GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA

FACULTY OF ELECTRICAL ENGINEERING

ETIMA 2023

SECOND INTERNATIONAL CONFERENCE

27-29 SEPTEMBER, 2023

TECHNICAL SCIENCES APPLIED IN ECONOMY, EDUCATION AND INDUSTRY

УНИВЕРЗИТЕТ
ГОЦЕ ДЕЛЧЕВ
ЕЛЕКТРОТЕХНИЧКИ
ФАКУЛТЕТ

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GOCE DELCEV UNIVERSITY, STIP, NORTH MACEDONIA

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PREFACE

The Faculty of Electrical Engineering at University Goce Delcev (UGD), has organized the Second International Conference ***Electrical Engineering, Informatics, Machinery and Automation - Technical Sciences applied in Economy, Education and Industry-ETIMA.***
ETIMA has a goal to gather the scientists, professors, experts, and professionals from the field of technical sciences in one place as a forum for exchanging the ideas, strengthening the multidisciplinary research and cooperation, and promoting the achievements of technology and its impact on every aspect of living. We hope that this conference will continue to be a venue for presenting the latest research results and developments on the field of technology.
Conference ETIMA was held as online conference. More than sixty colleagues contributed to this event, from five different countries with more than thirty papers.
We would like to express our gratitude to all the colleagues, who contributed to the success of ETIMA'23 by presenting the results of their current research and by launching the new ideas through many fruitful discussions.
We invite you and your colleague to attend ETIMA Conference in the future as well. One should believe that next time we will have opportunity to meet each other and exchange ideas, scientific knowledge and useful information as well as to involve as much as possible the young researchers into this scientific event.

The Organizing Committee of the Conference

ПРЕДГОВОР

Меѓународната конференција ***Електротехника, Технологија, Информатика, Машинство и Автоматика-технички науки во служба на економија, образование и индустрија-ЕТИМА*** е организирана од страна на Електротехничкиот факултет при Универзитетот „Гоце Делчев".
ЕТИМА има за цел да ги собере на едно место научниците, професорите, експертите и професионалците од полето на техничките науки и да претставува форум за размена на идеи, да го зајканува мултидисциплинарното истражување и соработка и да ги промовира технолошките достигнувања и нивното влијание врз секој аспект од живеењето. Се надеваме дека оваа конференција ќе продолжи да биде настан на кој ќе се презентираат најновите резултати од истражувањата и развојот на полето на технологијата.
Конференцијата ЕТИМА се одржа online и на неа дадоа свој придонес повеќе од шеесет автори од пет различни земји со повеќе од триесет труда.
Сакаме да ја искажеме нашата благодарност до сите колеги кои придонесоа за успехот на ЕТИМА'23 со презентирање на резултати од нивните тековни истражувања и со лансирање на нови идеи преку многу плодни дискусии.

Организационен одбор на конференцијата

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ENVIRONMENTAL AND ENERGY UTILIZATION OF MUNICIPLE WASTE – ONE PRODUCT, TWO SOLUTIONS

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Abstract

The world is facing an increasing need for energy which leads toward escalated exploitation of natural resources, mostly fossil fuels resulting with environmental pollution and global warming. Hence, the problem of finding and using alternative and clean energy sources is self-imposed. The environmental pollution problem increased the interest in allocating more funds for scientific and research work on the use of biodegradable waste, thus in many countries increased number of new power plants which utilize biomass and/or biogas increased.

Biogas is an interesting and important source of energy, especially when is generated from organic waste with an anaerobic digestion procedure. By digesting biodegradable waste originating from various organic sources such as mowing grass, cutting branches, biomass waste from farms and agricultural by-products, etc., in anaerobic conditions, the waste is fermented, and biogas is obtained as an energy source. Simultaneously, parasites and pathogenic bacteria are significantly reduced by more than 90%, which protects the groundwater, the disposal of waste in landfills, which causes water and land pollution, is reduced, and quality fertilizer is obtained for agriculture and other needs.

North Macedonia as primary agricultural country has large quantities of this type of waste which is a good prerequisite for their rational economical use to obtain both, electricity and heat. Production and utilization of biogas additionally opens opportunities for establishing a free market of electricity produced from renewable energy sources. Finally, produced biogas could find its utilization value as renewable energy source for various final customers starting from the largest, up to individual households or business users, as well as for utility companies for gasification of cities or gas stations.

Introduction

The rapid development of society as a result of the technical-technological revolution is mostly based on the possibilities of meeting the ever-increasing need for energy. Due to the inconsistency of energy needs and the possibilities for its provision, energy crises are happening, and as a result, there is an increased interest for improved and more rational use of existing and new renewable energy sources. Encouraging the use of renewable energy sources is a strategic goal of the EU, because it is in line with the Sustainable Development Strategy and enables the achievement of the goals of the Kyoto and Paris Protocols in terms of reducing greenhouse gas emissions, environmental protection, and reduction of global warming.

Several renewable or alternative energy sources are already in use. Some are in the development stage, and some are only in the research and analysis stage for their potential commercial utilization. In parallel with the energy crises, another important environmental crisis is happening, the so-called global ecological crisis, which was created because of the problems with increase amount of waste and its uncontrolled and irresponsible disposal which threatens the health of the people and the environment. Therefore, within the global economic policy, the issue of energy production from biomass using organic waste is also raised.

As there is growing concern about the excessive release of greenhouse gases into the atmosphere and their impact on ozone depletion, and the negative impact that inappropriate

waste disposal could have on human health and global warming, the well-known technologies for biogas production from waste have been re-examined. It is known that through processes of anaerobic fermentation of biodegradable waste, biogas could be obtained, which mostly contains methane as an energy resource, then carbon dioxide, and less hydrogen, oxygen, ammonia, etc. Various technologies have already been proven on a large scale for the use of biomass as a renewable energy source for obtaining electrical and thermal energy, as well as fuel for vehicles. In the EU, several hundred larger installations have already been installed for biogas production and utilization as renewable fuel in power plants for obtaining electricity, processing heat and steam, or fuel for transportation sector.

The energy potential of biomass in our country is significant to the extent that it should not be ignored as a potential energy source. Thus, an adequate energy strategy for energy utilization of biogas should be proposed. In this paper, the authors want to contribute to better understanding the process of production of biogas from organic waste using one pilot project. In this pilot project, the city Radovish and its public company responsible for municipality waste disposal is put in the center of the analysis. The aim of this paper is to provide an insight to the problem of waste disposal in our communities on a larger scale and in an environmentally sound way, and to put in focus the use of municipality waste as renewable resource for generation of biogas. In such way, with one positive action two solutions could be achieved: firstly, environmentally friendly disposal of the municipal waste, and secondary generation of biogas as renewable energy resource that could be used either for electric and/or heat energy generation or as a fuel for local transportation sector, individual cars or trucks.

Main sources for biomass production

After coal and oil, on a global scale, biomass is the largest classical primary energy source as a renewable and widespread raw material, unlike fossil fuels, whose quantities are limited and exhaustible. Biomass can be considered a strategic resource because it is not only renewable, but also available everywhere and from it one can obtain products important for human progress, which will improve the socio-economic status of the people and land. What makes biomass competitive is that it does not belong to the group of environmental pollutants. Biomass does not contain sulfur, and its processing does not release sulfur dioxide, enabling residual waste after the biomass production process to be used as a particularly good mineral fertilizer.

Biomass is defined as biodegradable materials obtained from agriculture, livestock farming and related industries and activities, as well as the biologically degradable part of the industrial and communal city waste [1], [2]. Biomass, in fact, is an organic material that originates from living organisms such as plants, animals, humans and microorganisms, which contain stored energy from the Sun, where they bind solar energy through photosynthesis. By its characteristics, biomass is a high-quality fuel. However, utilization of biomass as a fuel on a larger scale requires several actions to be taken ahead, mostly the collection, transportation, storage and bio-chemical treatment before biodegradable materials become usable biomass.

According to the EU Directive 2008/98/EC, biodegradable waste is any waste that can be decomposed anaerobically (without the presence of oxygen) or aerobic (with the presence of oxygen) decomposition processes, such as food waste, garden waste, paper and cardboard [3]. Numerous scientific and practical investigations are focused on the possibility of using biomass to obtain biogas, as a potential energy source. In general, all organic materials are susceptible to fermentation, from which processes biogas is obtained. The waste generated in agriculture, forestry, food and wood industry stands for a quantitatively significant part of the total generated waste. Additionally, biodegradable waste from households, green waste from city green areas and separately collected biowaste also represent a significant part of the total generated waste. Substantial amounts of residues (fluids and urine) are created in livestock

farming, which, together with bedding, create manure and biomass that can be further used. Apart from the desired products (milk, meat), intensive livestock farming also generates side products with limited applicability, such as feces, fluids, which should be removed and adequately used.

The largest producers of raw material for biogas production installations are animal farms, slaughterhouses, restaurants, hospitals and all other entities that produce organic waste. Growing plants to obtain more biomass will soon become a sought-after business, agriculture will revive, farmland will be protected, watercourses will be preserved. Plants with a high content of starch and oily substances are potential choice for biomass, and genetically modified woody plants and the cultivation of fast-growing special species of willows and apple trees are being investigated. Significant animal waste is also created in slaughterhouses, facilities for processing meat, fish, eggs, milk, cold stores, warehouses, markets, meat shops, fishmongers, catering, facilities for fattening and keeping animals, and everywhere else where animals are kept animal products are grown and produced. These types of waste represent vast amounts of raw material for anaerobic fermentation installations and obtaining biogas as energy and compost as quality fertilizer.

If we make more defined categorization of the most important organic materials for obtaining biomass, we should consider the following:

- Municipal waste:
  - Municipal wastewater, sewage water,
  - Septic tanks waste,
  - Sediment from fecal sewage,
  - Accumulated sediment from wastewater treatment plants,
  - Municipal solid waste, especially organic part disposed in a landfill,
  - Municipal solid waste, newly created,
  - Park and garden maintenance waste, etc.
- Agricultural waste:
  - Greenhouses waste,
  - Animal manure, stable waste,
  - Poultry,
  - Waste from growing flowers, wood or fruits,
  - Waste from growing vegetables
  - Agricultural residues such as straw, corn, husks, stalks, bones, etc.,
  - Plantation cultivation of plants specially intended for biomass production.
- The industrial organic waste:
  - Wood industry, forest maintenance, wood processing, construction wood residues,
  - Chemical industry residues,
  - Brewing industry,
  - Pharmaceutical industry,
  - Paper industry.
- Waste from slaughterhouses, carcasses,
- Kitchen waste, restaurants,
- Medical waste,
- Other types of biodegradable waste.

Table 1: Biomass and Biogas Data

Municipal waste	Energy value 6 – 15 MJ/kg
Domestic waste 1 [t]	60 m^3 – 150 m^3 biogas (50 % – 60 % methane) Equivalent to 35 – 70 litres of liquid fuel
Organic waste 1 [t]	Up to 100 m^3 of methane, i.e. *0.235 MWh of electricity,* *0.155 MWh of heat energy,* *350 kg of compost waste, and* *450 kg of liquid fertilizer*
Municipal solid waste	Methane production of 70 – 120 Nm^3 per ton or 50 – 90 Nm^3 per metric ton of treated waste
Organic waste 25 [t]	Provides energy for 1 household per year

Production of biogas

Biogas could be produced with decomposition and fermentation of organic materials with the complete exclusion of oxygen, t. e. with the so-called anaerobic microbic activities. The development of these processes occurs under special conditions, such as the type of substrate, temperature and pH value of the organic mixture. Because microorganisms are highly adaptable, almost any organic matter can be decomposed. In the process of biogas production fermentation residues are always formed which consist of a mixture of water, non-degradable organic substances, usually rich in cellulose and containing lignin, and inorganic substances such as sand, soil residues, salts and few other minerals. Fermentation always takes place in a moist environment, as microorganisms need at least 50% water in the initial substrate.

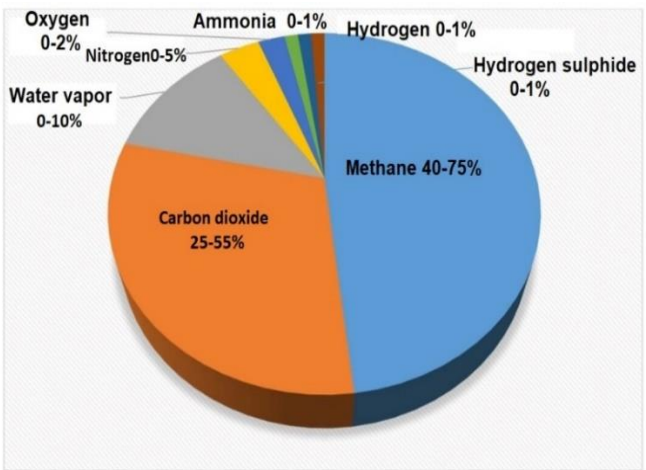

Figure 1: Typical chemical composition of biogas

Addressing its energy value, biogas usually has a heat value of 6.5 kWh/Nm^3, with calorific value and energy potential of approximately 20 MJ/m^3. Thus, from 1 m^3 of biogas with 65% concentration of methane and heat value of 6.5 kWh/Nm3, one could obtain approximately 2.5 kWh of electricity, 3.3 kWh of heat energy, or enough energy for one vehicle to travel almost 8.5 km.

How much and what kind of waste we create

As a result of everyday human activities, waste is constantly generated and disposed. Thus, in addition to the daily problems due to the increasing pollution of air, water and soil, there is a huge increase in the amount of waste materials, which in an ecological sense, leads to an increasing pollution of the environment. Modern way of leaving and packaging of goods creates more and more waste, which is increasingly difficult to deal with in an appropriate way. This leads to unpleasant situation where very soon we can be, plainly speaking, buried in waste. As a result of the excessive use of natural resources, and at the same time as a result of the creation of increasingly large amounts of un-used waste and its inappropriate disposed, today, globally we face occurrence of so-called global environmental crisis. As an example, by adequate treatment of the municipality wastewater and sewage in the specially designed treatment plants, one could produce on average 25 l of biogas per inhabitant per day, which is a significant value of biogas considering the number of inhabitants in one middle size town.

Biodegradable waste from the region of Radovish

The available amounts of biodegradable waste (biomass) from the region of Radovish have not been sufficiently and studiously studied in the framework of some kind of more comprehensive project for its use. In this analysis, we pay our focus on the most important and widely available organic materials in the form of biodegradable biomass that can be obtained from:

- the municipal waste collected daily from the citizens,
- the disposed waste at the landfill,
- the reduced waste sewage deposits,
- the wastewater from the treatment plant,
- wood waste and debris,
- waste and residues from the agricultural complex, and
- the waste from the local farms.

Communal waste

According to the Questionnaire of the European Commission for the preparation of an opinion on the request of the Republic of Macedonia for membership in the EU and the provided answers, with respect to the quantities of municipal waste generated, the daily production of municipal waste per inhabitant amounts to:

- for urban areas 0.70 kg/day/person
- for the rural areas 0.50 kg/day/person

On the other side, Figure 2 represents an average value in percentage shared between different waste materials in the total amount of municipality waste according to the available data from the public waste collection company “Plavaja” of the city of Radovish . Figure 2 shows that biodegradable waste amounts for almost 75% of the total municipality waste.

Solid waste dump

According to JP Plavaja [4] In 2021, from $27641 m^3$ solid waste that has been collected from the places for collecting solid waste at the territory of Radovish and deposited at the regional city landfill , at least 30% was biodegradable.

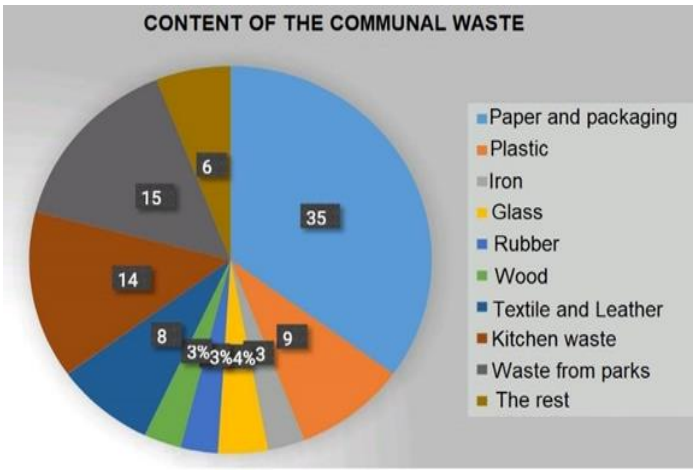

Figure 2: Contents of various waste materials in the total waste in the city of Radovish

Wastewater treatment plant

Realization of the project for putting into operation of the wastewater treatment plant in Radovish was a significant capital project for the creation of biodegradable waste and its future utilization. The outline of this environmental project is given in Figure 3. Only in 2021, this wastewater treatment plant has processed 2.100.400 m^3 of wastewater including fecal, industrial, and infiltrated rainwater [4].

The technological data from the wastewater treatment project show that after the fermentation of municipal wastewater there is the deposited sludge as a by-product. This deposited sludge could be further used and bio-chemically treated because it cannot be simply permanently deposited in or around the treatment plant. If we do that a huge landfill deposit space is required near the plant that would further pollute the surrounding environment. Only in 2021, the treatment plant has produced 624 m^3 deposit, which with the help of centrifuges is brought to an average solid content of at least 20%, This solid waste is currently deposited in the municipal landfill and represents significant environmental problem for JP "Plavaja", and the city of Radovish.

Potential biogas users

Biogas pumps for vehicles

The major chemical component of biogas is methane, that due to its significant energy value and modest price, recently has become widely used as favorable energy source in the transportation sector, especially for driving individual vehicles and tracks. Considering that other fossil fuels (oil and its derivates) are exhaustible and have a limited lifespan, biogas, i. e. methane as an unlimited resource, gradually becomes a fuel of the future.

More and more vehicle manufacturing companies are already producing vehicles that run on methane as an original fuel or produce additional equipment that enables existing vehicles being retrofitted to run on methane. In Macedonia, methane is already being added to vehicles at some of the existing gas stations and provides retrofitting of the existing vehicles which originally ran on petrol or diesel fuel. This provides us with hope to emphasize the installation for biogas production facilities and construction of dedicated biogas pumps have bright future and could be easily built in or near the populated areas.

Figure 3: Bird-view of the wastewater treatment plant in Radovish

Electricity generation from biogas

Biogas produced by means of bacteriological process called anaerobic digestion, could be converted into electricity and heat energy. Electricity can be sold at a preferential price, while thermal energy can be used for heating or cooling buildings, in various technological processes in industry, greenhouses, dryers, etc. Anaerobic fermentation is a stable and proven technology that provides an environmentally friendly energy supply solution.

If a biogas power plant could be erected in the vicinity of the wastewater treatment plant in Radovish, the electricity produced could be used as self-supply for the purposes of wastewater treatment. As a raw material for biogas production, we could use the sludge produced from the biological treatment of wastewater. This is especially important for smaller settlements where there is no possibility, or it is economically not feasible construction of wastewater treatment plant. For such communities, the wastewater from the sewage system can be directly applied to a biogas production installation. Also, from individual entities (business, households and others), which use settling plants (pre-treatment plants, septic tanks, or similar) for municipal wastewater, the entire municipal wastewater can be processed in the biogas production installation.

Biogas production - ecological aspects

Anaerobic digestion technology for biogas production reduces unwanted and uncontrolled methane emissions from landfills and reduce the volume of the waste disposed on landfills. Thus, instead of free methane release from landfills into the atmosphere and preventing forced depletion of the Earth's ozone layer, controlled production of biogas in biogas production facilities enables capture, storing and quality utilization of methane as valuable energy resource. Only methane gas contributes 10% to global warming, and its use as an energy source significantly reduces this percentage, thus also reduces the level of global warming.

At the same time, anaerobic digestion of organic waste for biogas production offers the possibility of reducing anthropogenic emissions of greenhouse gases that pollute the atmosphere and cause the greenhouse effect. An additional environmental advantage is the fact that anaerobic digestion could be considered as CO_2 neutral activity, because it results with no emission of CO_2 gases into the atmosphere. During the process of digestion, up to 99% of pathogenic bacteria are destroyed in the fermenter, and at the same time the considerable number of insects that usually follow the waste are eliminated. Substances that cause

unpleasant odors in untreated waste, such as fatty acids, phenols, phenol derivatives, are degraded in the biogas production installation and the emission of unpleasant odors is reduced by 90%. Finally, production and use of biogas substantially reduces the amounts of other toxic substances such as NO_X, which affects the increase in respiratory diseases in humans.

Knowing that coal and heavy oil reserves are limited and unfavorable due to their high environmental pollution effects, developed countries serious has been paid attention to the production of energy from renewable sources such as solar, wind, and geothermal energy, utilization of biofuels, e. g. biomass and biogas, etc.

Conclusions

The aim of this paper was to make a suitable contribution towards development of awareness of the effectiveness of biogas production, its positive environmental effects, and to renew or launch initiatives for proper activities for development of biogas production facilities. We also initiate and cherish any actions and cooperation with companies from EU and Asia which produce equipment for biogas production and have adequate experience in biogas production and utilization. Such cooperation and knowledge transfer could be of great benefit for the development of such installation in our country.

Construction of such biogas generation plants opens the possibility of reducing the anthropogenic emissions of gases that pollute the atmosphere and cause the greenhouse effect. It would have a positive effect on reducing biodegradable waste that at present we have in the country as mostly agricultural economy and decrease the amount of waste disposal in open or close landfills. Thus, utilizing the disposed waste as a raw material from the existing landfills that continuously pollute nature, underground water and air, in such biogas production facilities, we could, on one side we can protect our environment and improve the environmental footprint of our country, and on the other side we could generate valuable energy resource that can help our energy, transport and agriculture sectors.

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