0.33
Maraton	0.86	0.61	0.59
Norma	0.38	0.37	0.30
Gazda	0.69	0.48	0.23
Mv-454	0.70	0.46	0.45
Mv-500	0.56	0.42	0.39

80 N Hybrid	Grain yield kg/m^2	Plant dry matter kg/m^2	AG biomass C content estimate, kg
Mv-251	0.79	0.71	0.60
Maraton	1.06	0.90	0.78
Norma	0.79	0.67	0.55
Gazda	0.76	0.77	0.61
Mv-454	0.78	0.58	0.54
Mv-500	1.36	1.04	0.96

120 N Hybrid	Grain yield kg/m^2	Plant dry matter kg/m^2	AG biomass C content estimate, kg
Mv-251	0.83	0.75	0.63
Maraton	0.79	0.63	0.57
Norma	0.80	0.78	0.63
Gazda	1.14	1.17	0.92
Mv-454	1.17	1.13	0.92
Mv-500	1.43	0.62	0.82

C value $LSD_{0.05}$ Hybrid 0.112

Nitrogen 0.048

Table 2. Carbon sequestration of winter wheat (Triticum aestivum L.) varieties, Nagygombos

0 N variety	Grain yield kg/m^2	Plant dry matter kg/m^2	AG biomass C content estimate, kg
Mv Magdaléna	0.54	0.59	0.45
Alföld 90	0.68	0.75	0.55
Mv Suba	0.76	0.83	0.62
Mv Csárdás	0.69	0.76	0.58
Mv Toborzó	0.70	0.75	0.58

80 N variety	Grain yield, kg/m^2	Plant dry matter, kg/m^2	AG biomass C content estimate, kg
Mv Magdaléna	0.74	0.85	0.64
Alföld 90	0.71	0.77	0.59
Mv Suba	0.80	0.89	0.68
Mv Csárdás	0.81	0.88	0.65
Mv Toborzó	0.84	0.91	0.69

120 N variety	Grain yield, kg/m^2	Plant dry matter, kg/m^2	AG biomass C content estimate, kg
Mv Magdaléna	0.78	0.85	0.65
Alföld 90	0.84	0.84	0.67
Mv Suba	0.75	0.82	0.63
Mv Csárdás	0.79	0.75	0.62
Mv Toborzó	0.80	0.86	0.66

C value $LSD_{0.05}$ Variety 0.092

Nitrogen 0.067

Figure 1 presents a graphical evidence of carbon sequestration performance differences of the two crops examined.

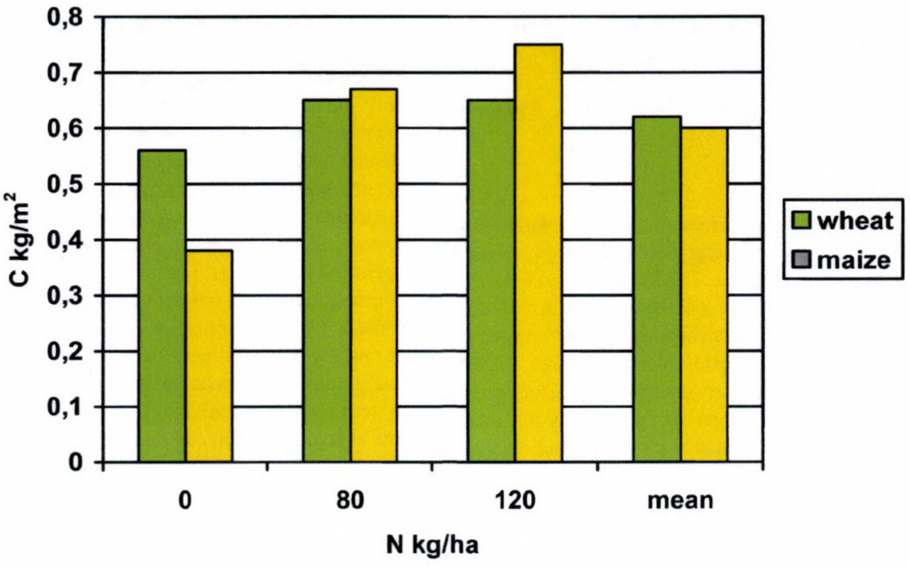

Figure 1. Nitrogen impact on carbon sequestration of grain crops, Nagygombos

Conclusions

Wheat in general was more stable regarding C values, however maize crop was proved to be more efficient concerning ascending N doses. All together in mean values there was no measurable difference between the two crop species. Crop variety and plant nutrition proved to be the most powerful factors influencing organic matter production. Interactions have been found between crop plant genotypes and N levels applied. Atmospheric C budget can be balanced by photosynthetic dry matter production of natural vegetation and agricultural crops. The latter can be influenced by agronomic applications.

Acknowledgement

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ENERGY DEMAND OF IRRIGATION – ENERGY AND CARBON SAVING IN THE PRACTICE

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Introduction

The continous increase of energy prices makes the irrigation more and more expensive. The cost of energy demand strongly depends on the system of irrigation technics. The irrigation equipment as a hydraulics energy transformation system is tested in this study theoretically. The general relationships show the connection among the main parameters (the real time irrigated area, the total pressure and the intensity of the irrigated water) influenced by the specific energy demand of irrigation. In this way the energy costs of irrigation can be calculated at any systems and operation characteristics.

The energetic process of irrigation

The energy issues of irrigation systems are usually not in the focus of the technical literature, either in the home or the international works. The Hungarian sources in this field (e.g. [1], [2], [3] and [4]) deal with the energy problems of pump stations only, the irrigation equipment and systems are usually outside of the circle of analyses. Even such an excellent detailed and standard edition like [5] does not have any chapters or parts about the energetics of different irrigation systems. At the same time a theoretical analysis is very useful at the choice of an irrigation system, the equipment to realise the goals of irrigation and the operation parameters, too.

Energetically the irrigation is an energy transforming process, some energy transformation appears in the elements of the system during the irrigation periods. The irrigation water needs defined energy for transportation and distribution depending on the system and the specification of elements. The general scheme of this energetic system can be seen on Figure 1.

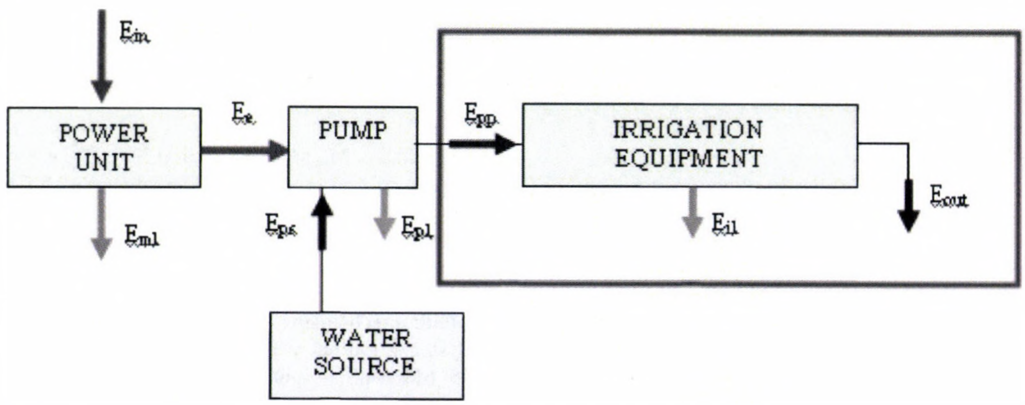

Figure 1. The energetical process of irrigation

The input energy (*Ein*) is transformed to effective power energy (*Ee*) by the power unit. The motor losses of the power unit (*Eml*) depend on the type of the unit: the maximum efficiency is 40 – 45 % at engines, and 80 – 85% at motors. But the actual efficiency is influenced strongly by the energetical adaptation of the power unit and pump, and also determined by the operation conditions. The advantage of the engine drived pumps is the variable revolution of the engine. In this case a relatively high efficiency can be set. At the motoric driving the same possibility can be realized only if the motor is also a variable revolution type. These installations are expensive but the plus investment returns in the course of a long time operation.

The effective energy for the pumping (*Ee*) has to cover the energy demand of water lifting from the water source (if there is), the increasing of water pressure energy after the pump (*Epp*) and all the losses of the pump (*Epl*). Concerning the irrigation equipment the Epp is the most important, because its value determines the quality of the irrigation and the correct operation conditions of the equipment.

The hidraulic power demand is determined by the irrigation equipment:

$$P_{hp} = 10^2 \cdot Q \cdot p_{pp} \text{ [kW]} \qquad 1$$

where *Q:* needed rate of flow, [m3/s]
ppp: pressure of the pump at the outlet, [bar].

$$p_{pp} = p_t + p_{out} \qquad \text{[bar]} \qquad 2$$

where *pt:* the pressure demand of the transport, [bar]
pout: pressure demand of the outlet, (the pressure demand of the outlet elements), [bar].

The pressure demand of transportation (the water streaming in the tubes of equipment) is calculated by the well-known analytical method. In this way the total pressure losses of the equipment can be determined as it follows:

$$p_t = \sum_i \Delta p_i = \sum_{i=1}^{n} \lambda_i \cdot \frac{l_i}{d_i} \cdot \frac{\rho_w}{2} v_i^2 + \sum_{j=1}^{m} \xi_j \cdot \frac{\rho_w}{2} v_j^2 \quad \text{[Pa]} \qquad 3$$

where: *λi:* frictional coefficient of the tube section, its value is usually λ = 0,01 – 0,02,
li: lenght of pipe section, [m]
di: inner diameter of pipe section, [m]
vi: velocity of water in the pipe section, [m/s]
ξj: local loss coefficient,
vj: velocity of water at the place of the local loss, [m/s]
ρw: density of water, [kg/m³].

(If the irrigation equipment is complicated, the use of a computer software is proposed.)

The equation (3) shows that the pressure losses (the energy losses of the transition) can be reduced by increasing the diameter of the tube sections.However, in case of increasing the diameter of the pipelines, the investment costs will also grow. To find an optimum diameter of the pipe sections is an important task at the planning of irrigation equipment.

Based on the above mentioned if the irrigation equipment has more distributor elements, the outlet pressure changes at each element. At the sizing process it is very important that the outlet pressure at the very last element (along the pipelines) would be satisfied.

Energetics of the irrigation equipment

The demand of transition and outlet pressure (namely the hydraulic power demand) is determined by the irrigation system and the construction of the actual equipment. But the general rule is that the energy demand is influenced by the outlet pressure if the distributed flow rate is constant. Based on the (1) the energy demand of the irrigation equipment is

where *Q:* distributed flow rate, [m³/h]

$$E = 10^2 \cdot Q \cdot p_t \cdot t_i \qquad [\mathrm{kJ}] \qquad 4$$

pt: total pressure (pressure demand of the suction + transition + outlet), [bar]

ti: operation time of irrigation, [h]

The irrigation time (*ti*) can be calculated from the intensity of irrigation (*i*) and the dose of irrigated water, h:

(Dimensions of (5) are: h in [mm], i in [mm/h].)

$$t_i = \frac{h}{i} \qquad [\mathrm{h}] \qquad 5$$

The effective average intensity of irrigation can be calculated as

$$i = 10^3 \cdot \frac{Q}{A} \qquad [\mathrm{mm/h}] \qquad 6$$

where *A* is the area irrigated at same time, [m²].

The energy demand of irrigation based on (5) and (6):

$$E = 10^2 \cdot A \cdot i \cdot p_t \cdot \frac{h}{i} = 10^2 \cdot A \cdot p_t \cdot h \qquad [\mathrm{J}] \qquad 7$$

A specific parameter can be the base for the evaluation or comparison of the different irrigation methods or equipment. While in (7) there are three variable parameters three specific values can be composed.

1. The specific energy of water dose unit is:

$$E_h = \frac{E}{h} = 10^2 \cdot A \cdot p_t \qquad [\mathrm{J/mm}] \qquad 8$$

2. The specific energy of irrigated area unit:

$$E_A = \frac{E}{A} = 10^2 \cdot p_t \cdot h \qquad [\mathrm{J/m^2}] \qquad 9$$

3. The specific energy demand of flow rate unit of irrigated water:

$$E_Q = \frac{E}{Q} = \frac{10^2 \cdot h \cdot p_t}{i} \qquad [\mathrm{kJ/m^3/h}] \qquad 10$$

If different irrigation techniques are decided to compare energetically, the equation (10) may be suggested as a base. However there might be interpretation problems concerning the explanation of the intensity during the evaluation process. Equation (10) shows the inverse proportion of energy demand and intensity (Figure 2). Because of many ways of water distribution, the intensity of irrigation is specific for the irrigation system and the actual equipment.

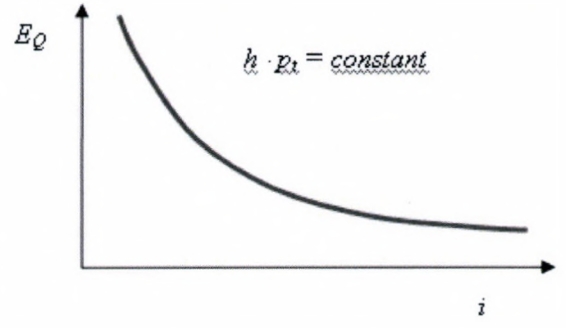

Figure 2. The EQ – i function

Sprinkling irrigation

If sprinkler irrigation systems are used, the total surface of soil is usually wetted similarly to the rainfall. At this method the outlet elements are sprinklers in standing or moving operation mode. As the intensity of the water is changing along the radius of sprinkling therefore an average intensity can be defined at any single spinkler. The average intensity can be calculated from the actual operational data.

If the aim of sprinkler irrigation is the supplementation of the lack of rainfall, it is necessary to distribute the water evenly on the soil surface. In this case every single plant has to get nearly the same volume of water. At sprinkler irrigation the total surface is wetted by the irrigated water, thus the breeding area takes in approximately the same amount of water (Figure 3). In this way the plants can utilize the nutrients of soil perfectly (all the wetted cubic capacity of soil is reachable for the plants.)

In case of sprinkler irrigation the average intensity of water and the total pressure vary relatively widely dependig on the construction of equipment. Generally the higher intensity needs higher pressure.

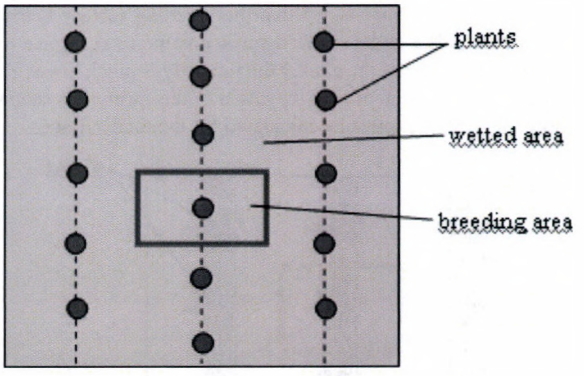

Figure 3. In case of sprinkler irrigation the total surface is wetted

In order to compare the different sprinkler irrigation technics concerning energy demand a new specific parameter is needed. Based on (10) the next equation can be written:

$$E_{Qh} = \frac{E_Q}{h} = \frac{10^2 \cdot p_t}{i} \quad \text{[kJ/m}^3\text{/h/mm]} \qquad 11$$

EQh means the specific energy .demand correlating with the flow rate unit and the unit of water

Equation (11) is used to calculate the EQh values of intervals of total pressure and intensity applied in the practice. The results can be seen in Table 1.

Table 1. Specific energy demand of sprinkler irrigation

Irrigation equipment	Pressure p_t [bar]	Average intensity i [mm/h]	Specific energy demand E_{Qh} [kJ/m³/h/mm]
Micro sprinklers	2 – 4	1 – 5	40 – 200
Moving systems	3 – 4	5 – 10	60 – 80
Reel systems with console	4 – 5	5 – 10	40 – 50
Reel systems with single sprinkler	5 – 10	10 – 20	20 – 100

As it can be observed in Table 1 there are not significant differences among the specific energy demands of the different sprinkler irrigation systems except for the micro sprinkler irrigation where the specific energy demand can reach the highest value of 200 kJ/m³/h/mm. So exclusively because of energetic aspects i.e. its high costs the micro sprinkler irrigation can not be suggested for rainfall replacement irrigation.

However, at sprinkler irrigation the water losses – and so the energy losses should also be taken into account. The reasons of loss of water can be the evaporation in the atmosphere, the transition effect of the wind and the evaporation of the soil surface. In unfavorable conditions the water- and energy losses can reach even 30 – 50%.

Drip irrigation

The drip- or trickle-irrigation is usually applied in plantations, arable land horticulture and greenhouses. The common characteristic of drip irrigation systems is the spot water distribution along the pipelines. If the pipeline is made from porous material, the water can be percolated on the wall of the pipeline. In this case the wetted area is linear. In the drip irrigation systems the intensity is not an evident parameter. The problem is showed in Figure 4.

If the irrigated water is calculated at the wetted area (or to the wetted cross section in the root zone) the intensity is relatively high. It also must be emphasized that the breeding surface is irrigated only partly. But if the referred surface is the total surface (or the breeding surface of the plants) the intensity is much lower. For the correct comparison of drip irrigation to the sprinkler systems, the average intensity must be calculated for the total surface.

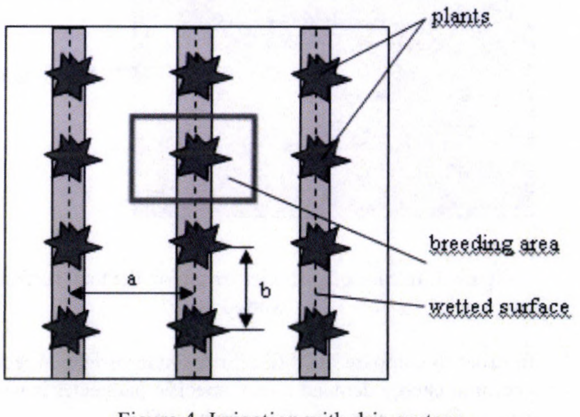

Figure 4. Irrigation with drip system

The breeding surface depends on the row space and the plant distance. The breeding area is exactly determined by the needs of plants and is influenced by the optimum utilization of the land. If the breeding surface is irrigated only in part, the roots of plants are concentrated in the wetted area or cubic volume. The other parts of the breeding surface are nearly unused.

The definition of intensity in drip irrigation systems is really correct only if the irrigated water volume is referred to the total irrigated area:

$$i = \frac{q_A}{A_b} = \frac{n \cdot q_1}{a \cdot b} \quad \text{[mm/h]} \qquad 12$$

where qA: irrigated flow rate of breeding area, [dm³/h]
$q1$: flow rate of the single dripper element, [dm³/h]
n: number of drippers per breeding area,
Ab: breeding area, [m²]
a and b: row space and plant distance, [m]

If one dripper pipeline is installed into each row, the number of drippers per breeding area is $n = b/t$, where t is the distance of the dripper elements along the pipeline. The intensity in this case is:

$$i = \frac{q_1}{t \cdot a} \quad \text{[mm/h]} \qquad 13$$

The specific energy demand of drip irrigation system is given by (11) and (13):

$$E_{Qh} = \frac{10^2 \cdot p_{\ddot{o}} \cdot t \cdot a}{q_1} \quad \text{[kJ/m}^3\text{/h/mm]} \qquad 14$$

Equation (14) shows clearly how the specific energy demand is influenced by the operational parameters. The data calculated for some tipical operation conditions by equation (14) can be seen in Table 2.

From the data of Table 2 it can be seen clearly that the specific demand of energy is changed more widely at drip irrigation than at the sprinklers showed in Table 1. The conclusion is that the drip irrigation may be energy saving or energy intensive depending on the operational characteristics, namely on the scheme of the pipelines (a), on the specific number of drippers along the pipeline (t), the pressure and the volume rate of drippers. Another important conclusion of the theoretical test is that the drip irrigation might be a water and energy saving irrigation system (that is mean low-carbon system) but in this case it should be taken into account that the breeding area of plants is irrigated unevenly. At the same time the effective energy demand of the drip irrigation is reduced by the minimal water losses, ie. the distributed water can be fully utilized by the plants.

Of course, the energy demand is only one aspect in the evaluation of different irrigation systems. There may often be circumstances when the energy costs of irrigation do not have high priority because of other more important agronomical or technical aspects.

Table 2. Specific energy demand of trickle irigation

Pressure p_t [bar]	**Distance of elements** t **[m]**	**Distance of rows** a **[m]**	**Flow rate of drippers** q_t **[dm³/h]**	**Specific energy** E_{Qh} **[kJ/m³/h/mm]**
1	0,2 0,4 0,6 0,8	0,5 1,0 1,5 3,0	1,5 2,0 2,5 3,0	7 20 36 60
2	0,2 0,4 0,6 0,8	0,5 1,0 1,5 3,0	1,5 2,0 2,5 3,0	13 40 72 160
3	0,2 0,4 0,6 0,8	0,5 1,0 1,5 3,0	1,5 2,0 2,5 3,0	20 60 108 240

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WIND AND GEOTHERMAL ENERGY RESEARCH AND EDUCATION AT THE FACULTY OF MECHANICAL ENGINEERING OF SZIU

Prof. Dr. László Tóth

Summary

- The Faculty of Mechanical Engineering of Szent István University has made significant efforts to create the "LOW-CARBON" economy and for the use of renewable energies already from the middle of 1980s. The present article summarizes the works connected to the wind and geothermal energies.
- The wind and the geothermal energies are very popular all over the world. The use of wind has stopped dead in Hungary in spite of that a considerable investors' interest and intent can be observed.
- About the towns and in certain agricultural plants and farms, the use of geothermal energy is significant and a further development is expectable due to the advantageous geological conditions in Hungary.
- It is improbable that Hungary will perform the ambitious plan of renewable energy use (14.65 % in the year 2020) without a more considerable utilization of the wind, the solar and the geothermal energy than that of the present ratio.

Keywords': research of wind and the geothermal energies,

About wind energy

The development of the utilization of wind energy, on an industrial scale, started practically in the years 1990s in Europe and in the United States. While in 1997 only a capacity of 60 to 80 MW was active, in these days an electric-power capacity of 240,000 MW is available all over the world and the forecast to 2020 is 1,500,000 MW. (The previous forecasts have proved under-estimated for all periods.) The turbines have changed a lot as well in spite of that they kept the original form but the horizontal-shaft three-blade model has remained the most successful design. Today the 2-MW-power wind turbines are erected in the greatest number however the serial manufacture of the 6 to 8-MW models has started as well. In addition, in China, already 10 and 12-MW pilot plants too were put in operation. A unit of 15 MW power will be erected in 2013 in the United States (Figure 1). Instead of the dense "forest like" wind farms, already – less frightening – sparsely erected plants will appear in the future (Figure 1).

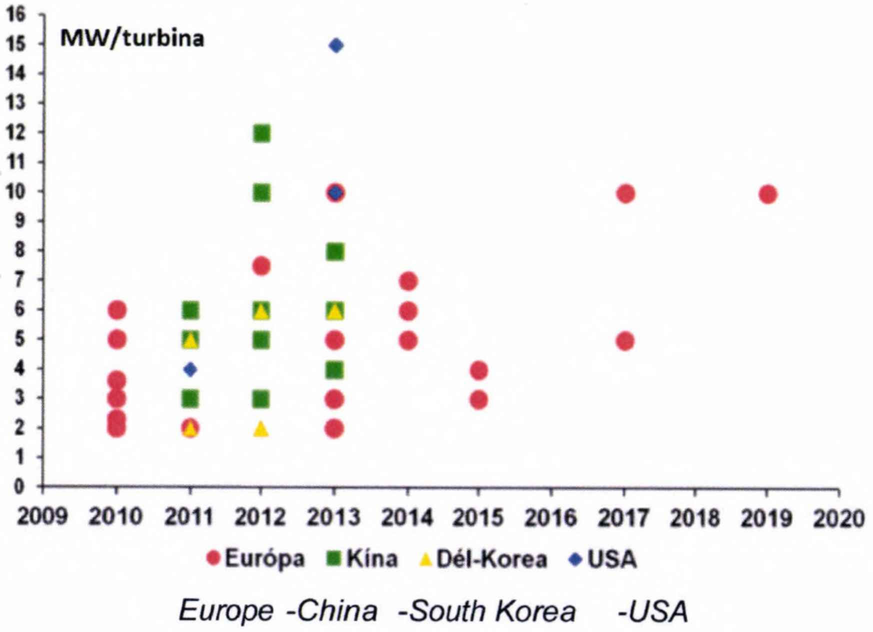


Figure 1. The expectable development trend

Energetic wind measurement

The Szent István University began to deal with wind energetic measurements in the 90s, and established the Hungarian Wind Energy Scientific Association (Magyar Szélenergia Tudományos Egyesület) for this purpose which is active at present as well. The Association carried out so-called energetic wind measurement differing from the meteorological tests in the Hungarian regions Komárom and Kisalföld. It was proved that these areas can be suitable for the erection of wind power stations or wind parks. In the following test, the group carried out measurements in the region Kulcs – about 10 km to the north from Dunaújváros – with such topographic conditions where an advantageous wind course can be expected (Figure 2). The results gained in this area of especially advantageous relief were similar to those of the region Kisalföld. After a one-year measurement series and the feasibility study the first wind power plant of 600-kW capacity connected to the main was erected with the collaboration of E-ON. Before this a 270-kW wind turbine at Várpalota which was erected by the TRANSELEKTRO. In the case of this plant, the Faculty of Mechanical Engineering of Szent István University carried out the type tests according to the European standards, and proved that the station provides the energetic values according to the rated performance.

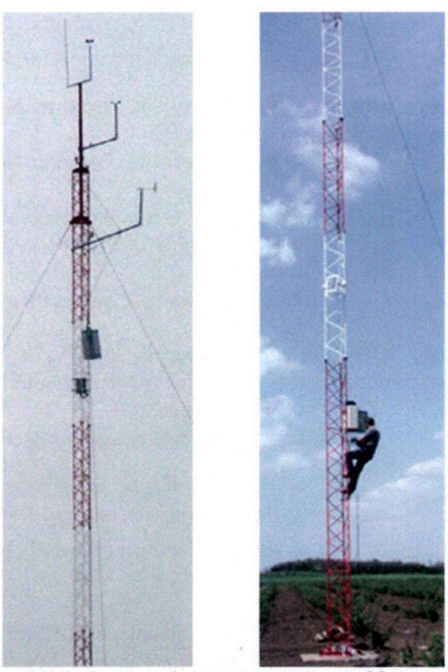
The first Hungarian wind turbine connected to the main (Kulcs 2002)

24-MW wind farm; btw. 2007 and 2009 Kisalföld

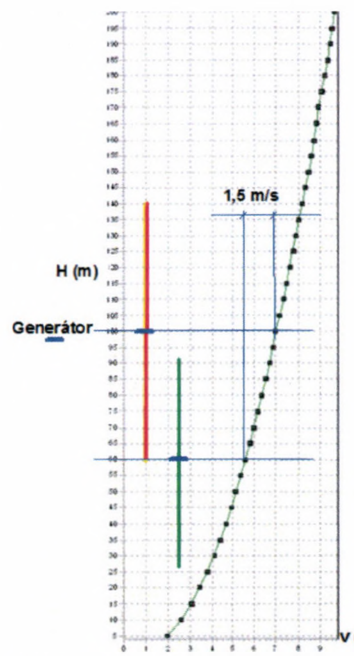
Figure 2. Wind power plants in Hungary

Wind measurement experiences

Having these experiences, the Faculty started improving different facilities such as erecting or siting stable as well as transportable wind measuring masts; these served expressly for energetic-purpose wind measurements. By these, the measurements were carried out above the height of 40 m, usually at least at two positions above each other in order to determine the exponential wind profile valid from the ground surface (Figure 3b). At the beginning the test data processing were carried out by the traditional methods but, considering that six or seven hundred thousand pieces of data had gained during each of the one-year measurements, later on software solutions were bought from Denmark (WindPro and VASP). These facilitated that energetic-purpose wind tests could be carried out on about forty sites in Hungary in the frame of the first SZÉCHENYI PLAN.



a) Wind measuring mast – upper and lower section



b) Vertical wind profile plotted against mast height

Figure 3. Measuring device and result

In co-operation of the OMSZ (National Meteorological Service), the University of Debrecen and the SZIU, the wind map of Hungary which serves the best the preliminary selection of wind farms even now was completed. The bought software pieces allowed carrying out different model calculations as well. Amongst others, we analysed the interaction of the turbines in the wind farms, the economic design of the electric power network, determining the distance of the so-called flicker effect of the wind mills, the propagation of noise and the construction of noise maps etc.

Development trend in Hungary – characteristics of development

The first plant was put in service in December 2001 in Várpalota. Up to the end of the year 2010 a capacity of 329.6 MW was installed (Figure 4). In 2009 a call for tenders on a capacity of 410 MW had been was planned but the announcement was failed thereby no wind power plant is being constructed at present. Expectably, it will be possible to erect again wind farms or higher-capacity turbines only in 2015 if the call for tenders was advertised in 2013 considering that, from the call, at least one year and a half is required for putting the plant connected to the main in service.

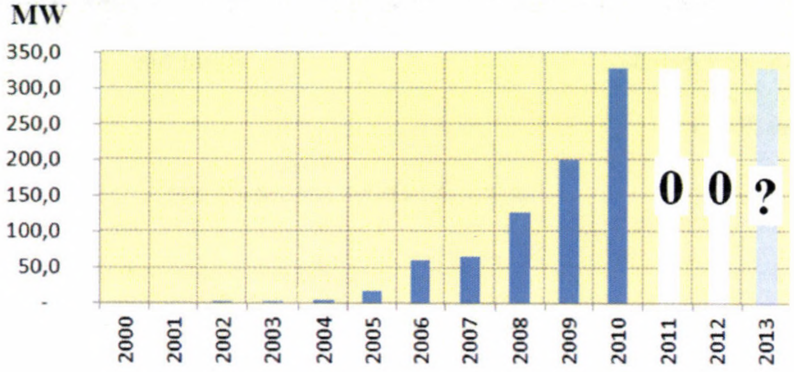


Figure 4. Development of the wind power capacity in Hungary

According to the suggestions based on the results of the Hungarian measurements, the most modern wind turbines will be imported. As another result of the tests, it was established that, taking the topographic conditions and surface frictions into consideration, the erection of wind power plants with 90 to 110-m tower height is expedient in Hungary. The degree of friction is considerable at lower heights and the power-yield potential is much lower. It is true of the plane area in Hungary as well but there the effective height must be increased because of the windbreak shelter-belts.

For checking the measurement results, the SZIU built a self-designed wind tunnel. After the tests the dismounted anemometers were re-calibrated in this tunnel and the measured results could be fully accepted if the measured values corresponded to the certificates provided by the TÜV (Technical Inspection Association). For the qualification of wind power stations, the professional terminology introduced the utilization factor according which the (sites) can be compared.

The expectable 620 to 625 GWh/year planned with the capacity of 330 MW[1] in Hungary proved to be 615 GWh/year (MAVIR (Hungarian Independent Transmission Operator Company) data, 2012). The country-wide average capacity utilization factor (Kf) is 21.2 %; it includes the putting in operation and the stopping cases as well. Even a value of 23 to 25 % was indicated for certain wind farms in accordance with the data of the earlier issued wind map.

The relationship of the theoretical maximum performance of the wind power turbine is –

$$P_{max} \cong \frac{16}{27} \cdot \frac{1}{2} \cdot A \cdot \rho \cdot v^3 \quad [W]$$

where $Pmax$ = theoretical maximum electric power of the wind turbine (W)
A = area swept by the rotor blades of wind turbine ($D2\pi/4$) (m^2)
ρ = density of air in the actual state (kg/m^3)
v = air velocity in the operating range (usually 3.5-25m/s)
16/27 = Betz's maximum efficiency factor.

The effective power is lower due to the aerodynamic, mechanical and electric efficiencies but the self-consumption of the system decreases it as well.

Accordingly, the annual energy production is –

$$E = k_f \cdot P_n \cdot 8760 \quad [W]$$

where k_f = capacity utilization factor
P_n = nominal power (generally lower by cca 10% than P_{max})

The cause of the advantageous Kf result is that the siting conditions were well considered and the fact that more modern

[1] The present wind power capacity (330MW) substitutes for an annual amount of natural gas of about 200 million m^3 and at the same time the emission of cca 400,000 tons CO_2 can be avoided (these mean import gas of approximately 14 milliard HUF value and CO_2 of 1.0-1.8 milliard HUF value).

plants were erected in Hungary while in Germany – where less modern plants were sited in the years 90s – the value of Kf was only 17 to 18 %.

Due to the rapid development, the wind energy will be competitive already in the year 2018 or 2020 with the quoted prices of electric energy. This is the forecast of the EWEA (European Wind Energy Association) and the German electric supply companies as well. In spite of these, today the wind energy still requires certain subvention – but only the produced energy without erection investment and only for 6 to 8 years until the invested capital and its interests will be recovered. The life of the plants is 25 to 30 years accordingly they supply essentially cheaper energy than that of the power stations using fossil fuel. Only the repair-and-maintenance costs determine the price of energy.

Education – energy policy

The learning of wind energy in the form of a facultative subject was introduced in the curriculum of the Szent István University. Taking the increased interest of students as well as the expectable progression of renewable resources into consideration, the Faculty established a specialized energetic engineering course. In the frame of that, besides the general energetic knowledge, the students learn chiefly the utilization of renewable energies, the establishment of systems and the adjunct engineering equipment. With the help of the researches, three PhD dissertations, several diploma pieces and TDK (Student Scientific Society) essays could be completed.

The teachers of the Faculty attended several energy policy forums e.g. on the preparation of the VET (Electric Energy Law) of year 2005 in connection with the wind energy. In the same year a call for tender was advertised for a 330-MW wind-power-plant capacity. Later the power stations were practically erected in those areas where our wind measurements carried out in the earlier years proved the economical siting of wind turbines. We collaborated in the preparation of the National Action Plan in the latter years, and assisted the elaboration of the National Renewable Energy Programme.

According to the forecast prepared at the Faculty, the electric energy production from renewables rated in the National Action Plan by 2020 can be performed only in the case if the present wind energy capacity of 330 MW will be improved to minimum 1000 MW. Theoretically, this can be achieved in the period between 2014 and 2020.

Geothermal energy

The research of heat pumping of geothermal energy requires first of all the investigations on the top 100-m ground layer. For the determination of the withdrawable heat or the heat reflow into the ground during cooling, the heat conductivity of the top soil layer should be known and it was the goal of our research. The values of this thermal conductivity were determined by the so-called TRT (Thermal Response Test) system. The test is especially important with large systems where 50 to 100 or 200 probes are planned to be placed. In this case, the question is the necessary distance between the probes at which the probes do not influence each other during either heat pumping or heat absorption (i.e. cooling).

In the course of the measurement, the temperatures of the outgoing and the return branches were recorded, respectively. Before the start of the probe tests, the rest state was recorded. As an example, the temperature data recorded along a single 100-m long probe can be seen in Figure 5. The measured temperature values changed between 6.03 and 17.78 °C.

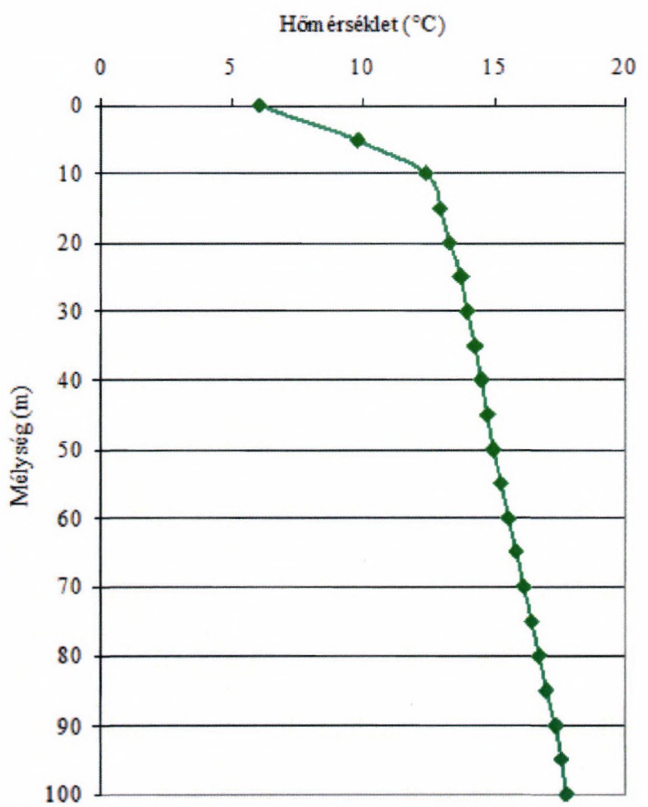


Figure 5. Depth (m) - Temperature (°C)
The undisturbed temperature as a function of the depth (Rest state – TESCO, Pesti út)

The second research project deals with the traditional horticultural utilization of the thermal energy – the pumping-out of the geothermal fluid and the energetics of the injection-back. In terms of the sustainability, the solution of the latter will be one the most important problems in the next period. The injection-back is an essential element since the water reserve is limited and exhaustible and, by an unreasonable use, a very important energetic resource (but later the water reserve itself as well) can be damaged.

In connection with our third research area, we carried out complete energetic measurements with domestic-type heat pump systems. In the present conditions, the use of heat pumps in households can be economical if their floor area exceeds 150 m2 but it is important here again that the system should include both the heat pumping (i.e. the heating) and the cooling as well. It is a general experience that in the summer season a reasonable amount of heat energy is stored in the ground in the case of cooling which can be available at a higher efficiency level in the autumn and early winter heating period. In large-scale systems with vertical closed probe (BHE Bore-Hole Heat Exchanger) solutions during the preparation works (before the final design), the basic condition of the planning model creation and the sustainability is the performance and the evaluation of the geophysical depth thermal test (TRT Thermal Response Test). With the help of the TRT testing (which can also be considered as a scientific approach), the expectable technical parameters can be estimated at a good confidence level. The operating systems planned in this way performed the expected parameter values according to the experiences.

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ALGAE UTILIZATION FOR LOW-CARBON ENERGY PRODUCTION

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Abstract

For each kilogram of microalgae, 1.65-1.83 kg of CO_2 is required based on mass balance. Microalgae contains high amount of protein (45- 70%), carbohydrates (33-64%) and lipids (16-40%) on dry basis. The net annual harvest of algal biomass cultivated in subtropical areas can be as high as 40 tons ha-1. Bioethanol is usually produced of organic based matter with high contents of sugars fermented by enzymes produced from yeast. Distillation and dehydration are used as the last steps for reaching the desired concentration (hydrated or anhydrous ethanol) that can be blended with fossil fuels or directly used as fuel. The main problem of digesting microalgae biomass without pre-treatment is the resistance of their cell wall. It can be concluded that algae are good feedstock for the production of biofuels based on their efficient production of starch, sugars and oils.

Keywords

algae, energy production, utilization, biofuel, low-carbon

1. Introduction

The global energy demand keeps rising dramatically since the beginning of the industrial revolution in the late 18th century. Algae have got a number of potential advantages compared to higher plants because of faster growth rates and the possibility of cultivation on non-arable land areas or in lakes or ocean, therefore attenuating food and feed competition (Stephens et al., 2010). A promising approach therefore seems to be the use of fast growing algae species for anaerobic fermentation to produce biogas, which then can substitute natural gas resources. Research on anaerobic fermentation of algae biomass goes back to more than 50 years. Species under investigation included several macroalgae such as Macrocystis, Gracilaria, Hypnea, Ulva, Laminaria and Sargassum. In contrast to higher plants and macroalgae, some microalgae like the green micro alga Chlamydomonas reinhardtii have the remarkable ability to produce hydrogen off water via hydrolysis due to illumination , which represents an additional environmentally friendly gaseous fuel. In the context of bioenergy production with microalgae it has been suggested that residual algal biomass should be converted into biogas via anaerobic fermentation (De Schamphelaire and Verstraete, 2009). Marine algae consist of polysaccharides (alginate, laminaran and mannitol), with zero lignin and low cellulose content, which make them easily convertible to methane by anaerobic digestion processes (Vergara-Fernandez et al., 2008). Only few works have evaluated the marine algae conversion by anaerobic biodigestion to methane production. The first studies evaluated algae species as Macrosystis pyrifera, Tetraselmis, Gracilaria tikvahiae, Hypnea and Ulva; these studies, in general, conclude that marine algae are good feedstock for the anaerobic digestion process, due to their high conversion rates and efficiencies obtained (Bird et al., 1981,Bird and Ryther, 1985,Fannin et al., 1983).

2. Microalgae classification

The term algae refers to both macroalgae and microalgae. Macroalgae are algae which form a multi cellular thallus, i.e. seaweeds (Richmond, 2004; Andersen, 2005). Microalgae, as the name suggests, are microscopic algae as well as oxygenic photosynthetic bacteria such as cyanobacteria which grow in salt or fresh water (Richmond, 2004). Microalgae are classified as diatoms (bacillariophyceae), green algae (chlorophyceae), golden-brown (chrysophyceae)and blue-green algae (cyanophyceae) (Rengel, 2008) . Microalgae are untapped resource with more than 25,000 species of which only 15 are in use (Raja et al., 2008), (Benemann, 2009). Total world commercial micro algal biomass production is about 10,000 tons per year.

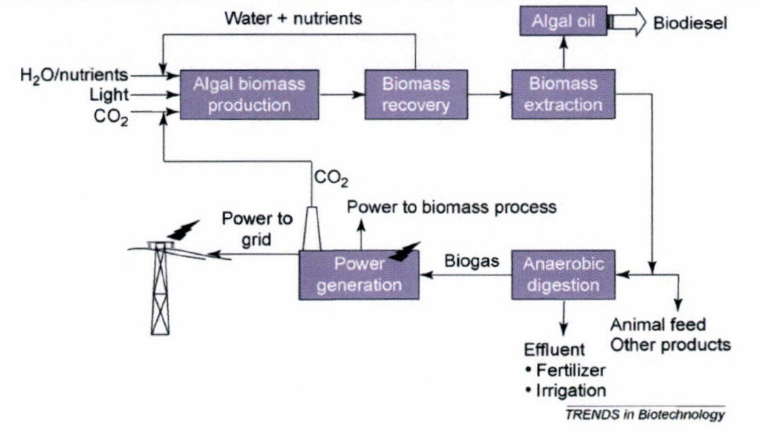

Figure 1. A conceptual process for producing micro-algal oil for biodiesel.

3. Algae growth requirements and productivity

Algae can be grown on saline/coastal seawater and on non-crop lands(desert ,arid and semi-arid land), resources for which there are no competing demands (Huntley and Redalje, 2007) . They also found that the combination of photoreactor and open pond cultivation has proved efficient for astaxanthin production. For each kilogram of microalgae, at least 1.65 kg of CO_2 is required based on a mass balance (Berg-Nilsen, 2006). A two-step cultivation process has been developed that involves a combination of raceway and photobioreactor designs. The first step is the fast cultivation of biomass in the PBR and the second step is stress cultivation in open ponds. A photoreactor first step allows good protection of the growing biomass during early stages by maximizing the CO_2 capture. After that the microalgae suspension is transferred to open ponds with low nitrogen nutrients and maintaining high CO_2 levels. The open raceway in the second step has some problems because lower density of algal biomass is less resistant to external contamination (Bruton et al., 2009). A conceptual process for producing micro-algal oils for making biodiesel is shown in (Fig. 1). The process consists of the micro- algal biomass production step that requires water, inorganic nutrients, carbon dioxide and light. In the biomass-recovery stage, the cells suspended in the broth are separated from the water and residual nutrients, which are then recycled to the biomass-production stage. The recovered biomass is used for extracting the algal oil that is further converted to biodiesel in a separate process. Some of the spent biomass can be used as animal feed and for recovering other possible high value products that might be present in the biomass.

Sea water supplemented with commercial nitrate and phosphate fertilizers, and a few other micronutrients, is commonly used for growing marine microalgae. As with terrestrial plants, the partial pressure of CO_2 in air is not high enough to exclude carbon limitation. An optimum value for algae is in the range of 0.1 kPa to avoid kinetic limitation. That means that air with more than 1% CO_2 has to be provided. Accordingly, algae plants should be built close to CO_2 sources, otherwise CO_2 transport may be a problem. Also like terrestrial plants, microalgae need nitrogen and phosphorus to build up biomass. Mass fraction of N is in the range of 0.1 up to 0.14. The advantage in closed photobioreactors is the possibility to apply only the necessary stoichiometric amounts without losing fertilizer into the environment. Furthermore, outgassing of N_2O into the atmosphere can be avoided (Posten and Schaub, 2009). Potential pathways from microalgae to fuels are shown in (Fig 2). Like higher plants, algae produce storage lipids in the form of TAGs (Triacylglycerols. The maximum theoretical algae biomass productivities (at 8–10% photosynthetic conversion efficiency) are estimated to be in the order of 77–96 g of dry matter (DM) per square meter per day (280–350 ton DM ha^{-1} a^{-1}) while reasonable target productions are projected as in the order of 27–62 g DM m-2 d-1 (100–227 ton DM ha^{-1} a^{-1}) (Stephens et al., 2010). In practice however, productivities are lower than projected. In raceway ponds, which is the mass culture system most commonly used for commercial applications, the peak productivities can range from 12–40 g DM m^{-2} d^{-1} (44–146 ton DM ha-1 a-1) and a well-managed pond might only achieve average productivities between 19–25 g DM m^{-2} d^{-1} (70–90 ton DM ha^{-1} a^{-1}) (Richmond, 2004;). Considering a water depth of 20 cm, a value of about 100 g DM m^{-3} mixed liquid d^{-1} is a fair number to keep in mind.

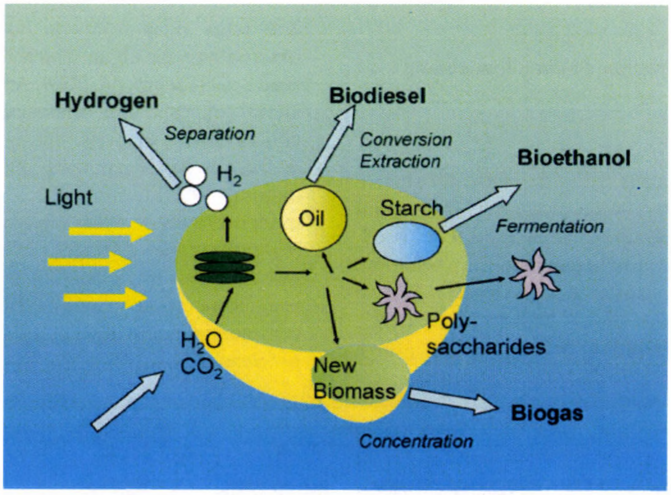

Figure 2. Potential pathways from microalgae to fuels .

Compared to closed photobioreactors, open pond is the cheaper method of large-scale algal biomass production. Open pond production does not necessarily compete for land with existing agricultural crops, since they can be implemented in areas with marginal crop production potential.

4. Comparison between algae and terrestrial plants

High oil content algae species could produce oil as much as 100 times of soybean on a same size land. Contrary to the fast growing and uniform composition of microalgae which can complete one life cycle every few days, plant and animal origin biomass suffer several limitations such as slow growing rate, relatively low oil contents, limited production capacity, high cost, etc. Microalgae are some of the most robust organisms on earth, able to grow in a wide range of conditions and produce more oxygen than all the plants on the earth. They are at the bottom of the food chain with many living beings depending upon them. After the vegetable oil is squeezed out of algae for biodiesel production, the dried remnant can be further processed to produce ethanol and other forms of energy and materials. Unlike the other lignocelluloses feedstock, microalgae contains high amount of protein (45- 70%), carbohydrates (33-64%) and lipids (16-40%) on dry basis, suggesting the need for investigation of its conversion into biofuels. Thermochemical liquefaction has been investigated for producing liquid fuels from a wide range of wet lignocelluloses feedstock . Ideally for efficient oil production algae should be able to accumulate more than 30% of their cell weights in oils. The micro-algal cells are tiny fuel factories and more significantly they manufacture those compounds naturally, which are chemically similar to petroleum-based fuels. These algal cells not only synthesize and store these useful oils , they can also crank them out. According to U.S. Department of Energy (USDOE) microalgae have been identified to have the potential to synthesize 100 times more oil per acre of land than any other plant (Nikolic et al., 2009). The advantages of using microalgae-derived biofuels are: 1.: microalgae are capable of all year round production, therefore, oil productivity of microalgae cultures exceeds the yield of the best oilseed crops, e.g. biodiesel yield of 12,000 l ha-1 for microalgae (open pond production) compared with 1190 l ha-1 for rapeseed, 2.: they grow in aqueous media, but need less water than terrestrial crops therefore reducing the load on freshwater sources (Dismukes et al.,2008) , 3.: microalgae can be cultivated in brackish water on non-arable land, and therefore may not incur land-use change, minimizing associated environmental impacts (Searchinger et al., 2008) , while not compromising the production of food, fodder and other products derived from crops, 4.: microalgae have a rapid growth potential and many species have oil content in the range of 20–50% dry weight of biomass, the exponential growth rates can double their biomass in periods as short as 3.5 h (Spolaore et al., 2006) , 5.: with respect to air quality maintenance and improvement, microalgae biomass production can effect biofixation of waste CO_2 (1 kg of dry algal biomass utilize about 1.83 kg of CO_2), 6.: apart from providing growth medium, there is the potential for treatment of organic effluent from the agri-food industry as nutrients for microalgae cultivation (especially nitrogen and phosphorus) (Cantrell et al., 2008), 7.: algae cultivation does not require herbicides or pesticides application (Rodolfi et al .,2009), 8.: they can also produce valuable co-products such as proteins and residual biomass after oil extraction, which may be used as feed or fertilizer (Spolaore et al., 2006) , or fermented to produce ethanol or methane, 9.: the biochemical composition of the algal biomass can be modulated by varying growth conditions, therefore, the oil yield may be significantly enhanced (Qin, 2005) , 10.: microalgae are capable of photobiological production of 'biohydrogen', 11.: biofuels generated from microalgal lipids have less emissions and contaminants as compared to petroleum based fuels therefore reduced greenhouse gas emissions, 12.: algae biofuel contains no sulfur, is non-toxic and highly biodegradable .The outlined combination of potential biofuel production is CO_2 fixation and biohydrogen production.

They have much higher growth rates and productivity when compared to conventional forestry, agricultural crops, and other aquatic plants, requiring much less land area than other biodiesel feedstocks of agricultural origin, up to 49 or 132 times less when compared to rapeseed or soybean crops, for a 30% (w/w) of oil content in algae biomass (Mata et al., 2010) . Considerable research and development is also being done on microalgae which are regarded as more photo synthetically efficient than terrestrial plants and as a consequence are more efficient CO_2 fixers (Liu and Ma, 2009) . This ability of algae to fix CO_2 has been proposed as a method of removing CO_2 from flue gases from power plants, thereby reducing the Greenhouse Gas (GHG) emissions.

Agricultural oil crops, such as soybean and oil palm, are widely being used to produce biodiesel; however, they produce oils in amounts that are miniscule (e.g. less than 5% of total biomass basis) compared with microalgae. Oil palm, for example, one of the most productive oil crops, yields only 5950 liters of oil per hectare, biodiesel yield from a parent vegetable oil is 80% of the oil yield per hectare. No other potential sources of biodiesel come close to microalgae in being realistic production biodiesel for vehicles.

5. The anaerobic biodegradation of algae

The anaerobic biodegradation of marine algae is carried out by three groups of bacteria (Leschine ,1995), 1.: hydrolytic and fermentative bacteria, which hydrolyze polymers, and ferment the resulting monosaccharide to carboxylic acids and alcohols; 2.: acetogenic bacteria, which convert these acids and alcohols to acetate, hydrogen and carbon dioxide; and 3.: methanogenic bacteria, which convert the end products of acetogenic reactions to methane and carbon dioxide. The energy content of biogas produced through anaerobic digestion is 16,200–30,600 kJ m-3 depending on the nature of the source of biomass. Several bacteria act during the anaerobic process, which initially involves hydrolytic bacteria (mainly cellulolytic and proteolytic) for the degradation of raw material, the acidogenic bacteria, hydrogenated and sulfate-reducers. Organic acids, gases, salts and oxidized organic matter (among others) are formed from these microorganisms. In a final stage, the methanogenic bacteria form methane, CO_2 and reduced organic compounds (Cooney et al., 2007). The anaerobic digestion (AD) process occurs in three sequential stages of hydrolysis, fermentation and methanogens. In hydrolysis the complex compounds are broken down into soluble sugars. Then, fermentative bacteria convert these into alcohols, acetic acid, volatile fatty acids (VFAs), and a gas containing H_2 and CO_2, which is metabolized into primarily CH_4 and CO_2 by methanogens (Cantrell et al., 2008) . Whole algae or algal oil extracts can be converted into different fuel forms, such as biogas, liquid and gaseous transportation fuel, kerosene, ethanol, aviation fuel, and biohydrogen through the implementation of processing technologies such as anaerobic digestion, pyrolysis, gasification, catalytic cracking, and enzymatic or chemical trans esterification.

Algae have high photon conversion efficiencies and can synthesize and accumulate large quantities of neutral lipids (biodiesel) and carbohydrates (bioethanol) along with other valuable coproducts (astaxanthin andomega-3fattyacids), from abundant and inexpensive raw materials (sunlight, CO_2, and inorganic nutrients). Methane from anaerobic digestion can be used as fuel gas and also be converted to generate electricity (Holm-Nielsen et al., 2009). Potential algal biomass conversion processes are shown in (Fig. 3). The process flow schematic for biodiesel production is shown in (Fig. 4).

6. Factors affecting algae biodegradation

According to the substrate used, optimal conditions are defined for biogas production, such as temperature from 30.0 to 35.0 °C, pH 6.8–7.5, a C/N ratio from 20 to 30, total solids from 7.0% to 9.0%, and time of 20–40 days. After digestion, the sludge can be used as a biofertilizer, incinerated or used in animal feed. The biogas production from this anaerobic digestion process is primarily affected by its organic loadings, temperatures, pH and retention time in reactors. Basically, long solid retention time and high organic loading rate give significant results in high methane yield . In addition, anaerobic digestion can operate in either mesophilic (35°C) or thermophilic (55°C) conditions.

Different researchers have pointed out that the main problem of digesting microalgae biomass without pretreatment is the resistance of the cell wall of the algae, even though the cell itself may no longer be living (Sialve et al., 2009). Thus, it seems that anaerobic microorganisms in conventional bio-methanation reactors do not have sufficient time to hydrolyze the lipids and the algal cell wall. The positive aspect of the digestibility of microalgae is the fact that the biogas has a high energy content i.e. over 60% methane (De Schamphelaire and Verstraete, 2009, Sialve et al., 2009). In addition, the biogas does normally not contain sulfur which causes corrosion in engine generators (Sialve et al., 2009). Finally, the potential enrichment of the biogas by using algae to remove CO_2 from the biogas seems to be plausible (Converti et al., 2009, Sialve et al., 2009).

7. Biochemical composition of algae

The gross chemical composition of microalgae is highly dependent on environmental factors such as light intensity, temperature and nutrients availability (Becker, 1994, Rodolfi et al., 2009). Generally, microalgae contain varying proportions of proteins, lipids, carbohydrates, nucleic acids, pigments and vitamins (Becker, 1994). Proteins and lipids are found in higher quantities, i.e. proteins ranging 10–60% DM and lipids within the range of 2% up to 90% DM (Becker, 1994, Spolaore et al., 2006). Carbohydrates in microalgae in the form of starch, glucose, sugars and other polysaccharides are present in concentrations ranging from 5% to 50% DM (Spolaore et al., 2006). In addition, microalgae contain highly valuable substances such as pigments, long-chain polyunsaturated fatty acids (LC-PUFAs), such as eicosapentaenoic (EPA) and decosahexaenoic (DHA) and vitamins such as A, B1, B2, B6, B12, C, E, nicotinate, biotin, folic acid and pantothenic acid (Becker, 1994, Spolaore et al., 2006).

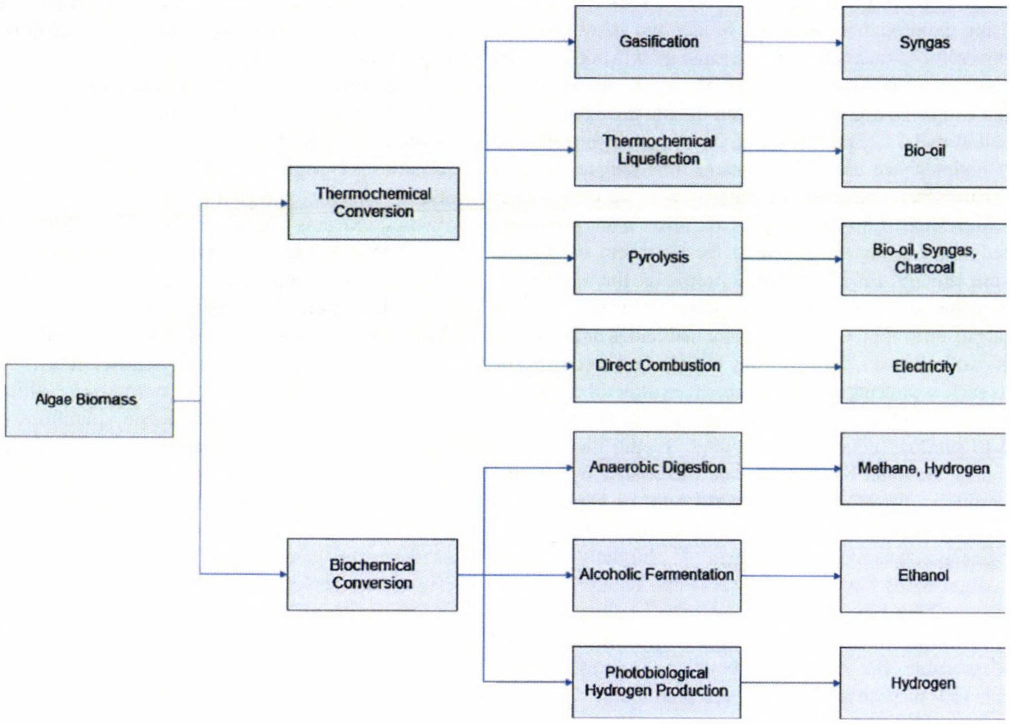

Figure 3. Potential algal biomass conversion processes.

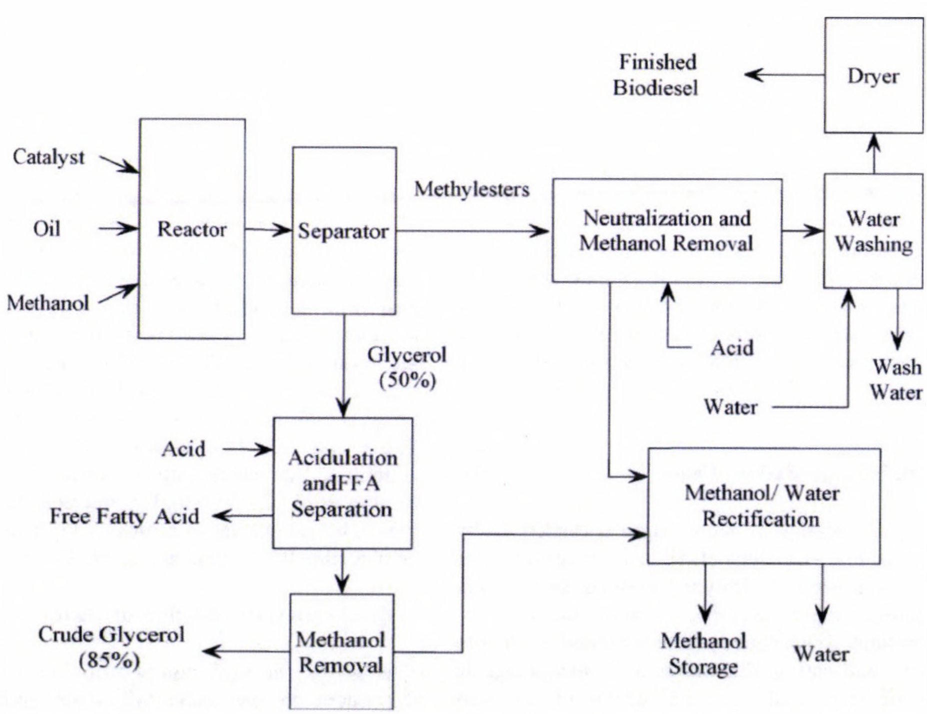

Figure 4. Process flow schematic for biodiesel production.

8. Conclusion

Microalgal biomass production requires water, inorganic nutrients, carbon dioxide and light. Microalgae contain lipids and fatty acids as membrane components, they can be grown on saline/coastal seawater and on non-crop lands(desert ,arid and semi-arid land), resources for which there are no competing demands. Horizontal tubular photobioreactors (PBRs) is not economically feasible due to negative NER values. The biofuels generated from microalgal lipids by anaerobic biodegradation of algae have less emissions and contaminants as compared to petroleum based fuels therefore reduced greenhouse gas emissions. Recovery of micro-algal biomass from the broth is necessary for extracting the oil.

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REFERENCE SYSTEM BASED PERFORMANCE EXAMINATION OF PV POWER PLANT

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Introduction

Our most significant renewable energy potential is the solar energy, the directly or indirectly usage of this is the basis of life. Al over the world they are strong attention today by the solar engineering and the connected researching areas. The ages of the low cost and high density energy sources will end in this century. This fundamental change also is reached by our answers of the global environmental problems, but today the intensive level of technological development is able to establish.

The current state of knowledge seems in Hungary that the best way of electricity production from solar energy is the photovoltaic energy technology. A study by the Hungarian Academy of Science shows the installation potential of PV systems in Hungary 4051.48 km2 area, which is means close to 484 974 GWh/a solar renewable electricity production potential (MTA, 2006).

In the top of the houses by the residential sector and the institutional buildings could be installed around 2500 MWP photovoltaic small power plans and these could produce about 2 846 GWh/a electricity. The technological potential at this level currently seems unattainable, but for example after 2021 by a European Union obligation as building renovations or new construction will have to reach the level of close to zero-energy buildings and the active solar energy equipments are essential part of these types of buildings.

The solar vision for the future must therefore prepare in Hungary too, where the "aggregators" will organize some smart producer and consumer groups with the small building integrated solar power plans. So these plans will be the huge elements of the electricity production structure, therefore the size of the installed solar electricity capacity and the capacity of the current domestic nuclear power plant (2000 MW) may be comparable.

The production of electricity from solar energy by a number of methods is known. The controllability and/or the possibility of the real-time forecasting of the energy production mean a growing importance by the technology evaluations.

The EPIA (European Photovoltaic Industry Association) examines the errors of the forecasting methods how it depends on the locations or the size of the systems. The inaccuracies of the forecasting cause more difficulty by the stabile and cost-effective operation of the electric grid. The size of the typical errors shows in the Figure 1. (EPIA, 2012).

The problems could be treatable technologically, but usually only with substantial additional costs (for example through the batteries, or purchasing reserve electricity). So eventually the restrictions of the establishing of the photovoltaic systems may be similar to that for wind energy

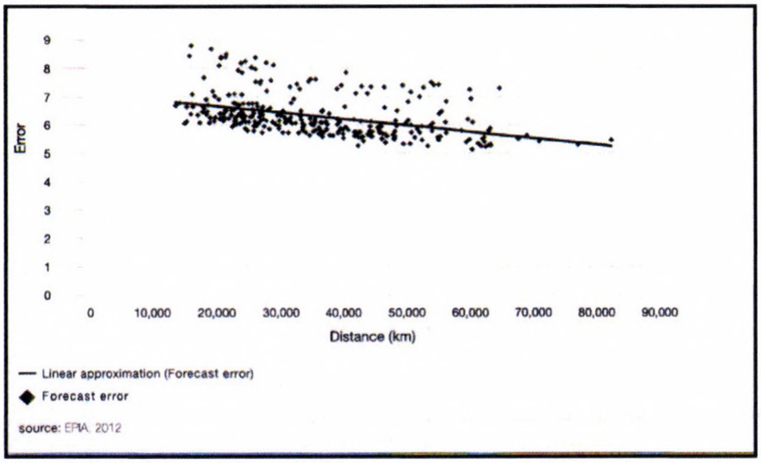

Figure 1. Forecasts errors example of the production of a PV portfolio (%).

The actually PhD research at the Szent István University in Gödöllő trying establish a real-time forecasting method with a new approach. The system can be suitable for the rapid and accurate prediction of the electricity production of some PV portfolios (which systems consist of many small PV power plants in top of the houses).

Methods of Evaluation

The comparison of different methods for sizing charts the Table 1 gives a good summary. It can be seen that a better approximation with numerical methods are available (Mellit et al, 2007).

Table 1. Various sizing models and test methods

Sizing methods	Typical relative errors	
Analytical	% (A_{PV})	% (C_U)
	9,1	2
Numerical	% (A_{PV})	% (C_U)
	8,3	1,2
Hybrid	% (A_{PV})	-
	7,14	
Special (Mellit) methods	% (A_{PV})	% (C_U)
	8,5	2,5

By the sizing and modeling of the photovoltaic systems the analytical models were the dominant software's for a long time. These are based on theoretical physical models and the limits of accuracy for today is already practically reached by them, The analytical formulas to solve, a large quantity of data to be provided to ensure an unrealistic expectation of the portfolios in the PV systems

The new model is only based on detailed investigation of a reference PV power plant. The reference error is the difference between the analytically modeled and measured production. This error is based on mainly the same physical effects, so the measured error. The measured errors are spreading, and these effects are could be similar by other PV systems. So this spreading of errors can be very useful if we will be able to modeling the directions and speeds.

This spreading can be difficult to describe analytically, but the necessary data would not be able to measure. However, some good approximations can be with numeric programming.

The method is thus:

- a database for future expected energy production;
- a specific measurement (by the reference PV station), which is based on the deviation as an error is determined;
- the numerical model structure, model training and testing

The definition of the errors

The error measurement is based on an examination of the difference between the actually measured and the expected (modeled) average power production. The actual mathematical error measurement and explicit formula for determining the appropriate required. The main aspects are as follows:

- to be relative numbers because of different rating systems in comparison with the performance goal
- to be a relative value, and whose denominator and the ratio values characterized by transparency the different conditions of the periods of the year and the different systems.

The equivalent peak load hour (Sharma, Tiwari, 2011) in a given time shows a value kind of performance. Thus, the actual performance of the system could be illustrated in relation to utilization. In the energetic the peak load hour is related to a time period and the energy production, but the equivalent peak load hour is characterized by energy-generating operating capacity in a given moment.

By sizing a PV system is the equivalent peak load hour defined as follows:

$$h_{ekv} = \frac{\zeta_{real}}{I_P} \qquad 1$$

Where hekv is the equivalent peak load hour, in h, Vreal is total specific amount of solar electricity in kWh/m^2, IP is current value of the global radiation intensity during in kW/m^2.

The model used for the relative error factor can be written as follows:

$$f = \frac{\left(h_{ekv} - h^*_{ekv}\right)}{h_{ekv}} \qquad 2$$

Where h_{ekv} is the analytically expected equivalent peak load hour, and h_{*ekv} is the measured expected equivalent peak load hour.

Neural network predictive modeling

The reference PV system must be located in right direction and distance from the PV portfolio so that the weather fronts typically one or two days to reach the region where the PV portfolio is operating. The numerical model for the PV portfolio with similar type of photovoltaic systems could reasonable accuracy. The outputs of model are the expected (predicted) values of the error factors. The meteorological conditions' nature (the weather front migration speed, direction) indicates the neural network requirements. The model system structure is shown in the Figure 2.

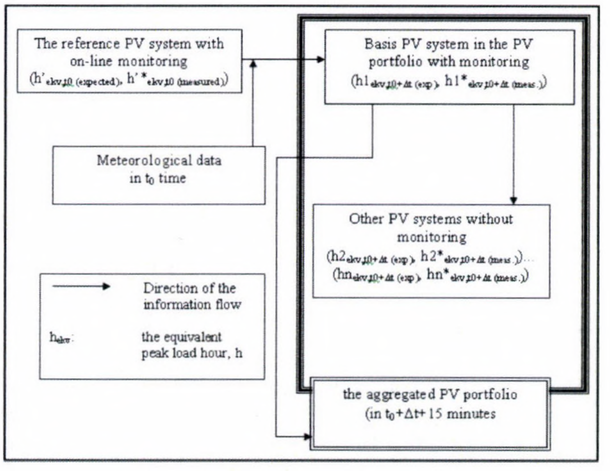

Figure 2. On-line scheduling flowchart.

The figure shows that the reference PV power plant and a one power plant in portfolios (bases PV systems) with on-line monitoring system may be suitable for the entire portfolio to a specific timetable.

The results of the measurements from monitoring systems are shown by Table 2 and Table 3.

Table 2. Reference system data table

t'_0	Δt	$h_{ekv,t0}$ (expected)	$h'^*_{ekv,t0}$ (measured)	f'_{t0}
t'_1	Δt	$h'_{ekv,t1}$	$h'^*_{ekv,t1}$	f_{t1}
t'_2	Δt	$h'_{ekv,t2}$	$h'^*_{ekv,t2}$	f_{t2}
t'_3	Δt	$h'_{ekv,t3}$	$h'^*_{ekv,t3}$	f_{t3}
...	...	...	...	...
t'_n	Δt	$h'_{ekv,tn}$	$h'^*_{ekv,tn}$	f_{tn}
...	...	...	...	...
t'_m	Δt	$h'_{ekv,tm}$	$h'^*_{ekv,tm}$	f_{tm}

Table 3. The basis system (in portfolio) data table

T_{0+k}	Δt	$h_{ekv,t0}$ (expected)	$h^*_{ekv,t0}$ (measured)	f_{t0}
T_{1+k}	Δt	$h_{ekv,t1+k}$	$h^*_{ekv,t1+k}$	f_{t1+k}
T_{2+k}	Δt	$h_{ekv,t2+k}$	$h^*_{ekv,t2+k}$	f_{t2+k}
T_{3+k}	Δt	$h_{ekv,t3+k}$	$h^*_{ekv,t03+k}$	f_{t3+k}
...	...	...	...	...
t_{n+k}	Δt	$h_{ekv,tn+k}$	$h^*_{ekv,t04+k}$	f_{tn+k}
...	...	...	...	...
t_{m+k}	Δt	$h_{ekv,tn+k}$	$h^*_{ekv,t04+k}$	f_{tn+k}

The neural network method is shown in Figure 3.

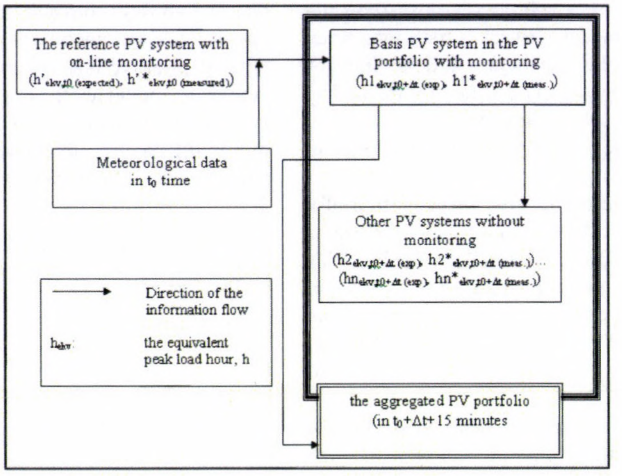

Figure 3. The neural network model block diagram.

Results and discussion

The research work aims the integration of autonomous or grid connected PV systems could be more safely and more cheaply, as presently possible. The obstacles to the spread of PV systems, which need for accurate 15-minute schedules, but the PV technology can not able to give these. The accurate knowledge of more several small systems' power production is not known for the system operators.

During the research, analyze and appreciate the opportunity to how can be produced information on the total average PV performances in a micro-region based on measurement and evaluation of a chosen reference photovoltaic system.

The research thesis is expected that the average performances of the systems can be modelled with reasonable accuracy with an on-line examination of a reference system.

Further expected result is the errors between the average performances according to analytical programs and the actual measurable values are able to make predictive forecasting.

The research with the new methods based on reference system could be long-term (day) forecast. The long-term forecasting using neural networks methods.

Conclusion

The forecast of electricity production of some PV portfolio with the knowledge of typical direction of weather fronts can be made more accurate.

This new method which only based on few pieces reference photovoltaic small power plans with on-line monitoring system and the analysis of errors could help to connect and integrate a large number of small PV systems to the grid,

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STATE OF THE ART IN THE HUNGARIAN FIELD RESEARCH: THE EFFECT OF TILLAGE ON CO_2 EMISSION

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Abstract

There are many methods used by researchers to measure CO_2 flux after different tillage tools and methods. Our research was made to measure the effect of different tillage methods on the CO_2 flux from soil and to evaluate the effect of conservation tillage tools on CO_2 emissions. Beside of these the research aim is to exactly determine the CO_2 emission savings of conservation tillage methods.

Our research has shown that the use of the environment-oriented, mulch -tillage methods can play a major role in reducing of greenhouse gas emissions by increasing the rate of organic matter oxidation.

Our objectives were to develop a reliable and method to measure the short, intermediate and seasonal effect of different tillage methods on the CO_2 flux after tillage.

Introduction

Carbon dioxide flux from soil is an important factor in the increasing of the concentration of greenhouse gases in the atmosphere. Any increase in soil carbon has important benefits for the sustainability and productivity of the agro ecosystem. CO_2 is one of the most important greenhouse gases, because increase in its concentration causes about 50% of the total radiative forcing (Rodhe, 1990).

Improved agricultural practices have great potential to increase carbon sequestration and decrease the net emission of carbon dioxide and other greenhouse gases, but available information has not been synthesized in a form that policy makers and land managers readily can use to mitigate CO_2 emissions in relation to the potential greenhouse effect.

Intensive agricultural production systems that include intensive tillage result in soil degradation and erosion that impacts soil, water, and air quality. The effects of conservation tillage and residue interactions on greenhouse gas fluxes and soil carbon should be evaluated. Soil scientists have studied the dynamic nature of soil carbon from an agronomic perspective, but not from an environmental context. Thus, more information is needed to advance the current understanding of how agricultural production systems can be modified to enhance environmental quality.

We need direct measurements to quantify CO_2 flux as affected by agricultural management practices. Information is needed on both the short-term effect of agricultural management decisions and the long-term effects, as they may affect global climate change. (Jori, 2004)

Limited measurements are available on CO_2 evolution immediately after tillage in the field. Gas fluxes were measured using closed chamber system. The atmosphere immediately above the soil surface is enclosed by the chamber and the change in concentration of CO_2 or N_2O one hour after closure is measured. This change is a result of net emission from the soil and enables gas flux to be determined, using both manual and automated closed chambers. (Jori et al., 2004) The manual chambers (Clayton et al., 1994.) were cylinders of diameter 0,4 m, pushed into the soil to a depth of 50 mm and with the head space enclosed with an aluminium lid. Gas samples were taken in syringes or aluminium sampling tubes and subsequently analyzed in the laboratory by gas chromatography.

The CO_2 flux from the tilled soil surfaces was measured using a large portable chamber described by Reicosky, (1990), and Reicosky and Lindstrom (1993). Measurements for CO_2 flux were initiated within 5 min of the last tillage pass. Briefly, the chamber (volume of 3.25 m^3 covering a horizontal land area of 2.67 m^2) with mixing fans running was moved over the tilled surface until the chamber reference points aligned with plot reference stakes, lowered and data rapidly collected at 2-s intervals for a period of 80 s to determine the rate of CO_2 and water vapor increase. After the appropriate lag times, data for a 30-s period was used to convert the volume concentration of water vapor and CO_2 to a mass basis then linearly regressed as a function of time to reflect the rate of CO_2 and water vapor increase within the chamber expressed on a unit horizontal land area basis.

Environment-friendly CO_2 conservation tillage practices were described in Hungary by Birkás (2002). She pointed on importance of controlling microbiological activity and improving sustainable soil protection. Tillage CO_2 emission investigations made by domestic researchers are using similar measuring techniques as described by foreigner studies.

Jóri and Gyuricza (Jóri 2004) grounded short term measurement techniques by using low volume closed chamber with different instrumentation. Tóth and Koós (2006) were investigating the differences of soil CO_2 flux of experimental field with six different tillage treatment plots. They used cylindrical sampling chambers, samples were taken from the chambers with needle. Zsembeli and Kovács (2007) used 18 liter and later 2,8 liter chambers with metal frame and water isolation. They pointed on the close correlation between the intensity of CO_2-emission and the structural state and organic matter content of the soil.

Materials and methods

Aim of the studies was to examine the short and intermediate term and the seasonal influence of tillage on soil CO_2 emission.

Our aim was to determine the difference in the effect of conventional and conservation tillage methods on the CO_2 flux from soil. Reducing soil CO_2 emission to keep soil carbon has important benefits for the sustainability and productivity of the agro ecosystem. The adequate use of low emission tillage systems has the potential to increase soil productivity and profitability of farming systems by increasing yields or reducing production.

Short term study description:

Short term studies were made on different fields with different treatment operations. Study conditions are summarized in Table 1.

Intermediate study description:

Intermediate study was conducted on clay loam soil at Enying Ltd. Farm. The study was initiated on 15. August 2004 9:00am and finished on 16. August 2004 2:00pm. The intermediate influence of tillage on soil CO_2 evalution was assessed by recording 2 series of successive measurements. Each series included a pre-tillage measurement to assess „reference" flux uniformity, followed by two different past-tillage measurement to compare fluxes along tilled and undisturbed plots. Plots were set out on wheat stubble. For the tillage treatment commercially available Kverneland BB115 plough and Kuhn Optimer compact disc harrow were used (Table 2).

Table 1. Conditions of short term studies

No.	Operation/ Date	Field	Weather condition	Machine	Working depth, cm
1.	Stubble mulching on wheat stubble 07.15.2003	Enying "S4"-field	Dry, sunny, 28°C	Rába-IH disc harrow+ Güttler roller	14-16
				Komondor mulch tiller	14-16
				Kverneland CLE chisel plough	24-26
2.	Primary tillage on corn stubble 09.23.2003	Enying "S10"-field	Dry, windy, 20°C	Rába-IH disc harrow+ Güttler roller	19-21
				Kverneland BB 115 plough	24-26
				Kverneland CLE chisel plough	33-37
	Primary tillage on corn stubble 10.16.2003		Dry, windy, 16°C	Komondor mulch tiller	18-20
3.	Secondary tillage on corn field 04.29.2004	Enying "S10"-field	Dry, windy, 23°C	Syncrogerm 6M seedbed maker on primary tillage plots	9-11
4.	Stubble mulching on raps stubble 06.06.2007	Hosszúvíz "A1"-field	Dry, sunny, 26-28°C	Pöttinger Synkro field cultivator + Pöttinger Lion rotary harrow	16-18
				Pöttinger Synkro field cultivator	22-25
5.	Stubble mulching on what stubble 14.07.2007	Mesztegnyő "H1"-field	Dry, sunny, 25-28°C	Middle-deep loosener	38-45
				Pöttinger Synkro field cultivator	22-25
				Pöttinger Synkro field cultivator + Pöttinger Lion rotary harrow	16-18
				Symba X-press disc harrow	18-22
6.	Stubble mulching on wheat stubble 15.07.2007	Hosszúvíz "A1"-field	Dry, sunny, 28-31°C	Symba X-press disc harrow	18-22
7.	Primary tillage on wheat stubble 08.09.2011	Mesztegnyő "T1"–field	Dry, sunny, 28-31°C	Middle-deep loosener	38-42
8.	Stubble mulching on sunflower stubble 09.17.2011	Mesztegnyő "T1"–field	Dry, sunny, 25-28°C	Pöttinger Synkro field cultivator	14-16

Table 2. Site and treatment specification of the intermediate study

No.	Operation/ Date	Field	Weather condition	Machine	Working depth, cm
1.	Stubble mulching on wheat stubble 07.15.2003 - 07.16.2003	Enying "S4"	Dry, sunny,28°C	Kuhn Optimer compact disc harrow	12-14
				Kverneland BB115 plough	24-26

Seasonal study description:

Seasonal effect of the different primary tillage was observed by analyzing the data of Enying Ltd. Farm "S10" field. Data of CO_2 flux after stubble mulching on three different plots were recorded at 09.23.2003 and seasonal effect was observed by collecting CO_2 flux data of the plots after seedbed preparation at 04.29.2004.

Instrumentation

Soil CO_2 fluxes were measured in situ in earlier studies the INNOVA 1312 Multi Gas Monitor (Fig.1.) were used. Because of the high cost of INNOVA system for the latter studies –after a field validation process – a TESTO 535 CO_2 tester was regularly used. (Fig.2.)

The sampling was taken by using closed sampling chambers, which were continuously developed on the basis of former studies experiences. Earlier studies were made using 8 litre polyethylene sampling chamber (Fig.2.), later to extend CO_2 flux sampling stability, the 27 litre polycarbonate chambers, with air circulation (Fig.3.) were used. Sampling was made on every plot on minimum three random places (Fig.4.). The chambers were emptied after each measurement. Proposed repetition of gas exchange measurements (Table 3.) was specified by the supposed intensity of CO_2 flux. Specification of measure process was made to make different studies comparable. Air CO_2 concentration and temperature and also the soil temperature was measured and registered, to determine the exact value for soil CO_2 flux and the relations between these characteristics.

Table 3.Optimal measure cycle of CO_2 measurements

Measure time	Measure cycle duration
Short term measurements	
0-90 min	15 min
90-240 min	30 min
Intermediate measurements	
0-4 hour	40 min
4-9 hour	60 min

Figure 1. INNOVA 1312 Multi Gas Monitor

Figure 2: TESTO 535 CO2 tester and 8 liter portable chamber

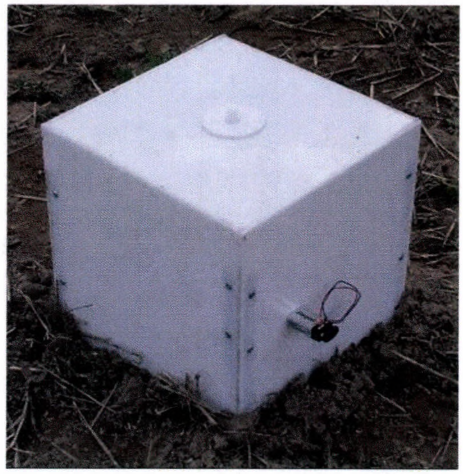

Figure 3. The 27 liter portable chamber

Figure 4. Portable chambers on the test field

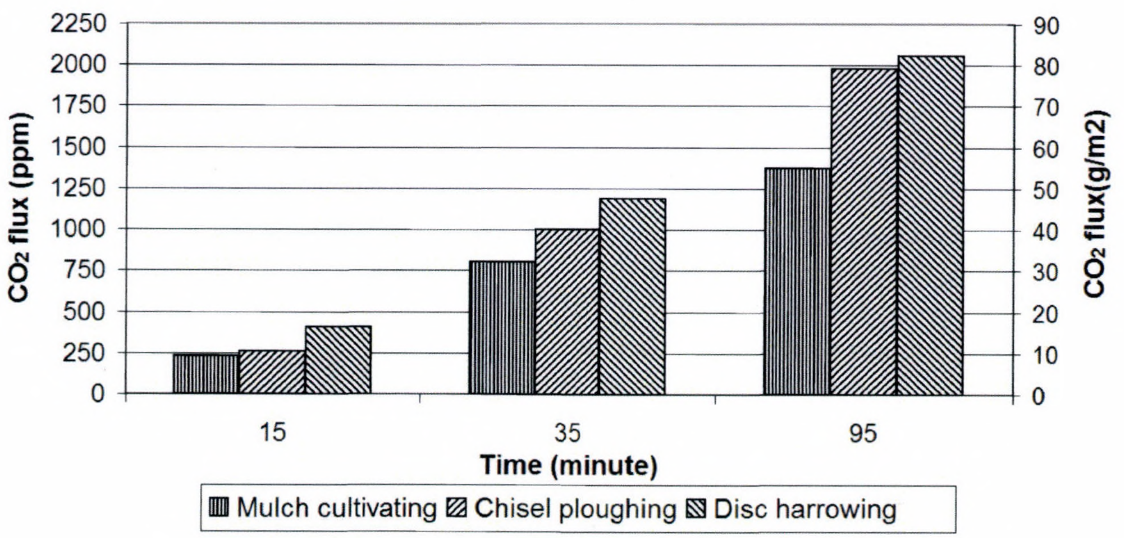

Figure 5. CO_2 flux versus time after stubble mulching (1. study)

Evaluation of the trends of measured data has shown that except the moldboard plow, immediately after tillage was not observed significant differences. The CO_2 flux measured after 60 minutes shows some advantages for mulch tiller where the rear part (spring loaded crumbler) of the machine was effective.

Intermediate influence:

Analyzing the intermediate (Fig.6.) emission of soil CO_2 has shown that short (e.g.3-5hours) measurement data can be extrapolated to calculate intermediate emission data considering soil temperature, moisture content and tillage intensity.

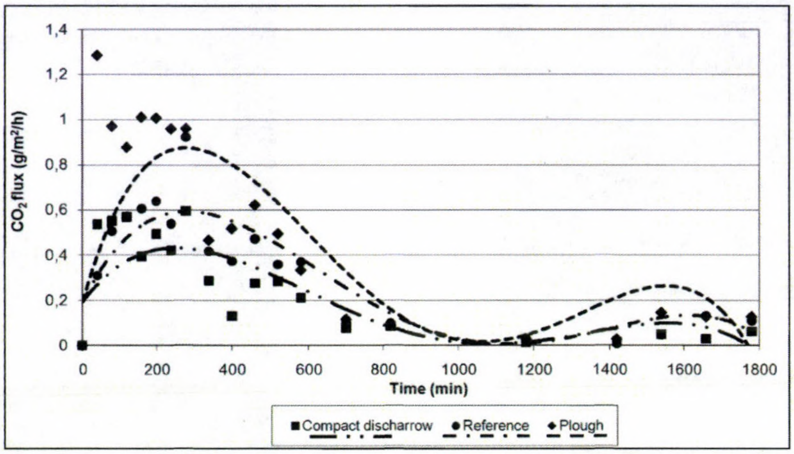

Figure 6. Intermediate (30 hour) emission of CO_2 after tillage

Seasonal influence:

The CO_2 flux as a function of time for each primary tillage treatments in October, in the first 1,5 hours can be compared on Fig. 7. In the case of chisel ploughing the emission was measured along the shank and between of them and was counting an average for the whole field.

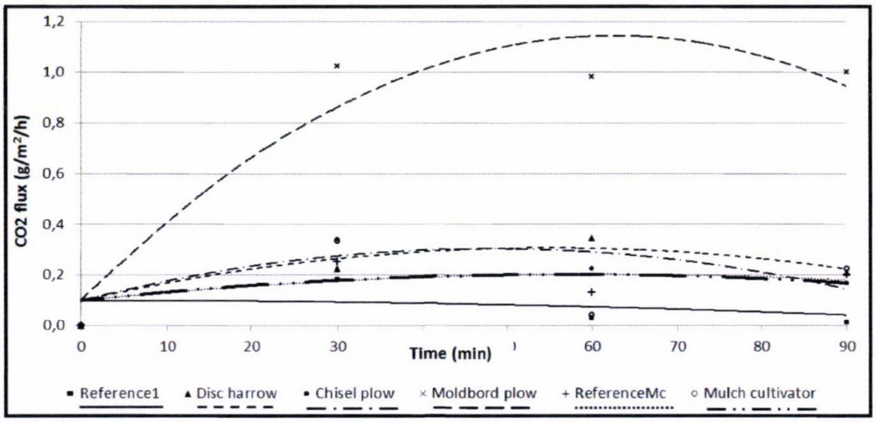

Figure 7. CO_2 flux versus time after different primary tillage operations (2. study)

The higher CO_2 fluxes were related to depth and intensity of soil disturbance that resulted in a rougher surface and larger voids. The initial fluxes were relatively large from the moldboard plough surface and the increasing was not high. The fluxes from the chisel plough and disc harrow surface showed a similar trend.

The CO_2 flux after seedbed making in spring as a function of time for each primary tillage pre-treatment in the first 90 minutes can be compared on Fig. 8.

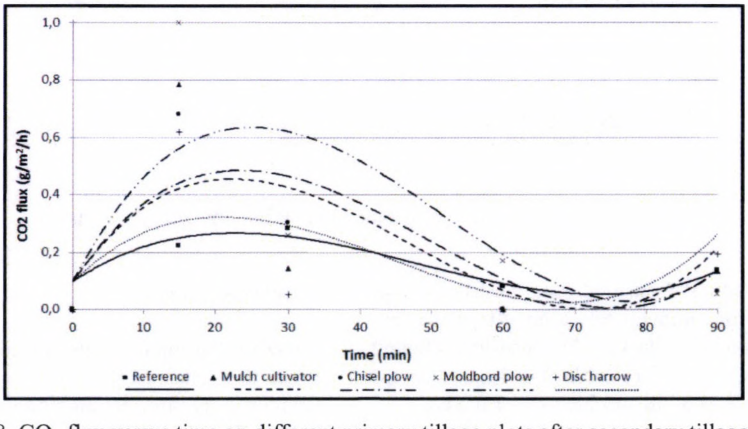

Figure 8. CO_2 flux versus time on different primary tillage plots after secondary tillage (2. study)

The long-term (seasonal) effect of the different primary tillage was observed after seedbed preparation. All conservation tillage implements produced less CO_2 then the moldboard plough. Because of the conservation tillage implements were primary designed to leave crop residue on the surface they can have a second beneficial effect that results in less CO_2 loss.

Results in practice:

To utilize the results of the investigation of CO_2 emission of tillage practices, there is a need to develop special tillage machines which are suitable to satisfy the requirements of low emission tillage practices. There are several manufacturers who produce machines which can be used to lower the CO_2 emission of tillage, but Hungarian field conditions make necessary to cooperate with domestic companies to develop the adequate machines.

Figure 9. SX MulchMaster cultivator

Figure 10. SX disc ripper

Figure 11. SX 480D Air Seeder

Our effort of the past years to develop these machines for Hungarian field conditions was succeeded as the three basic machines (mulch cultivator(Fig.9.), mulch loosener (Fig.10.) and mulch seeder(Fig.11.)) of the low carbon loss tillage practice were getting started production. The results of CO_2 emission studies were put in practice with these machines thus the comprehensive spread of low CO_2 emission tillage practices can be started.

Conclusions

There is a great need to determine exactly the amount of tillage induced CO_2 loss of different tillage practices, to have enough information to determine correctly the CO_2 savings of conservation tillage methods. Studies in the past years were pointed on the importance of correct measurement techniques.

Investigated the results the study has shown that the developed sampling chamber and measurement method is suitable to determine adequate soil CO_2 emission of different soil types and treatments.

The examination of only the short term influence of tillage on soil CO_2 emission can lead to faulty implications because the cognition of the duration of initial high emission is unavoidable.

Naturally like of measurements are very important. The cumulative method, where the emitted CO_2 is collected for hours or longer in the same chamber covering the same area of soil surface, according to our measurements can change the natural environment of soil under the sampling chamber. Therefore to get correct results of longer investigations, the method with ventilated sampling chambers have to be used, where the chambers were emptied after each measurement and the sampling is followed on a new place on the test plot where the surface was undisturbed after the treatment. Studies have shown that there are high variances between the results of cumulated and ventilated measuring methods of long term measurements. It is also important to use chambers with larger basic area and higher volume-area coefficient to get more reliable results by long term measurements.

Measuring long term effect of CO_2 flux by every commercially available tillage machine is not an effective method. Short term measurements (3-6 hours) are suitable to determine the initial emission after tillage and this information is useful to the relatively exact estimation of the long term effect.

The weather condition, first of all the temperature has a great influence on the soil CO_2 flux. Below 10°C has no significant differences between the different tillage methods

Summarized the results were getting from the field research of different tillage treatments the following conclusions can be drawn:

- The intensive tillage, like moldboard ploughing that disturbs the soil to depths and leaves the surface rough can result in essential carbon loss, because the plough not only fractures and opens the soil which can allow fast CO_2 and oxygen exchange, but also incorporates residue into the soil which feeds a microbial population explosion. In the case of conservation tillage, most residues are left on the soil surface, so a small portion is in closed contact with the soil moisture and can be available to microorganisms,
- The order of different primary tillage implement by measured CO_2 fluxes : moldboard plough, chisel plough, heavy disc harrow and mulch tiller,
- The results suggest that selection of primary tillage implement that maintains surface residue and minimizes soil disturbance could help CO_2 loss.

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EXHAUST GAS TESTS USING OF BIOFUELS IN IC ENGINES

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1. Introduction

Important action is to limit climate change and to reduce emissions from fuel utilization for the European Union (EU). In principle, there are many options to do, for example these priorities have been done by providing proportion of renewable energy in the fuel mix. The biofuels (biogas, vegetable oil, biodiesel, bioethanol etc.) are also parts of the renewable energy mix. Biofuel means liquid or gaseous fuel for engine use produced from biomass. Numerous studies demonstrate that the biofuels are environmentally sustainable and they have positive impacts on energy supply. The production of biofuels will help you find the balance in agriculture because biofuels can be generated from biomass, agricultural wastes and non-food plant material. In addition to the objective of saving emissions, EU biofuels policy aims to ensure the necessary energy and to decrease unemployment. So we would like to contribute to the EU requirements through our research. Such as exhaust gas tests using of biogas and different kinds of vegetable oils and biodiesel in internal combustion engines.

Keywords

biofuel, biogas, vegetable oil, internal combustion engine, exhaust gas, emission

2. The biogases as fuels and the emission

Emission tests were made on 24.6 kW power, 4 cylinder Wisconsin Motors Continental TM27 type gas engine with biogases. In our laboratory experiments the biogases were represented as mixtures of methane and carbon-dioxide and the tests were performed with these constant composition gas mixtures. Changing composition of biogas makes it difficult to test and would be uncertain general conclusion from test results.

Furthermore, the engine pre-ignition timing was stable because previous experiments indicated that operating range (function of air ratio) basically does not change due to the changing of pre-ignition timing, so the test engine can be operated stably. (Note: In case of various composition of biogas it is necessary to optimize the ignition timing.) So the constant conditions have allowed more reliable conclusions.

So we made engine tests under the following conditions: different air ratios ($\lambda \approx 0.8$-1.6), constant boost pressure (0.8 bar), constant compression ratio (1:11), specified pre-ignition timing (40°) and constant speed (1500 1/min). The air ratio factor is the most important parameter (gas engines usually operate at high access air – $\lambda \approx 1.2$-1.6) in terms of emission.

Mixed gases – with increasing carbon dioxide – fuelled engine cause increasing CO2 in the exhaust gas (Figure 1). However, the increasing CO_2 emissions clearly due to the CO_2 content of biogases.

But there are many air pollutants from human activity and energy conversion, including nitrogen oxides (NO_x) and sulphur dioxide (SO_2). Those different compositions of biogases which have higher carbon dioxide content would have positive impact on NO_x emission in case of lean-burn operation, decrease can be 50%.

In case of $\lambda > 1.2$ air access ratios the cooling effect of the surplus air results lower NO_x emission, however, NO_x formation depends on the temperature. The engine operation with increasing carbon-dioxide content of gas mixture – by reason of drawing-off of combustion and cooling effect of carbon-dioxide – results further decreasing.

With increasing of carbon-dioxide rate of the applied biogas, the circumstances of the combustion are getting worse.

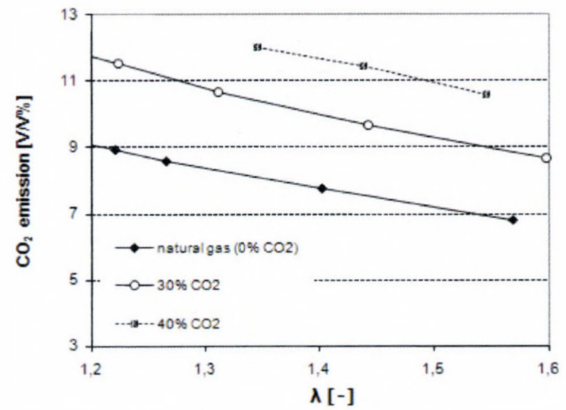

Figure 1. CO_2 emission of the gas engine

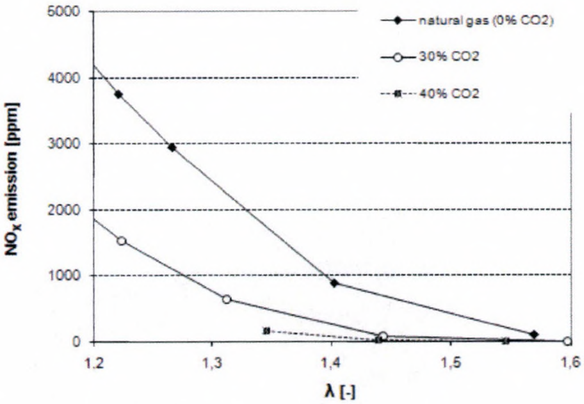

Figure 2. NO_x emission of the gas engine

The CO emission, however, in range of λ=1.2-1.4 air access ratios – independently of carbon-dioxide content of gas mixture – stabilized on lower values. In case of λ>1.4 air access ratios the dragging-on of combustion result increasing CO emission (and higher quantity of unburnt hydro-carbons). In terms of CO emission, unambiguously, it can be determined that the traditional gas engine is operated with gas mixture with low methane content, there is no effect on CO emission if the gas engine operates permanently in range of λ=1.2-14 air access ratios.

Furthermore, measuring of the methane content in the exhaust gas can give points of reference on the goodness of combustion process. Increasing the air absence and dragging-on of the combustion result similar tendencies considering the unburned hydrocarbons emission, too. It can be discovered that considering the incombustible hydrocarbon content of the exhausted gases there is no significant deviation present between the operation of natural gas and gas mixtures with a higher carbon-dioxide content in the range of λ=1.2-1.4 air access ratio.

The operation in the range of λ=1.2-1.6 air ratio gives lower emission in total.

Further studies are needed to compare systematically the environmental and energy performance of biofuels, taking a full lifecycle approach. We should create green house gas (GHG) balance in Hungary and in Europe.

3. The vegetable oils as fuels and the emission

In the frame of research supported by National Research and Development Programmes (NKFP) we determined engine brake bench results and emission components using of pressed 5 kinds of sunflower oils mixed with diesel oil, 4 kinds of rape oils mixed with diesel oil and RME. Our tests were performed by meeting requirements of the EU 24 and EU 49 standards with PERKINS 1104C C.I. engine type (Stage: EURO-2).

Table 1. ECE R49 Standard

Working point	RPM (1/min)	Loading (%)	(Nm)	Weighty factor
1.	idle speed	0%		0.25/3
2.	$n_{M_{max}}$ 1400 1/min	10%	30 Nm	0.08
3.		25%	76 Nm	0.08
4.		50%	151 Nm	0.08
5.		75%	227 Nm	0.08
6.		100%	302 Nm	0.25
7.	idle speed	0%		0.25/3
8.	$n_{P_{max}}$ 2400 1/min	100%	302 Nm	0.10
9.		75%	227 Nm	0.02
10.		50%	151 Nm	0.02
11.		25%	76 Nm	0.02
12.		10%	30 Nm	0.02
13.	idle speed	0%		0.25/3

In the cause of our tests we put down CO, HC, NO_x, CO_2 and O_2 components of exhaust gases and determined smoking too. For defining concentrations of CO, NO_x, and CO_2 gas components a gas analysing computer working by spectrophotometer, type SERVOMEX XENTRA 4900 was used after adequate preparation of sample gas. A flame ionisation detector type RATFISCH RS 5 was used for defining CH emission.

After the emission tests it was stated that among the 5 kinds of sunflower oil mixed with diesel oil 4 fuels fell behind with 6.93%-24.94% from the CO value of diesel oil (Figure 3).

Among 4 kinds of rape oil mixed with diesel oil we noticed substantial falling (65% and 39.61 %) in two cases and rising (9.52 % and 4.56% twice). The pure RME showed 26.42% less CO emission the mixed fuel containing 10% RME decreased by 73.57%. CH emissions of all the vegetable oil-diesel oil mixed fuels remained under CH values of diesel oil (Figure 4).

To compare the values of mixed fuels with sunflower oils to diesel oil dropped by 18.6 % - 34.88 % and also slid by 26.16% - 66.28% using mixed fuels with rape oils. The pure RME represented 5.23% less CH values, the mixed fuel containing 10% RME dropped by 55.81%.

Among the 10 kinds of vegetable oil-diesel oil mixed fuels we measured higher NO_x values than diesel oil in only two cases of mixed fuels (Figure 5).

The samples with sunflower oils were slightly more favourable, than rape oil samples. Nine samples remained below the diesel fuel by 6.94% - 13.61%. Our further remark is that, the values of pure RME exceeded the NO_x limit of diesel oil with 6.54% and the mixed fuel containing 10% RME also exceeded by 10.72%.

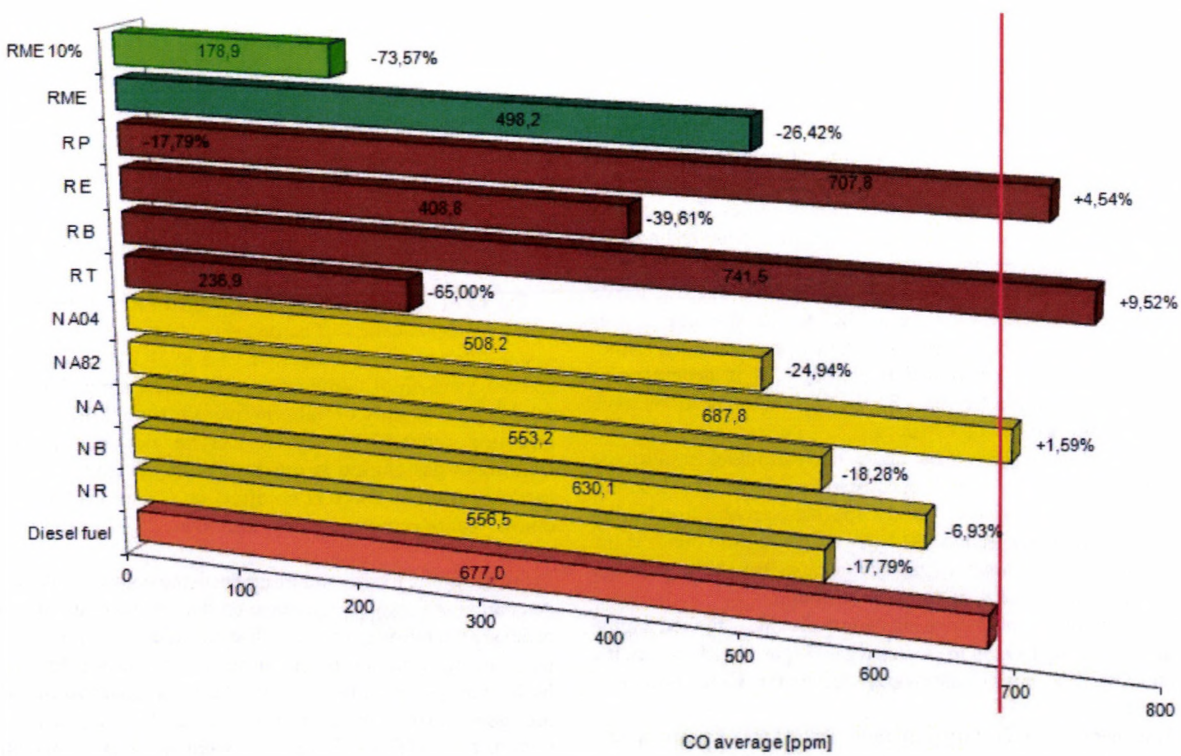

Figure 3. CO emission values

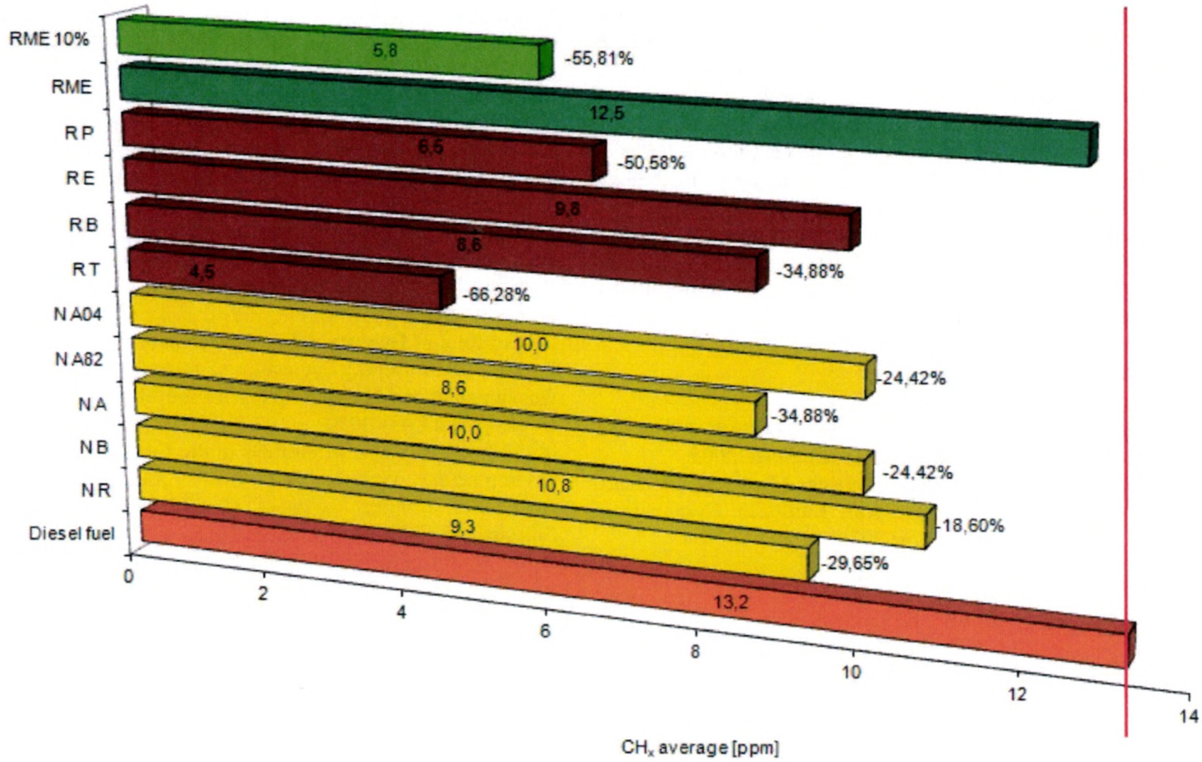

Figure 4. CH emission values

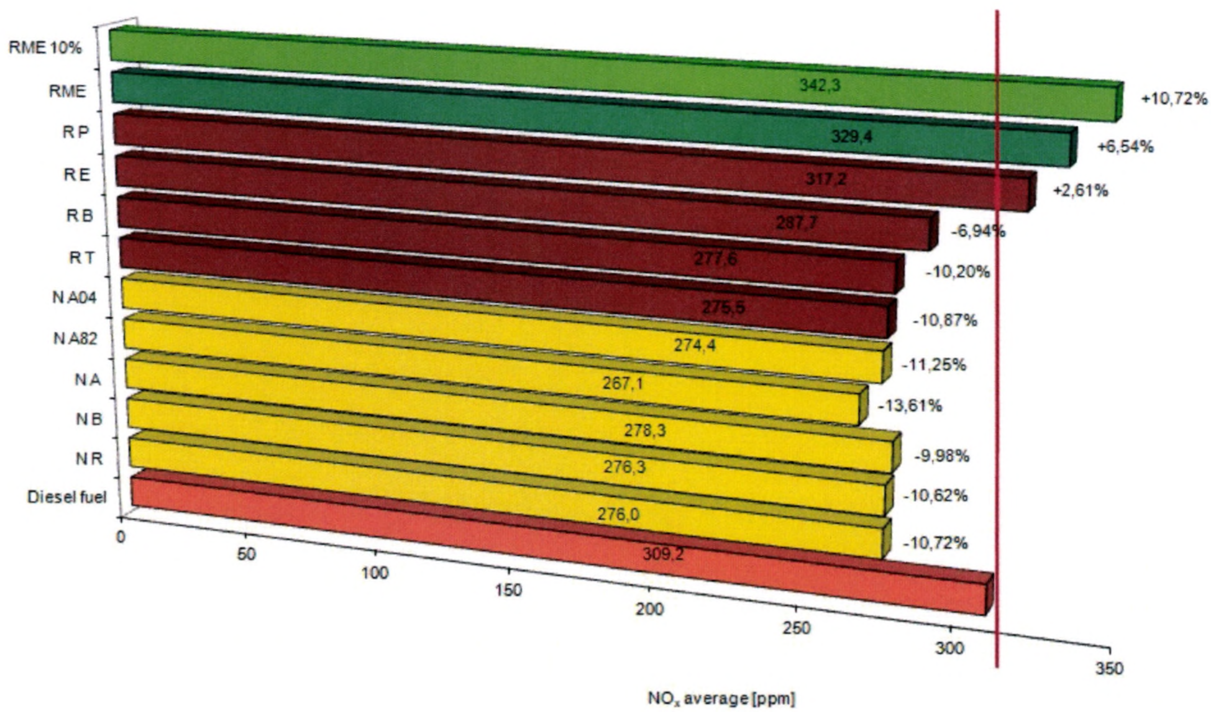

Figure 5. NO_x emission values

4. Conclusions, suggestions

It can be concluded that biogas and vegetable oils are applicable as fuel in internal combustion engines. The emission values of biofuelled engine are less than of fossil fuelled engine.

It can be determined that further researches are needed to compare systematically the environmental and energy performance of biofuels. Nowadays, it is being promoted besides the crop production (food production) to energy crops (biofuel production).

In summary, results of the research show that the biogas and different kinds of vegetable oils will have significant role in the future. And renewable energy carrier can be promoted by continuous innovative activities.

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THE MECHANICAL-TECHNOLOGICAL MODELLING AND THE EXPECTED YIELD OF WOODY ENERGY PLANATATIONS

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Summary

Basing on relevant scientific literature and on the fundamental knowledge of special technologies the authors of the present work introduced the technology models and yield estimating calculations specially applicable for woody energy plantations.

Several technologies can be identified for growing woody energy plantations. The planted wood species determines the type of the cultivation technology fundamentally, as it assigns the time and way of harvesting, planting design, the workflow of nursing, tending and of other activities. Besides the investigation of suitable technologies the amount of the produced dendromass is also of high importance. Our research also focused on elaborating calculations for wood yield estimation, which are suitable for the high reliability prediction of the amount of wood produced by these plantations.

Keywords

renewable energies, biomass, woody energy plantations, technology, model, wood yield

Introduction

In order to fulfill the requirements of the European Union, Hungary has been making efforts to increase the proportion of its renewables in energy production. It can be expected that by the year of 2020 Hungary will have reached the limit of 14.65% which was set in the Hungarian Action Plan for the Utilization of Renewable Energies. By respecting the potentiality of our country, biomass can be considered as the major resource for renewable energy in the future, which is also outlined in Figure 1. The domestic stock of biomass can be estimated between 350-360 million tons, out of which 105-110 million tons are regenerated annually. About 38-43 million tons of this amount can be used for energy production (Gőgös, 2005).

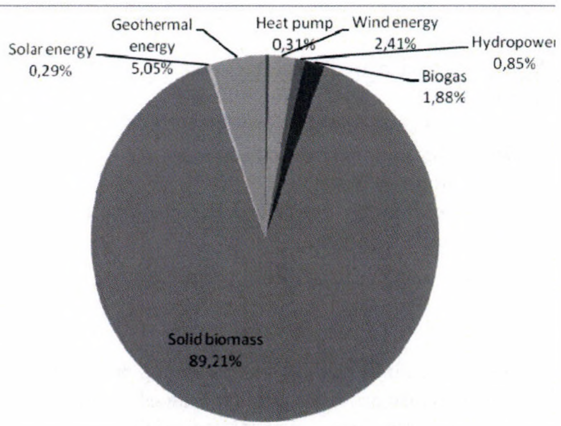

Figure 1. Utilization of renewable energy resources in 2010 (Reproduction from Tóth, 2011)

Woody energy plantations represent a significant proportion of the biomass resources (Figure 2.) providing raw material for mixed operation- and biomass-based power plants and heating plants, complementing the fuelwood resources extracted from natural forests.

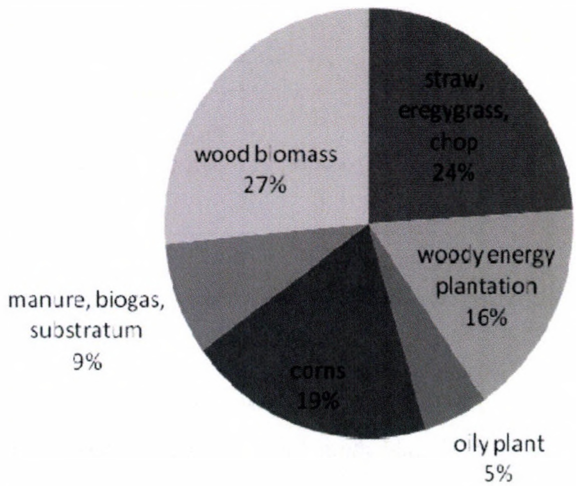

Figure 2. Types and proportion of biomass in Hungary (Czupy et al. 2012)

Woody energy plantations are special plantations with fast-growing wood species producing fuelwood. They can be characterized with a higher specific energy yield than natural forests. The setting up of such plantations with fast-growing special clones means also that the planting, tending and harvesting works and technologies and the methods for wood yield estimation can and will differ significantly from those applied for natural forests. In the case of woody energy plantations the traditional forestry technologies and models may need to be revised and transformed.

Materials and methods

Relevant scientific literature and practical experience have provided a basis for the characterization of the technologies applied on woody energy plantations. For yield estimation field data (diameter at breast height, diameter at base, stem length, bulk) and the diagrams deriving from these data have been used.

Results, discussion

The technologies applied at woody energy plantations

There are several different technologies for the cultivation of woody energy plantations. The planted wood species influences significantly the techniques that can be used, as it determines the time and method for harvesting, the planting design, the methods for efficient weed control and also other factors. Table 1. summarizes briefly the typical cultivation workflow of a woody energy plantation.

It should also be noted that economic calculations are indispensable for the appropriate design of a woody energy plantation, in order to choose the most suitable technology and economic solutions for the given circumstances, resulting in the highest profit. Several factors should be considered when estimating wood yield, like plantation size, location, approachability, distance from the timber utilization sites (e.g. wood chip burning power plants, wood chip storages, railway connections, etc.). The actual agricultural policy (e. g. subsidization) as well as the trend of the purchase price have a significant impact on the overall economic efficiency of the plantation. The purchase price of wood chip was 16.500 Ft per oven dry metric ton (ODMT) in 2010, which increased up to 17.200 Ft per ODMT by 2011. Beside the power plants, more and more consumers emerge on the market for wood chip (e.g. heating plants, briquette- and pellet producing factories, users of household pellet stoves) which makes prices soar even higher.

Table 1. Technologies in woody energy plantations

Action	Aim and timing	Description
Site-preparation	Providing a well-prepared and good quality site for planting.	The type and amount of work depends on the state of the planting site. E.g. at a weedy site it is advisable to carry out weed control for a whole growing season, or to make a total weed control at the end of the growing season.
Nutritive supply	Improving or maintaining soil fertility	Some of the nutritives taken up from the soil will recirculate into the ground during defoliation. Yet, this involves only a small fraction which makes the supplying of nutritive deficiency essential. Organic manure, green plant waste, artificial fertilizers and wood ash can be used for this purpose.
Establishing the planting design	Setting up the growing space matching the wood species	Influenced by: wood species, site characteristics, aim of cultivation, expected yield, harvesting method, etc.
Choosing the most suitable cuttings and saplings	Founding a healthy and strong plantation	Basic materials can be used only in accordance with the requirements of the regulation No. *110/2003. (X. 21.)* of the Ministry of Agriculture and Rural Development. Only healthy and undamaged saplings and cuttings should be planted. The certificates proving the origin and cloning identity should be archived.
Planting	Cuttings: in early spring. Saplings: in autumn.	Manually or with a forestry cutting planting machine. In case of a lack over 10% supplement planting should be carried out after the first harvest.
Tending	Keeping up the highest growth rate during the operation of the plantation, ensuring maximum wood yield. Providing sufficient air circulation and water household in the ground. Preventing soil compaction.	Mechanical weed control: power-driven (tiller, combinator, cultivator) or manual. Other: chemical, biological, integrated weed control.
Protection against pathogens and parasites	Avoiding profit loss, keeping the health and wholeness of the plantation.	With moderate occurence there is no need for protective steps, mass propagation should be avoided however. Agains game damage: fence
Harvesting	After growth season (from November till March)	Appliances: ➢ chainsaw + mobile chipper; ➢ trailer with logger and chipper; ➢ baling machine; ➢ mobile logger and chipper (depending on the size of the plantation).

Technological models

When establishing technological models site area and planting design were considered as major parameters. The recommended planting design was 3 m x 0.5 m. The row distance of 3 meters allows the utilization of traditional agricultural power machinery for the mechanized tending and harvesting processes. Applying 50 cm stem distance is the best for manual tending work which needs to be done during the first year of the rotation. Figure 3. depicts the workflow of the technology for small plantations up to 3 hectares.

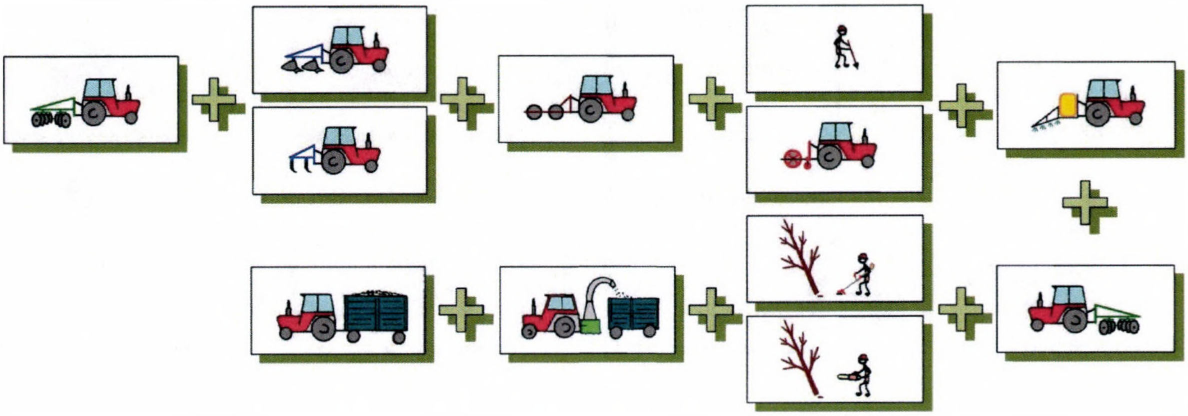

Figure 3. Technological model for plantations up to 3 hectares

Prior to the planting, site preparation needs to be carried out which involves either stubble-stripping, deep phoughing (with a subsoiler) and seedbed preparation or only simple ploughing and seedbed preparation. The planting of the cuttings and saplings can be done manually with a tree planting spade or with a small size sapling/cutting planting machine. The tending of the rows (chemical weed control) can be done with a dispersing machine. Harvesting is carried out using a chainsaw or a brushcutter. The timber is chipped using a mobile chipper, then the chip is forwarded to the place of utilization. The applied machines should all have a power requirement which can be supplied by a medium category all-purpose tractor. Figure 4. depicts the technological model for 3-20 hectare plantations.

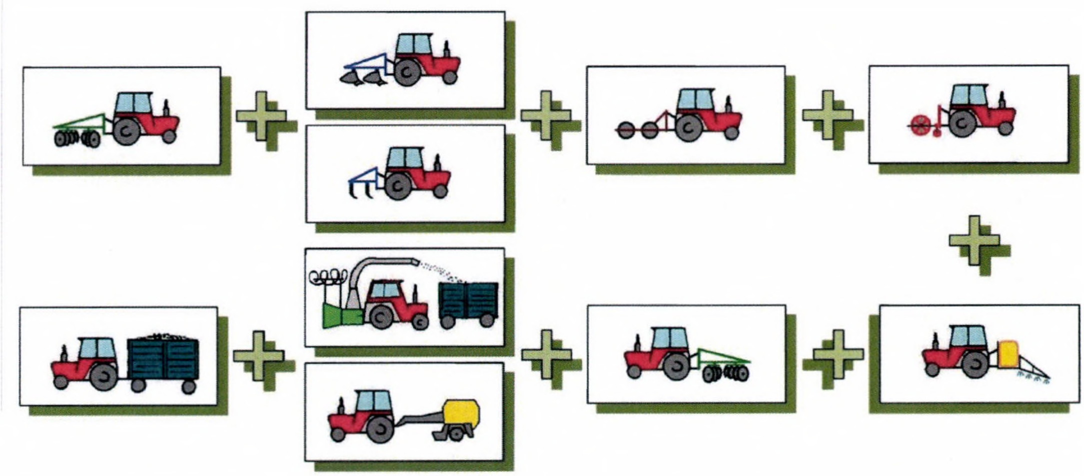

Figure 4. Technological model for 3-20 hectare plantations

Site preparation is followed by the planting of the cuttings and saplings using a device operated by a medium category all-purpose tractor. The tending of the rows (chemical weed control) can be done with a dispersing machine. Harvesting is accomplished with a mobile logger and chipper or with a baling machine which carries out logging and baling in a single step. This is followed by the transport of the biomass to the place of utilization. The power requirement of the applied machines is higher than that of the previous category. For plantations larger than 20 hectares the technological chain of operations is depicted in Figure 5.

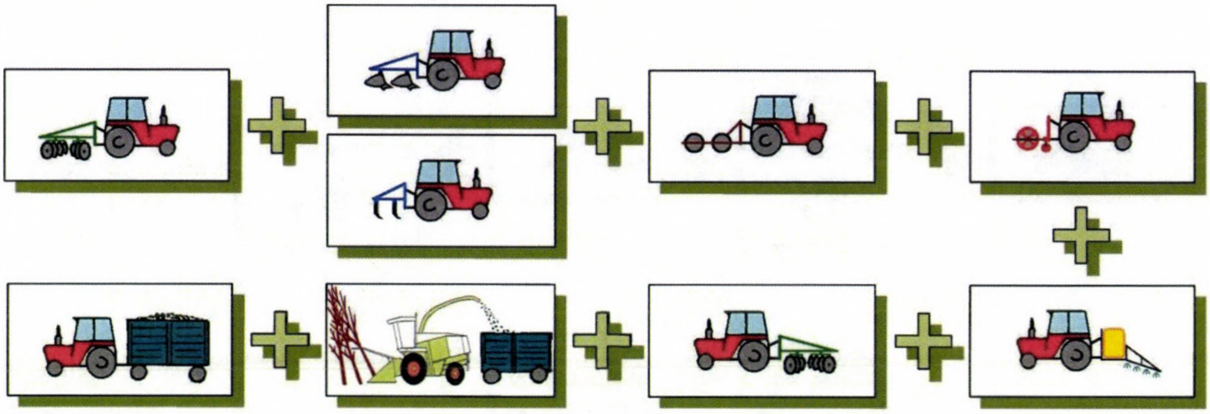

Figure 5. Technological model for plantations over 20 hectares

For the plantations of this size operations differ only in the way of harvesting compared to the previous models. High-performance mobile logger-chipper harvesters can be used for these tasks.

Estimating wood yields

Calculations and tables suitable for yield estimation of natural forests cannot be applied in the case of short-rotation woody energy plantations, as those data and calculations refer to volumes of timber and to stems having a diameter at breast height larger than 5 cm. The applying scientific literature cites several methods for yield estimation of woody energy plantations (e.g. mass functions, Kopeczky's equation, etc.).

In the course of our investigations the yield data of a two-year-old poplar clone plantation have been evaluated. 10 m wide sampling areas were assigned where the diameter at breast height and the diameter at base were measured. In the case of two of the sampling areas trees were felled and stem length and bulk was also determined. Using these data relationships were established between stem diameters at different levels and bulk (Figure 6.).

Using the determined equations wood yield was estimated for all those areas where the measurement of bulk and stem length had not been carried out to evaluate the wood yield for a large number of samples.

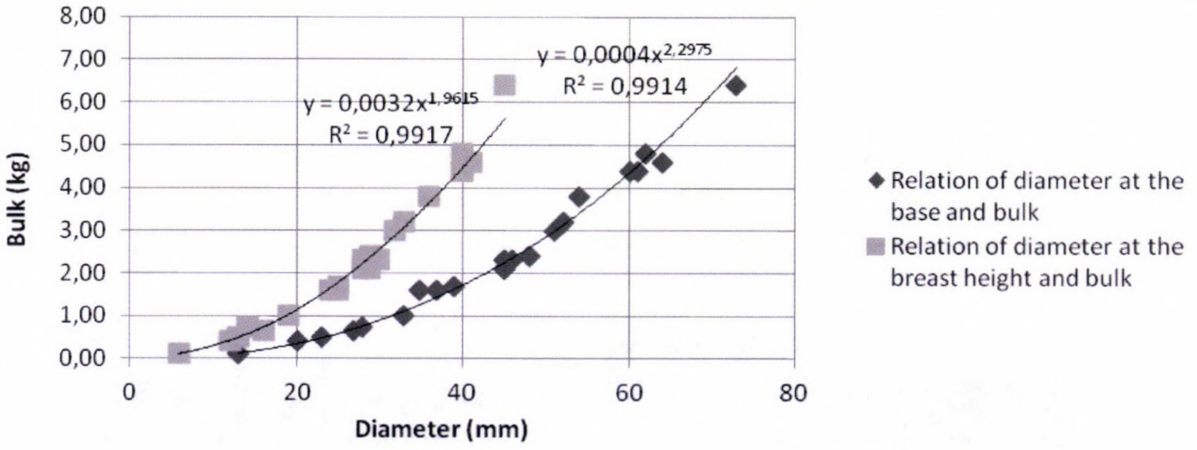

Figure 6. Relations between diameter at base and bulk and relation between diameter at breast height and bulk in the investigated two-year-old plantation

At the investigated 5-hectare plantation 8240 stems could be counted altogether. Using wood yield estimation by the diameter at base the result was 20,93 tons/hectare. The estimation by the diameter at breast height resulted 19,2 tons/hectare which is closer to the value determined after the harvesting of the plantation (19,6 tons/hectare). In the future our research on wood yield survey and estimation will be continued. It is to be determined, how the calculated mathematical relationships could be used with other species and with different plantation age.

Summary

The technologies and yield estimating strategies for woody energy plantations differ significantly from those of natural forests as these plantations involve the monocultural cultivation of fast growing wood species requiring special planting design and technological background. The establishment of special technological models has already commenced and has been developing and so have the procedures for wood yield estimation.

It is our aim to work out firmly founded technological models and yield estimating methods which are applicable in practice.

Acknowledgements

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THE ENERGETIC POTENTIAL OF HUNGARIAN FORESTS

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Abstract

The effects of the biological regularities of the forests and the decisions made by silvicultural experts make the extractable volume of timber plannable and predictable (categorized by wood species, tree utilization, size, and quality) for several decades in advance.

From the logged volumes and from the predicted ratio of fuelwood the volume of the fuelwood is calculated which can be extracted during the following 10 years. Evaluation of combined data reveals that the annual potential for producing fuelwood is nearly 5 million m3, the volume of harvesting losses is about the half of this value. The potential for root timber extraction is even lower (about 0.3 million m3), because the extraction of the stump can only be carried out at some of the logging sites. The utilization of this dendromass cannot be achieved completely because of the original purpose of the forests, different stand conditions, non-supporting logging systems, and other alternative technologies for the utilization of felling site harvesting losses.

Keywords

Renewable energies, dendromass, wood stock of forests, fuelwood, harvesting losses, stump

Introduction

The significance of renewable energies (wind-, solar-, water-, geothermal- and biomass power) has sharply increased by the present days, as the utilization of these resources is in accordance with environmental protection efforts as well as with the concepts of sustainable development. In Hungary, the ratio of renewables rises progressively in primary energy consumption, having reached as much as 7% by now and according to national strategies this level should be further increased. Biomass represents the most important resource for renawable energy in Hungary (over 80%). The most considerable source of biomass (about 80%) is the utilization of dendromass. Respecting these data it can be established that wood, as a renewable resource takes 4-4.5% share out of the domestic energy consumption.

Four major sources of fuelwood production can be distinguished:

- Fuelwood originating from traditional silviculture (state-owned forests and privately-owned forests) which is most commonly designated as domestic fuelwood, export fuelwood, long log fuelwood, fuelwood for power plants, energywood, etc.);
- harvesting losses collected during tree utilizations, by-products, material from thin branches and twigs, stumps, etc.;
- by-products formed during the processing of timber, used wooden products;
- timber from woody energy plantations, commonly utilized in form of chips.

According to the statistical data of the Forest Management of the National Food Chain Safety Office (NÉBIH) the growing stock of the Hungarian forests is 362,2 million m^3 gross, current growth is 13,1 million m^3 gross per year, annual timber extraction represents 8,1 million m^3 gross per year. Growing stock of the Hungarian forests increases steadily as the sum of the volume of extracted timber and tree mortality does not exceed the volume of current growth (Figure 1.).

The energetic potential of Hungarian forests depend mainly on the expectable volume of fuelwood as well as on the possibilities of felling site harvesting loss utilization. In the year 2011 the net volume of the fuelwood assortment was 3.932.626 m^3 which represents 56.5 % of the overall timber production (Figure 2.).

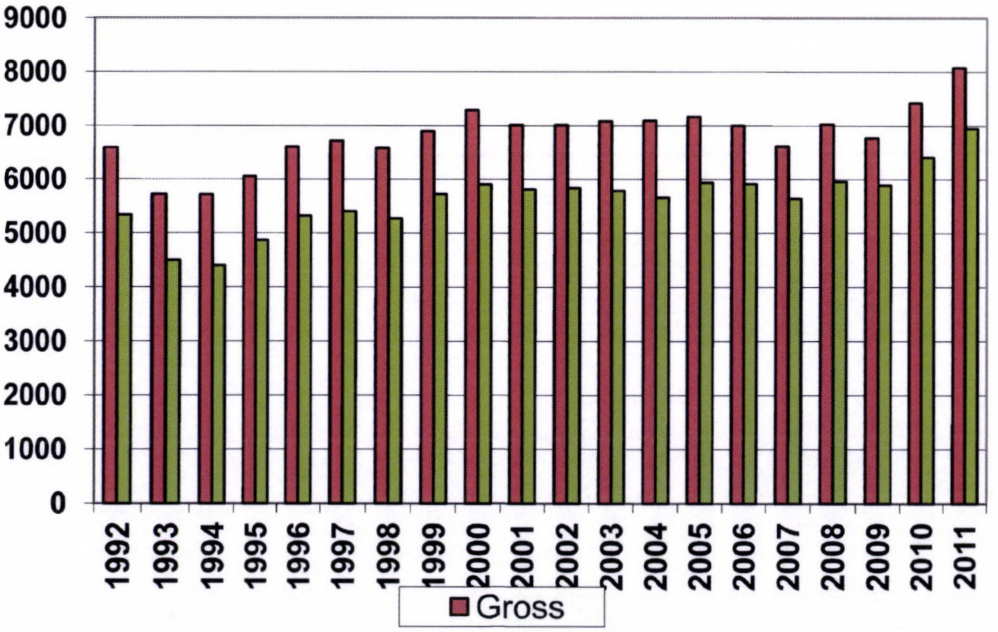

Figure 1. Trend of gross and net extracted timber volumes [ezer m^3] in the last 20 years

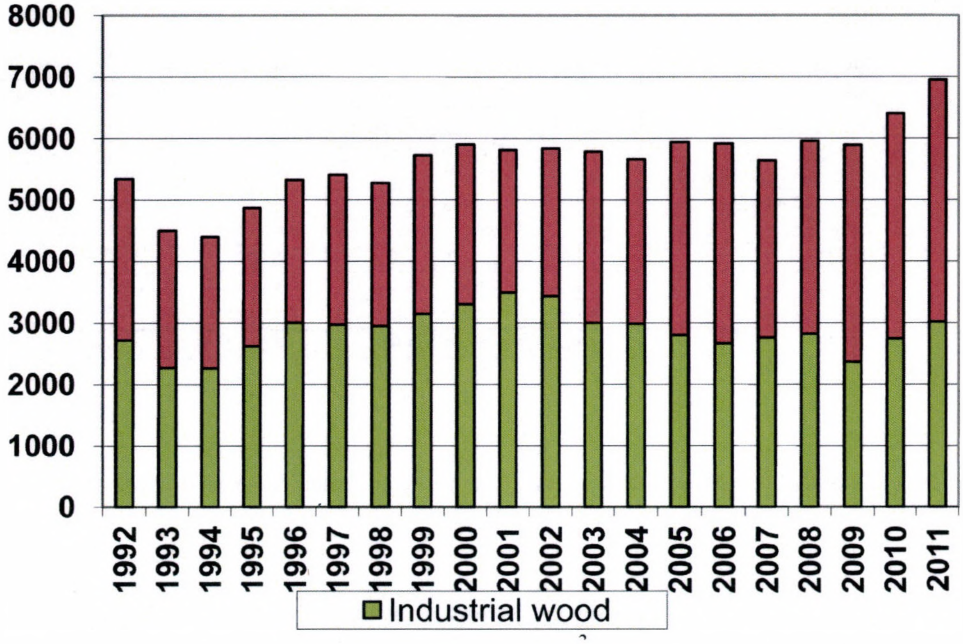

Figure 2. Trend of net timber production [ezer m³] respecting assortments in the last 20 years

The effects of the biological regularities of the forests and the decisions made by silvicultural experts make the extractable volume of timber plannable and predictable (categorized by wood species, tree utilization, size, and quality) for several decades in advance. According to the listed parameters the high reliability prediction of the volumes of extractable timber can be carried out broken down to assortments, size and quality.

Actualization of the assortment structure

Applying the simplified size-class-based assortment planning method of the Forest Research Institute, assortment composition can be determined in different size-classes and in forest stands with different stem diameters by the use of special calculation datasets. These datasets and tables, however, reflect assortment structures, which were timely one or two decades ago, thus they will differ significantly from the current national factual data.

In order to actualize the old datasets, first the summarized assortment distribution was compared to the current data in the case of each wood species. The assortment structure of the forest stands (characterized with the average diameter at breast height, $d_{1,3}$) was summarized using weight factors, which involve the distribution of average logging volumes as a function of stem volume (and also $d_{1,3}$), taking into account the expectable changes triggered by the final harvests and increment thinnings of 2011 as well as the distribution of the expected final harvests of the next two decades, modified with the estimated ratio of intermediate cuttings.

By comparing the old combined national assortment structure to the current statistics, index numbers could be calculated which reflect the degree of differences between the two datasets. The old assortment percentage values (belonging to a given $d_{1,3}$) were multiplied by these index numbers, determined for each of the assortments. The $d_{1,3\text{-wise}}$ summary of the new values gave, however, results higher or lower than 100%. For this reason the values of the new columns were corrected using correction numbers which reflect the degree of deviation from 100 %. These final data were regarded as the new $d_{1,3\text{-wise}}$ dataset of the current national assortment structure. The percentage data of these new columns together with the new assortment structure (calculated using the weight factors) verified the values of the current national statistics.

According to our deduction and calculation the above introduced method for updating is both mathematically and professionally correct. It can be used for proper assorting of timber, although the method itself can be regarded as a good approximation only. Our updating method is suitable for upgrading previously recorded national datasets using up to date comprehensive statistical data, provided there are inherent connections between part figures.

Using this method, the percentual distribution of the assortments, extractable from an average quality forest stand, as a function of average diameter at breast height, can be approximated. Thus, we can obtain more detailed information than using only currently recorded statistics.

The expected gross volume of fuel wood and harvesting losses in the next 10 years

According to the NÉBIH statistics of 2011 the growing stock of the stands that will become mature for logging in the next 10 years, can exceed 107 million m³ gross. Table 1. summarizes the data broken down by wood species and quality class.

Table 2. shows the growing stock volume of the forests becoming mature for logging in the next 10 years broken down by wood species. Netting of the volumes was carried out using the species-dependent ratio of the felling site harvesting losses. The volume of extractable timber exceeds 84 million m³ net.

By subtracting the data in Tables 1. and 2. the volume of felling site harvesting losses can be obtained. According to Table 3. the annual volume of these losses can reach as much as 2.4 million m³, which could be utilized potentially for energetic purposes.

Table 4. shows the approximated ratio of fuelwood in the next 10 years broken down by species and quality class, respecting the updated assortment structure and the applying data of NÉBIH from the year 2011.

Table 1. Growing stock of the stands becoming mature for logging in the next 10 years [m³ gross]

Species	Class 1	Class 2	Class 3	Class 4	Class 5	Total
Black locust	7 936	439 003	7 098 054	7 419 124	11 797 947	26 762 064
Beech	851 984	3 472 523	3 285 208	438 640	63 986	8 112 341
Turkey oak	18 408	1 472 276	8 811 070	3 583 163	181 103	14 066 020
Other hard broadleaved sp.	81 163	632 592	1 630 120	1 362 386	810 780	4 517 041
Other soft broadleaved sp.	73 022	993 493	2 553 412	818 427	224 644	4 662 998
Softwoods	256 844	1 544 016	3 850 485	2 009 696	1 310 152	8 971 193
Hornbeam	3 406	87 400	1 125 513	2 004 658	219 611	3 440 588
Oak sp.	765 049	4 074 577	8 118 742	2 484 652	193 618	15 636 638
Poplar, willow	197991	3179097	9471631	4781586	4059521	21 689 826
Total	**2 255 803**	**15 894 977**	**45 944 235**	**24 902 332**	**18 861 362**	**107 858 709**

Table 2. Extractable volume of timber in the stands becoming mature for logging in the next 10 years [m³ net]

Species	Average losses [%]	Class 1	Class 2	Class 3	Class 4	Class 5	Total
Black locust	22,8	6 127	338 910	5 479 698	5 727 564	9 108 015	20 660 313
Beech	14,9	725 038	2 955 117	2 795 712	373 283	54 452	6 903 602
Turkey oak	17,6	15 168	1 213 155	7 260 322	2 952 526	149 229	11 590 400
Other hard broadleaved sp.	19,4	65 417	509 869	1 313 877	1 098 083	653 489	3 640 735
Other soft broadleaved sp.	17,2	60 462	822 612	2 114 225	677 658	186 005	3 860 962
Softwoods	31,0	177 222	1 065 371	2 656 835	1 386 690	904 005	6 190 123
Hornbeam	27,6	2 466	63 278	814 871	1 451 372	158 998	2 490 986
Oak sp.	22,8	590 618	3 145 573	6 267 669	1 918 151	149 473	12 071 485
Poplar, willow	24,4	149 681	2 403 397	7 160 553	3 614 879	3 068 998	16 397 508
Total		**1 792 200**	**12 517 284**	**35 863 761**	**19 200 206**	**14 432 664**	**83 806 115**

Table 3. Felling site harvesting losses in the stands becoming mature for logging in the next 10 years [m³]

Species	Average losses [%]	Class 1	Class 2	Class 3	Class 4	Class 5	Total
Black locust	22,8	1 809	100 093	1 618 356	1 691 560	2 689 932	6 101 751
Beech	14,9	126 946	517 406	489 496	65 357	9 534	1 208 739
Turkey oak	17,6	3 240	259 121	1 550 748	630 637	31 874	2 475 620
Other hard broadleaved sp.	19,4	15 746	122 723	316 243	264 303	157 291	876 306
Other soft broadleaved sp.	17,2	12 560	170 881	439 187	140 769	38 639	802 036
Softwoods	31,0	79 622	478 645	1 193 650	623 006	406 147	2 781 070
Hornbeam	27,6	940	24 122	310 642	553 286	60 613	949 602
Oak sp.	22,8	174 431	929 004	1 851 073	566 501	44 145	3 565 153
Poplar, willow	24,4	48 310	775 700	2 311 078	1 166 707	990 523	5 292 318
Total		**463 603**	**3 377 693**	**10 080 474**	**5 702 126**	**4 428 698**	**24 052 594**

Using the net volumes of extractable timber and the approximated ratio of fuelwood assortment the expected volumes of fuelwood produced in the next 10 years can be calculated (Table 5.). Global data reveals that the potentiality of fuelwood production can reach almost 5 million m³ per annum.

The total energetic potentiality of domestic forests in the next 10 years is estimated to consist of 49.3 million m³ fuelwood and 24 million m³ felling site harvesting losses. These values could further be increased by refining the approximations and the determination of timber volumes of forest utilizations. It must be considered, however that the utilization of this dendromass cannot be achieved completely because of the original purpose of the forests, different stand conditions, non-supporting logging systems, and other alternative technologies for the utilization of felling site harvesting losses.

Table 4. The approximated ratio [%] of fuelwood in the next 10 years

Species	Class 1	Class 2	Class 3	Class 4	Class 5
Black locust	35,8	57,4	79,1	89,5	100,0
Beech	7,2	30,1	53,1	72,2	91,3
Turkey oak	20,1	51,7	83,4	89,6	95,9
Other hard broadleaved sp.	25,7	52,1	78,6	88,6	98,6
Other soft broadleaved sp.	18,0	42,4	66,8	75,1	83,5
Softwoods	11,3	13,8	16,3	40,0	63,6
Hornbeam	26,8	54,4	81,9	88,1	94,2
Oak sp.	13,0	39,0	65,0	80,5	96,0
Poplar, willow	3,9	4,9	5,9	17,9	29,9

Table 5. Expected volumes of fuelwood production in the next 10 years [m^3]

Species	Class 1	Class 2	Class 3	Class 4	Class 5	Total
Black locust	2 193	194 616	4 332 246	5 127 886	9 108 015	18 764 956
Beech	51 942	890 907	1 485 414	269 638	49 735	2 747 636
Turkey oak	3 051	627 715	6 052 912	2 646 143	143 075	9 472 897
Other hard broadleaved sp.	16 800	265 861	1 032 758	972 899	644 311	2 932 629
Other soft broadleaved sp.	10 907	348 949	1 412 310	509 187	155 274	2 436 626
Softwoods	20 047	147 349	434 381	554 395	575 037	1 731 210
Hornbeam	662	34 409	667 477	1 278 211	149 818	2 130 578
Oak sp.	77 046	1 226 906	4 071 690	1 543 939	143 522	7 063 102
Poplar, willow	5 827	117 329	420 364	645 669	916 167	2 105 356
Total	**188 475**	**3 854 040**	**19 909 551**	**13 547 968**	**11 884 954**	**49 384 990**

The energetic potential of stump extraction

Silviculture has gained a widespread and several-centuries-old knowledge on the quality and volume of timber that can be extracted directly from forest stands. Nevertheless, this timber involves only the parts of the stems above the cutting surface and almost no data can be found on the vast volumes of organic matter that is left back in the ground. Dendromass as an energy resource is generally considered as the dendromass above the ground. In spite of the fact that the technical conditions of stump processing are already known, the effective utilization of the extracted stump has not been achieved yet. The extracted stump is most often considered as a waste matter, or it is bunched into piles and left back at the logging site, or it is transported away from and deposited without ever using it as an energy resource. Yet, the energy policy of the European Union and Hungary as well as the increasing demand of green energy urge the energetic utilization of the stump.

In the present days in Hungary the extraction of the stump is not carried out with the intention of producing raw materials, it is only one of the mechanized working operations during site preparation, one of the essential silvicultural tasks. It is a costly operation indeed, which means that it is only applied when reasonable enough (e.g. site conditions, or the planted species require intense turning of the soil or thorough deep ploughing). Stump extraction and the following intense site preparation with turning of the soil can only be performed when the surface is flat or slightly wavy and only in the case of some genetic soil types (e.g. sandy soils). Considering sandy soils, after the stumping the subsequent deep ploughing can improve the water- and air balance of the soil, which can increase the survival rate of the following forestations, which will in turn decrease the costs for tending and forestation to such a degree which compensates the expenses of stump extraction.

For the estimation of the number of extractable stumps per hectare the OSAP datasets (Report on forestations and loggings) for the year 2011, published by NÉBIH were used. These include data reported annually by the forest owners on loggings and forestations. Stumping was carried out mosty in black locust-, poplar- and softwood stands. For this reason the estimation of the volumes of extractable stumps was carried out for these wood species. According to the data, after-forest regeneration was carried out at 6641 hectares with black locust, at 1603 hectares with poplar and at 111 hectares with Scots pine during the investigated year. The gross yields of these forest stands were 1.260.000 m^3 black locust-, 360.000 m^3 poplar- and 36.000 m^3 Scots pine timber.

By studying the scientific literature the following assumptions were used for determining the ratio of stump and root-wood basing on the volume of timber above the ground.

- black locust: 15-25%;
- poplar: 10-20%;
- Scots pine: 10-20%.

Using these average values the potential of annual production of stumps in the next 10 years related on one hectare forest coluld be determined as follows: 252.000 m^3 for black locust, 54.000 m^3 for poplar and 5.400 m^3 for Scots pine.

Acknowledgements

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MODELING THE ENERGY-EFFICIENT AND NATURE-FRIENDLY CORN DRYING PROCESS BY USING MICROWAVE ENERGY

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Abstract

In this study the simulation possibility of microwave crop drying, as the rather energy-efficient and eco-friendly technology, is presented, by applying semi-empirical method. Although the microwave dehydration is a really complicated process with numerous hardly known parameters, by using the global principles of similarity method, there is a chance to derive the microwave drying rate function, by modifying the basic equation of surface evaporation process. This possibility comes from the analogies between the convective and microwave dehydration process when they are considered as applied energy and mass transport.

Keywords

microwave drying, modeling, similarity method

Introduction

The drying is a very complicated process with many influencing parameters, thus the ideal modeling considerations should be validated from practical point of view. Semi-empirical models for convective drying have been well developed; consequently they can serve appropriately precise data for the practice (Bihercz and Beke 2006). However, the microwave drying process has numerous special features that frequently hinder the process description.

Some of the modeling problems of microwave drying can be listed as follows.

- Moist material put into the microwave cavity perturbs the space.
- The special morphology of drying biological material causes inhomogeneous energy distribution.
- The effect-mechanism of microwave energy inside the material is partly known only
- The dissipation rate of microwave energy depends on the material geometry, the phase state of moisture content and the efficiency of space filling as well.

In order to manage the problem listed above the most probable method could be a deliberate adaptation of the adequate scientific findings.

Theoretical backgroung

If we investigate the microwave drying as an applied energy and mass transport the following principal basic equations can be used (Chen and Pei 1989).

The balance equation for the liquid transport:

$$\frac{\partial}{\partial \tau}(\varepsilon_w, \rho_w) + \nabla \mathbf{J}_w = -S_p \qquad 1$$

The balance equation for the vapor transport:

$$\frac{\partial}{\partial \tau}(\varepsilon_g, \rho_v) + \nabla \mathbf{J}_v = S_p \qquad 2$$

The balance equation for the energy transport:

$$\rho c_p \frac{\partial T}{\partial \tau} = \nabla(\lambda \nabla T) - S_p \cdot q_o + \Lambda_V \qquad 3$$

The (1-3) general formulations of the governing energy and mass transfer equations are based on the assumption that the wet material is continuous, homogeneous and isotropic. In the case of drying the biological material these conditions are impossible to fulfill.

It has been proved that there is no difference between the nature of convective and microwave water get-off process of material with different morphologies and water regime (Beke, Mujumdar and Giroux, 1997). This phenomenon demonstrates the similarity in the mass transport.

By investigating the integrated temperature curves of drying materials with different structures it was found that the material temperature is independent from the energy transfer method, which proves the existing global similarity in the energy transport (Beke, Mujumdar and Giroux, 1997).

The balanced effects of latent parameters of drying process usually are taken into consideration by introducing the so-called drying coefficient (k). If we can show the appropriate connections between the drying coefficients for convective and microwave drying it could serve proof for similarity of cross effects in convective and microwave dewatering processes as well.

The drying coefficient was investigated by several researchers and it was found that k can be described with an Arrhenius-type equation as a function of material temperature (Henderson and Pabis 1961):

$$k = C_1 \exp\left(-\frac{C_2}{\Theta}\right) \qquad 4$$

Discussion

As it is known, the specific microwave power can be counted as the driving force of the microwave dehydration and in this meaning it plays the same roll that the temperature does in the convective drying. In the case when the similarity exists for the cross affects in both drying methods a modified Arrhenius equation must be an appropriate tool to specify the drying coefficient as a function of the specific microwave performance, which is expressed as

$$k = C_3 \exp\left(-\frac{Q_a}{p}\right) \qquad 5$$

The experimental data prove that after the warming up period the change of the specific microwave performance is low enough to ignore its influence on C_3 and Q_a. On this assumption Equation (5) can be set up to count k for two optional values of specific microwave power. Constituting their difference, after some modification, the next formula is obtained:

$$Q_a = \frac{p_1 p_2}{p_1 - p_2} \ln \frac{k_1}{k_2} \qquad 6$$

If Equation (5) is a valid formula, Equation (6) results straight line in the „$\ln k - 1/p$" coordinate system, with angular coefficient of Q_a. As Fig. 1 shows the measured data follow the Arrhenius theory with an acceptable deviation for all of products. In this respect Q_a, which is a kind of energy to the so-called activity energy in chemical reaction kinetics, is needed so that the drying process starts. Its value is in a reciprocal ratio to the applied specific microwave power.

According to the general law of similarity method the semi-empirical models that are valid for convective conditions – after the appropriate modification – can be usable for the conditions of microwave drying as well. In this meaning the drying coefficient plays similar roll to that of the specific reaction rate in the chemical reaction kinetics.

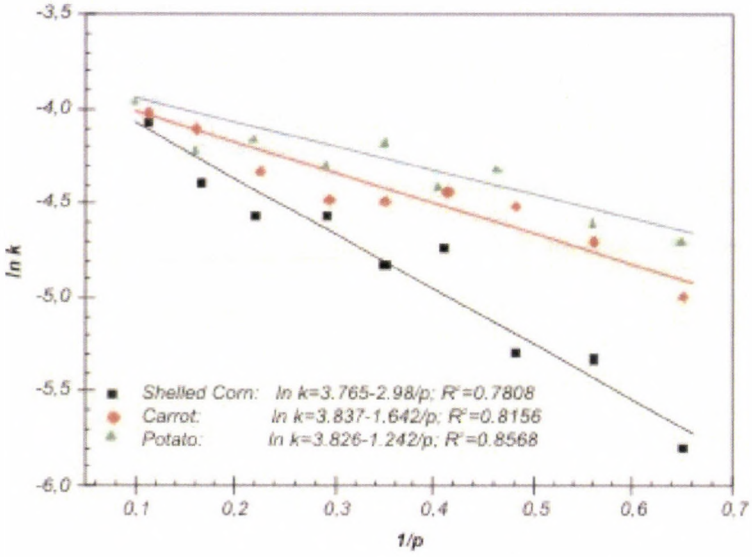

Figure 1. ln k-1/p functions for some agricultural products

By means of the global principle of similarity method there is a chance to originate the governing equation of microwave drying in the transport function of the surface evaporation. This problem can be managed easier if the dehydration potential coefficient (ϑ) is introduced, as Equation (7) shows.

$$\vartheta = \frac{X - X_e}{X_e} \quad 7$$

The roll of dehydration potential coefficient is similar to the widely used moisture rate (Y), but ϑ gives possibility to analyze the effects of different initial moisture content of drying material to the process simulation.

The drying rate as a function of the dehydration potential coefficient shows exponential character and its maximum (in the critical point) in theory is equal to the evaporation rate on the free water surface. By taking this fact into consideration the equation of drying rate in the microwave field can be derived by using the evaporation equation and a correction parameter as Equation (8) shows.

$$S = \frac{p \cdot 60}{q_o + \Delta\Theta \cdot c_w} \exp\left(-\frac{m}{\vartheta}\right) \quad 8$$

The m energy factor involves the influence of significant cross effects. First of all it marks the excess energy (energy difference) that is needed to drying of wet material compare to the energy consumption of free water surface evaporation (Figure 2).

In parallel with increase of moisture content and the intensification of the water get-off process the amount of energy factor will decrease (Fig. 3). In addition, the m is in close connection with the linearized sorption isotherms and with the drying coefficient as well. The actual value of the energy factor can be obtained from Equation (8).

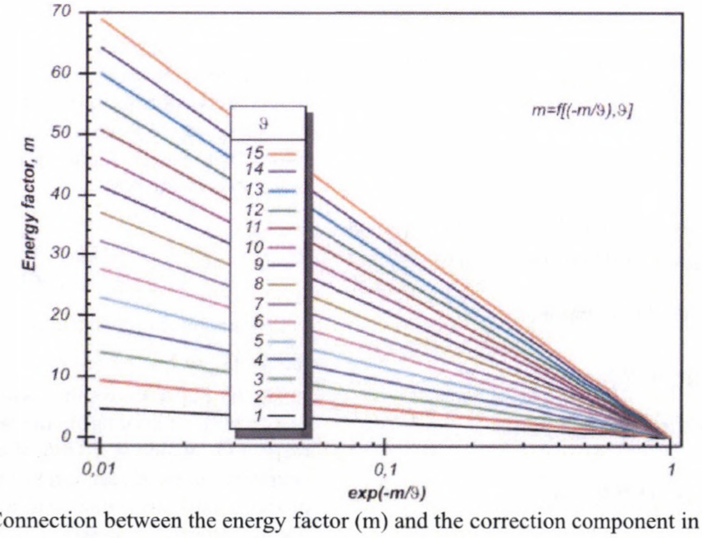

Figure 2. Connection between the energy factor (m) and the correction component in Equation (8).

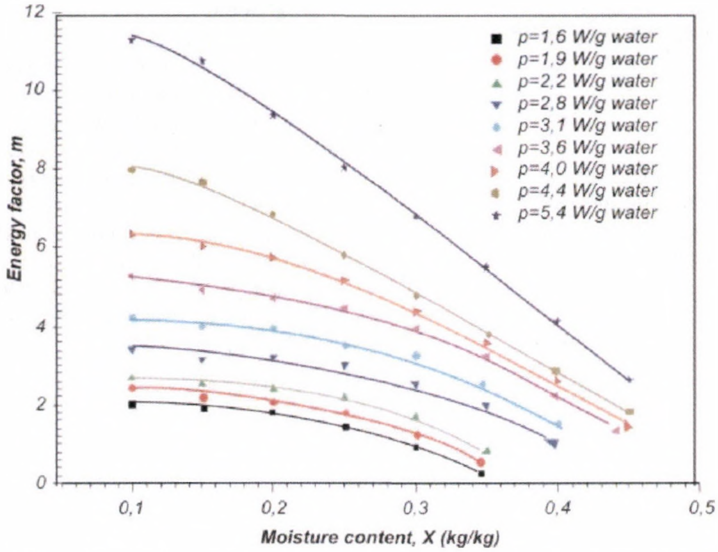

Figure 3. The change of energy factor as the function of moisture content of drying material

By means of Equation (8) and the formula (9), that was used to calculate the relevant moisture content values, an appropriate Simulink model can be built. The result is shown by Fig. 4. (Typical intervals: $0<p<5$ W/g water, $0<\tau<90$ min and $X_1=0{,}5$ kg/kg).

$$X = X_1 - \int\left(\frac{\partial X}{\partial \tau}\partial \tau\right) \qquad 9$$

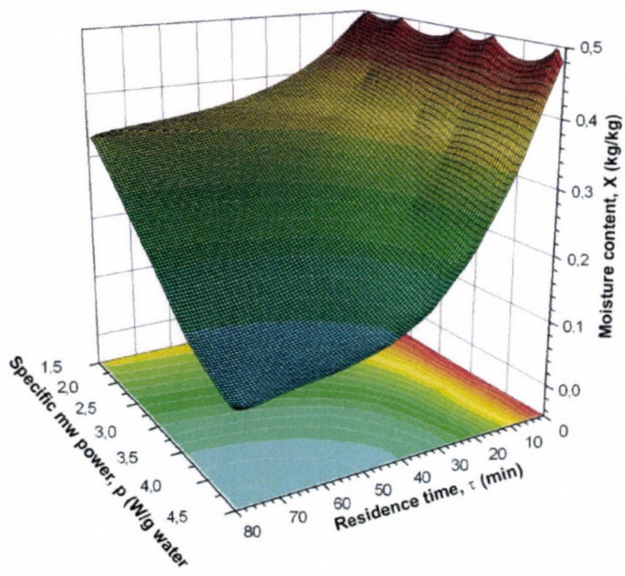

Figure 4. p-t-X relations for shelled corn drying in microwave field coming from Simulink model

Conclusions

In the case of drying the biological materials with inhomogeneous internal structures the semi-empirical models describe the dewatering process with acceptable accuracy

On the principles of similarity method the microwave drying can be modeled by using such semi-empirical simulation procedures that are valid for the conditions of convective drying.

The drying rate of biological materials in microwave field can be described with the balance equation of free water surface evaporation, if it is appropriately modified by introducing the energy factor (m) and the dehydration potential coefficient (ϑ).

Nomenclature

C_1, C_2, C_3	constant
J	current density vector (A/m2)
Q_a	activation energy
S	drying rate (kg/kgmin)
S_p	evaporation rate (kg/m3s)
T	temperature (K)
$Y = \dfrac{X - X_e}{X_1 - X_e}$	moisture ratio
c	specific heat (kJ/kgK)

c_p	isobaric specific heat (kJ/kgK)
p	specific microwave power (W/g water)
q_o	latent heat (kJ/kg)
ε	porosity
ρ	density (kg/m^3)
τ	time (s)
λ	heat conductivity (W/mK)
Λ_V	volumetric dielectric performance (W/m^3)
Θ	temperature of water/material (°C)
ϑ	dehydration potential coefficient

Subscripts

w	liquid	*v*	vapor
g	gas	*1*	initial
e	equilibrium		

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ECO-ENERGY QUESTIONS REGARDING THE PRODUCTION AND UTILIZATION OF AGRIPELLETS

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Abstract

In addition to the environmental reasons, growing energy demand, running out of fossil fuel supplies, and the expected increase in gas prices, all indicate that we must change in our power supply. The opportunities among the renewable energies available in Hungary largely lies in the utilization of biomass. This compressed energy has come into the purview of Europe and our country too. The EU market is ideal for wood-pellet production. In Hungary, due to the characteristics of its agricultural industry large amounts of herbaceous biomass is available. Straw and various agricultural by-products can be used as the raw materials for agripellets. Common complications of the various by-products used in pellet production are the the ability to store and manage them, in addition to their combustion. Therefore it is important to create pellets that will reduce the energy put into transportation and improve the combustion parameters.

Despite the fact that we have the herbaceous raw material base, the agripellet production is only slowly developing in our country. One reason for this is that while we have various agripellet combustion furnaces and boilers, these systems are relatively expensive. In addition, due to the high ash content of herbaceous plants it can not be burned in wood pellet boilers. Furthermore furnaces in the market are relatively few. However, Austria and a number of EU countries are helping with subsidies for the initial investment to make the changeover to pellet heating.

In our studies we dealt with the biodiesel production generated from the by-product of rapeseed stalk. After the grinding process we produced rapeseed stalk pellets with a small pellet making machine. Studies show that we can obtain a lot of energy from the rapeseed stalk. The location of the examination took place in T&T Technik Ltd. in Szentes. They are producing agripellets from different agricultural by-products. In the future I would like to expand on energy balance research in the area of agripellet production.

Keyworlds

agripellets, energy balance, renewable energy

Introduction

Due to the climate and geological features (characteristics) of Hungary there are large amounts of wood and herbaceous biomass in which a significant part can be used for energy purposes. The pellet production in the biomass sector is one potential area for solid biomass. The pellets are produced at high pressure, and are compressed into a cylindrical shape. It is characterized by a high density and compactness. The diameter of the pellets are 5-10 mm, and they are 10-25 mm in length [1]. During timber processing and furniture production wood chips and shavings are produced, which can be processed into wood pellets and briquettes. The wood-base resources that are needed to increase the production are limited. However, the agricultural by-products that are generated each year on arable lands are increasing. This is mostly due to the reduction of livestock that would normally use these by-products.

In addition, due to the nutrient content a part of the by-products, in particular straw and crop residues, are returned to the soil after chopping. Nevertheless lignoceluloses cannot be returned in unlimited quantity into the soil because the excessive recirculation of herbaceous residues cause the penthose-effect. Therefore, the cellulose decomposing bacteria reduces the nitrogen content of the soil, which allows significant amounts of fertilizer input to be balanced [2]. Thus, the raw material base of agripellet production is given.

Situation of Pellet Plants in Hungary

The European pellet sector began to develop rapidly in recent years. Between 2000 and 2010 the pellet consumption has increased more than ten-fold in the European Union. The number of European pellet plants has reached 700 in 2010. Due to the dynamic development of pellets it has become necessary to enlarge the base of raw materials used because the quantity of by-products from the wood industry is limited [3]. This is why agripellets have appeared in market.

Agricultural plant materials, residues, and waste are excellent heating fuels in pellet form. These plants are reproduced annually and can be harvested. The ash content of agripellets (made from herbaceous plants) is between 3-10%, in addition the heat values are more varied than wood-pellets [4].

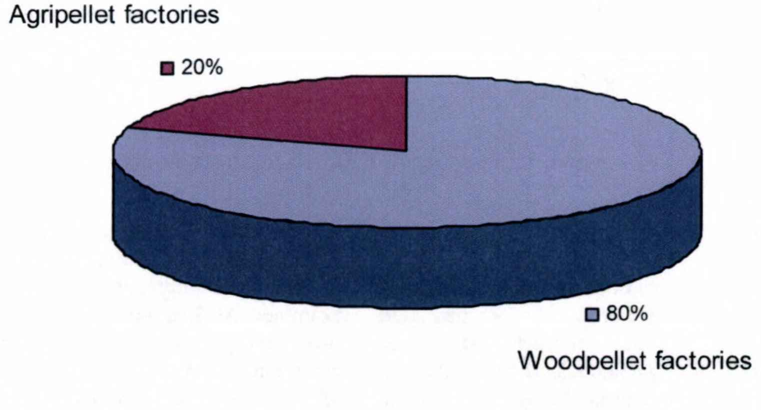
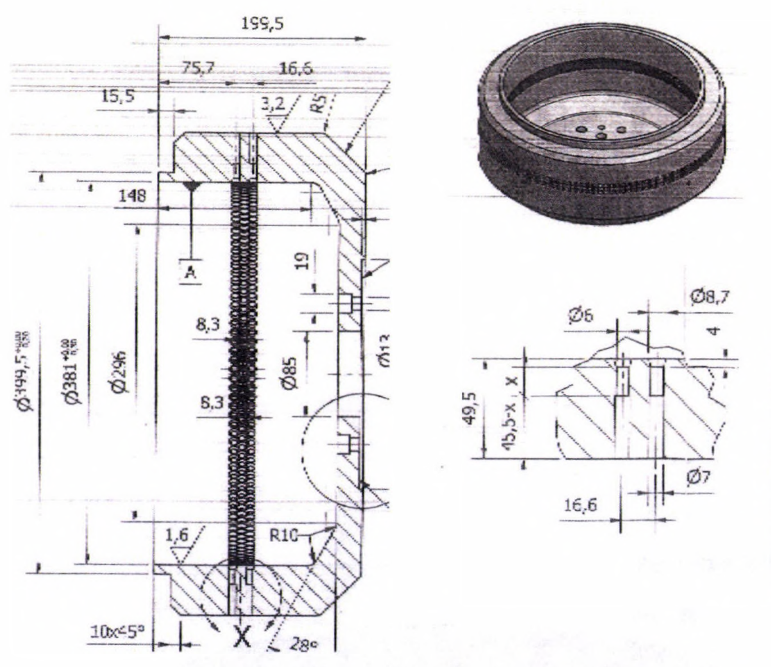


Figure 1. Wood- and agripellet plants in Hungary [5] /Source: Hungarian Pellet Association/

The first figure shows the operating agripellet and wood pellet plants in Hungary. The agripellet production was less than eight thousand tonnes in 2010 and this was mostly sold domestically, which is in contrast to the wood pellets that are mostly exported to foreign markets. Unfortunately, customers often meet with poor quality or friable agripellets. This has worsened the assessment of pellets, which are made from herbaceous plants. The spread of agripellets could help with the initial support of furnace investment. In our country we shouldn't calculate the availability of raw materials necessary for the production of agripellets, as large amounts of agricultural by-products are available. At the same time investments in technology and development are necessary for the advancement of the sector. It is necessary to establish a pillar in the "green economy". The companies have already entered the market but the barriers in combustion technology impede the spread of residential utilization. Currently the market for traditional heating methods is more popular [6].

Production of pellets

The pellets are compressed energy that produce energy at a high (800-900 bar) pressure. Depending on the moisture of the raw material it is common to have to apply some kind of drying technology, which often requires a lot of energy. A specific technology developed in Szentes can produce good quality pellets from materials with a 30% moisture content. During the production of agripellets the incoming raw material first enters into the bale opener. The necessary grain size for pelleting is prepared by hammer mill. The manufacturing of pellets takes place in press-machines at a high pressure and temperature. The cylindrical shape of pellets formed by the pressing machine mould can be flat or cyclic in shape. The diameter of the pellets are variable, the most common is the 6-8 mm size. Due to the high pressure and temperature the lignin in the biomass is partially melted, it will hold together the particles after their release into the machine. The base material is inside the machine pressing mould, where the rotating mould seizes it and then in the inner mantle (0,5-1,00 mm) it is forced under closed rollers. Base materials are compressed by rollers in the peripheral surface of pressing machine mould into the appropriately trained bore, and hatching rods in the external mantle use a crushing knife to cut them to the correct size. It is of paramount importance in the production of high quality pellets to coordinate the press-hole and raw material. The second figure shows that the wall thickness of the pressing machine mould is broken into two different diameter bores. One of the bores in the inner mantle after the initial cone starts with 6 mm in diameter, this is called a compression hole, while the outer periphery has a 7 mm diameter bore that goes against the press hole, and it is this bore that leads out. The bore length design depends on what kind of tree species (hard or soft) or straw pellets are being manufactured. The softer the species the longer the compression timber bore, while the shorter one for hardwood can be pressed into the right firmness [7].



MATRICA	
TÍPUS	"X"
22	12
a	14
b	17
c	21
d	24
e	26
f	28
g	30
h	32
i	33
j	34
l	36

Figure 2. Cross-section of the pressing machine mould

Pelleting rapeseed stalk

In Hungary, in recent years, as a result of the manufacturing of biodiesel the growing area of canola production has increased significantly. Cultivation is taking place on nearly 300 hectares in the last few years. The straw generated, as by-product, is substantial, and varies between 3-6 tons per hectare. Most of the rapeseed stalk is returned to the soil after it is chopped into the ground but it is possible that some of the stubble is burned. Pellets were produced from rapeseed straw after grinding them with small pellet equipment and their energy characteristics were examined. At first, rapeseed stalks must be ground down to the correct size, which is done at a hammer crop mill. After grinding, good quality pellets were managed to be produce without any additional work or material. Pellets produced from rapeseed stalk are not fractured; these lengths were between 3,5-4 cm and 6 mm in diameter. Straw and pellets were examined in an energetic laboratory. The calorific value, moisture- and ash content were determined; table 1 shows the results.

The ash content is important energetically because the design of the combustion plant is essential. The ash content of wood-pellets is low, less than 1%, while the ash content of herbaceous plant pellets is higher about 3-10%. The determination of moisture content is important because of the compressing, if it is too high or too low the pellets will fall apart or crumble. The optimal moisture content is between 10-12%.

Table 1. Energetic characteristics of rapeseed stalk

	Moisture content W %	Heat value MJ/kg	Ash content AS %
Rapeseed stalk	12,5	16,0	5,1
Rapeseed pellets	11,5	16,2	5,1

Presentation of the studies

The location of examination was T&T Technik Ltd., an argipellet provider company, which operates in Szentes. They developed specific pellet production lines with which good quality different blend pellets from herbaceous-plant materials are produced. A wide variety of agricultural by-products are utilized, among others, wheat straw, corn- and rapeseed stalk, derivatives of oilseeds, waste from grain cleaning plants, as well as pellets that have been made from energy-cane and energy-grass.

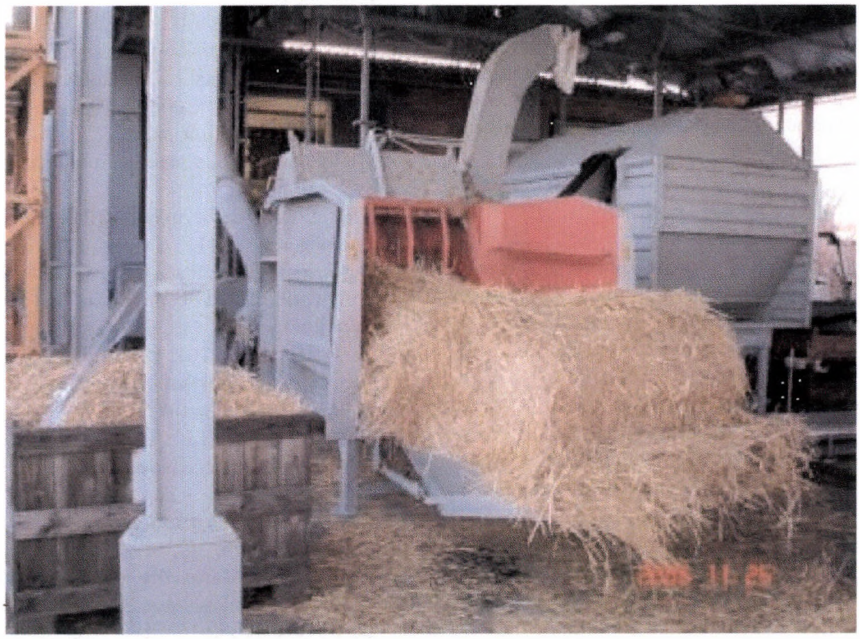


Figure 3. T&T Technik Ltd. agripellet plant, bale-opener, wheat straw before the grinding process

Blend pellets are often produced in the factory. The laboratory tests were performed with two samples. The first sample contained a higher proportion (60%) of rapeseed stalk. In addition the basic materials were corn stalk, wheat straw and tailings. The second sample contained less rapeseed stalk (40%) and more wheat straw and tailings. Calorimetry measurements were performed on the two samples, as well as the ash contents were determined with a glow-furnace examination. The second table shows the results.

From the results of the experiment we can conclude that sample 1 has a higher calorific value and lower ash content. The larger amount of rapeseed stalk causes higher heat value results in the 1st sample. The higher ash content of sample 2 may be caused by wheat straw and duck-bill. The moisture content and heat value of the two examined samples can be considered a good value for agripellets. The ash content is also optimized for the different ash content of straw and crop residues, which are usually around 5-10%. Due to the higher ash content it is required that special moving grate furnace is used when using agripellets. An important question is how much energy can we invest in the production process and how much energy is gained back. The use of energy varies depending on the basic material and the quantity produced per hour. The amount of pellets produce per hour is around 700-1000 kg. The energy consumption is 120-170 kWh. Most important specific energetic indicators are calculated by using the measured and calculated values. The balance of the energy efficiency is the energy content of product and primary energy input relative to 1 tonne of product. The energy efficiency is reduced with: energy intake of energy content of product / energy content of product * 100.

Table 2. Results of the examination of moisture content, heat values and ash content

	Moisture content W %	Heat value MJ/kg	Ash content AS %
Sample 1	9,6	16,65	5,27
Sample 2	8,6	16,01	8,39

The energy demand in primary energy of the basic technology for 1 tonne product is 1713 MJ (476 kWh). Primary energy of 1 tonne of pellets from the basic production technology energy demand is 1713 MJ (476 kWh). From the 1st sample the calculated recovered energy to the energy balance is 1:9,7, that is, ten times of the primary energy invested can be recovered. The energy balance is 1:9,4 if it is calculated using the heat value of sample 2. Expressed in degrees of energetic efficiency:

$$H=(E_o-E_i)/E_o*100 \quad [8],$$

where: H: energetic efficiency,
E_o: energy output,
E_i: energy input.

The value of the 1st sample is 89,7% and the 2nd sample is 89,3, which can be considered good values. The energy spent on delivery does not appeared in this data. This would be a significant change in the energy balance because of the law of bulk raw materials. Therefore, efforts should be made for the local utilization of products.

Conclusions

Energy efficiency of wood pellet manufacturing was examined by our previous studies at Pellet Product Ltd., which operates in Petőháza [9]. The energy efficiency of production was 92,3%, which is a very good value thanks to the high heat value of pine shavings. In comparison, 89,5% efficiency of agripellet production is a good value from an energetic point of view and well worth it. On the basis of laboratory tests, rapeseed stalk pellets have a high calorific value compared with herbaceous plants. Examining the whole process of cultivation and output energies interesting conclusions were established. We examined how much energy per hectare can be obtained from the seeds of rapeseed and how much of the stalk. In the case of 2,5 tonne/hectar an average yield is approximately 60 GJ of energy from the seeds. When calculating with 3 tonne/hectar the utilizable quantities of rape stalk is 48 GJ, while calculating with 4,5 tonne/hectar it is 73 GJ energy [10]. It is noteworthy that often the same amount of energy left in arable lands such as rapeseed seeds can be obtained. In Hungary, there is a large potential for the utilization of agricultural by-products. The production of high energy efficient agripellets can be an effective way to utilize the energy left in the fields.

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POSSIBILITIES OF ALGAE IN BIOMASS ENERGY AND FOOD PRODUCTION THROUGH GAS EMISSION MITIGATION

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Abstract

Global scarcity and territorial inequalities of resources, diminishing stock-type resources are causes for the economy to change to a sustainable operation. Transformation of CO_2 into useful organic compounds promises economically viable way for these goals. Phototrophic CO_2 biofixation of microalgal species is a promising alternative to other CO_2 sequestration approaches, at the same time producing commercially valuable products. This paper rewievs the possibilities of algal technologies in terms of their products and the effect of filtered and flue-gas CO_2 on algal biomass production.

1. Objective

Global scarcity and territorial inequalities of resources, diminishing stock-type resources are causes for the economy to replace present value chains and technologies for renewable ones. As regards emissions, there are several international protocols of global environmental summits stipulating CO_2 mitigation. Novel carbon capture strategies have to be established in order to reach thses goals. Transformation of CO_2 into useful organic compounds via photosynthesis promises economically viable and sustainable way for these goals.

As Ho et al. [24] summarise the history of algal technologies, microalgae and cyanobacteria that are present on the Earth since the very beginnig [43] with well-established traditions of human utilization [47]. Nevertheless, technologies for algae cultivation exist only since a few decades ago [11]. This is due to the rapid increase in global population from the early 1950s on, that made microalgae and cyanobacteria, which have high protein and nutrients content, good candidates for food enhancement. In addition, microalgae and cyanobacteria have considerable potential for other purposes, including food additives, biofuel, cosmetics and pharmaceuticals. Combinations with other technologies such as biomass energy and agricultural production are also promising [2], [20].

This paper aims to rewiev the possibilities of algal technologies in terms of their products and their CO_2-mitigation ability.

2. Possibilities of algae in biomass production for energy, food and other purposes

As highlighted by Bai [5], energy market has a very considerable share within the fossil energy based global economy, which equals 7 trillion USD in 2008, representing 13% within the global GDP. Oil production and consumption in the world reached 5 trillion litres in 2008. This huge amount is, however, environmentally not sustainable, both in terms of resources and emissions. Nevertheless, its infrastructure (from production through transportation, processing, distribution through consumption) represents an incredibly huge value that is almost impossible to replace in the short term. Thus, invading this nearly infinite market by alternative fuels is a giant market possibility and an environmental necessity, although a difficult economic task to solve.

As regards the economic and social-political relations of fuels, the European Union and Hungary share the same problems [7]: the EU's dependency reaches 55% in energy import and 80 % in oil import, and Hungary has even greater dependency, which is ca. 66% in total energy and near 90% in oil products.

Algae-based biofuels as next generation propellants can be compared to an ideal alternative fuel, which is [7] renewable; economic (compared to products from mineral oil, to other alternative fuels and to other uses of their feedstock); potentially able to fully replace oil; at least partly able to utilize the oil-economy's infrastructure (cars, pipelines, stations). If possible, next generation fuels also eliminates the worries raised by first generation biofuels, in general: causing famine partly directly ("food fed in cars"), partly indirectly (through decreasing food- and feed prices); consuming arable land and causing tropical deforestation; using more energy for their production, as gained by their utilization; having adverse environmental and nature protection effect is, due to industrialized production and special species; resulting in few workplaces because of automated technologies. Algae-based biofuels conform many of these characteristics, except that of economy at present level [5]. However, resources and economic sustainability and overall potential advantages over other sources of other biofuels [4] make algae fuels to the ultimate alternative to petro-diesel [44] in the long term. This is the most important usage type of algal energy, though other uses are also prospective [30].

These all imply the prospectivity and the need for further research results, technology, management, economy and policy enhancemenmts, to mention some important areas of development. The existence of algae containing 30–75% of lipid by dry basis (these can be also called oilgae) [17] present good prospects for algae-biodiesel. However, the cultivation and downstream processing technologies have to be carefully rewieved and further developed for better efficiency and economy [27].

Considering gas emission mitigation pruposes of microalgal technologies, they do not necessarily contradict to algae-biodiesel production. Investigations effects of flue gas aeration on lipid production in Chlorella sp. MTF-7 [14] have shown, that lipid content have not increased with flue gas aeration compared with CO_2-enriched gas (25%) aeration, but the lipid production was higher, due to increased biomass production.

Algae-based biomass production has advantages compared to traditional crop production [6], since their reproduction is very fast, which can allow a harvest even every week, involving relatively modest capital need because of a continuous operation of the processing plants. paired with excellent light utiliztaion, algae can poduce more biomass per area than dry-land plants (even 150-300 t/ha), at the same time needing no arable land. Instead of using food production resources, algal by-products of biofuel processing can serve as feedstock for food and feed. Moreover, a proper technology instalment can easily be adjusted to the needs of different species and production purposes, e.g., to switch from energy production to feed production, or to produce any type of energy. The fact that also flue gas can be effictecely and safely used for food biomass production is also promising in terms of economy of technologies and safe food supply. A study has revealed that "extending the flue gas treatment prior to the cultivation unit by a simple granulated activated carbon column led to an efficient absorption of gaseous mercury and to the algal biomass composition compliant with all the foodstuff legislation requirements" [19].

In addition to the products listed in Table 1, microalgae have also represent a possible solution to a number of environmental problems, as well as GHG mitigation as waste treatments. Algal technologies are well suited to waste water management [12], combining nutrient removal with biomass and biofuel production. The composition of liquid pig manure is also favorable to algae production [8]. Based on outdoor experiments, Bai et al. [3]

recommend the adaptation of a 12- to 14-day rotation period. An algae farm operated this way requires a relative modest amount of capital while achieving sludge management and energy porocudtcing purposes. This way, a feasible microalgal-CO_2 mitigation model for commercial use can be facilitated (Ono and Cuello, 2006), not only fixing CO_2 effectively, but also converting biomass to different valuable by-products. These includes such is biodiesel, and also lutein and other pigments for health food applications, pharmaceiuticals, cosmetics, even photoluminescent markers for research applications.

Table 1. Purposes and types of algae technologies

Microalgal species	**FOOD AND FEED**	**ENERGY (biofuels)**	**OTHER (cosmetics, pharma-ceuticals)**
Botryococcus braunii/Chlorophyta		[12], [13]	
Chlorella vulgaris / Chlorophyta	[11], [47], [33]	[12]	[23], [50]
Dunaliella salina / Chlorophyta	[36], [47], [28], [16]		[36], [47]
Haematococcus pluvialis /Chlorophyta	[47], [16]		[47], [16]
Isochrysis galbana /Chlorophyta	[37]; [42]		
Lyngbya majuscule / Cyanobacteria	[46]		[46]
Muriellopsis sp. /Chlorophyta	[10]; [16]		
Nannochloropsis spp./Heterokontophyta	[54]	[12], [13]	
Odontella aurita / Bacillariophyta	[42]		[42]
Phaedactylum tricornutum / Bacillariohyta	[51]; [1]	[51]; [1]	
Porphyridium cruentum / Rhodophyta	[22]		[22]
Spirulina (Arthrospira spp.) /Cyanobacteria)	[47], [49], [9], [33], [15]		[47], [49], [43], [33], [15]

3. Possibilities of algae in CO_2 emission mitigation

Greenhouse gases are the radiatively active gaseous constituents of the atmosphere, which contribute to the phenomena of global warming. According to recent studies, carbon dioxide (CO_2) is the most important of them, while methane (CH_4) and nitrouse oxides (NO_x) represent considerably smaller quantities in the atmosphere [29]. Trapping CO_2 through carbon sequestration strategies is therefore a current global environmental issue.

According to Ho et al. (2011) [24], CO_2 emissions stem mainly from power plants burning fossil fuels (e.g., coal, oil, and LNG). Major flue gas components are carbon dioxide, SO_x and NO_x [31]. Besides power plants, other large future possibility is to use algae in the mitigation of transportation emissions [21]. Using flue gas to cultivate microalgae is a promising way of mitigating CO_2 emissions [18], [34] but could suffer the problem with the growth inhibitory effects arising from the presence of high concentrations of NO_x and SO_x. Therefore, isolation of high CO_2-tolerant microalgae is the first step toward the development of a feasible microalgae-based system for CO_2 capture from flue gas [52]. For example, Chiu et al. [14] have used Chlorella sp. MTF-7 that was isolated in laboratory by chemical mutagenesis. Scendesmus species are also reported to suit these purpose [25].

Table 2 shows some literature results on how CO_2 affected algal biomass growth in experiments using CO_2-enriched air and and real flue gases.

Table 1. Purposes and types of algae technologies

Microalgal species	CO_2 (%) [a)]	Tempe-rature (°C)	NO_x/SO_x ($mg\ L^{-1}$)[a)]	Specific growth rate (d^{-1})	Biomass productivity ($mg\ L^{-1}\ d^{-1}$)	Reference
Chlorella sp. MTF-7	2	25	0	1,25	250	[14]
Chlorella sp.	2	25	0	1,23	247	[14]
Chlorogleopsis sp.	5	50	N.D	0,65	40	[39]
Chlorella sp. MTF-7	10	25	0	0,75	150	[14]
Chlorella sp.	10	25	0	0,74	148	[14]
Nannochloris sp.	15	25	0/50	N.D	350	[38]
Nannochloropsis sp.	15	25	0/50	N.D	300	[38]
Chlorella sp.	15	25	0/60	N.D	1000	[32]
Hot spring algae	15	50	N.D	3,00	267	[26]
Chlorella sp.	20	40	N.D	5,76	700	[45]
Chlorella sp. MTF-7	25	25	0	0,95	190	[14]
Chlorella sp. MTF-7	25	25	5/12	1,85	370	[14]
Chlorella sp.	25	25	0	0,93	185	[14]
Chlorella sp.	25	25	5/12	1,15	230	[14]
Chlorella sp. MTF-7	25	25	5/12	1,85	370	[14]
Chlorella sp. MTF-7	25	30	5/12	1,95	390	[14]
Chlorella sp. MTF-7	25	35	5/12	1,60	320	[14]
Chlorella sp. MTF-7	25	40	5/12	1,20	240	[14]
Chlorella sp.	25	25	5/12	1,15	230	[14]
Chlorella sp.	25	30	5/12	1,05	210	[14]
Chlorella sp.	25	35	5/12	0,70	140	[14]
Chlorella sp.	25	40	5/12	0,55	110	[14]
Chlorella sp.	50	35	60/20	N.D	950	[35]
Chlorella sp.	50	25	N.D	N.D	386	[48]
Chlorella sp.	50	25	N.D	N.D	500	[53]
Chlorocuccum littorale	50	22	N.D	0,95	44	[40]

a) Chiu et al. (2011)[14]: flue gas from the coke oven of a steel plant contained approximately (20-)25% CO_2, 4% O_2, 80 ppm NO and 90 ppm SO_2. The flue gas was provided at 0.05 vvm.

5. Conclusions

As the above results have shown, phototrophic CO_2 biofixation using fast-growing microalgal species is a very promising alternative to conventional CO_2 sequestration approaches, at the same time producing commercially valuable products [24]. The potential of microalgae as a source of renewable energy, food an non-food ingredients has received considerable interest, but further optimization of mass culture conditions are needed. [12] Future research has many was to develop these technologies in terms of strains, cultivation, processing as well as system economy, so as to establish and spread economic system variatons, to further develop recently not economic systems and to pave the way for future developments of algal technologies.

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